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Groundwater Potential Zone Identification using Remote Sensing and GIS Techniques - A Case Study of Karwi Block Area, Uttar Pradesh, India

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Abstract: *The study deals with identification of potential groundwater areas in parts of Karwi block area, Chitrakoot district, Uttar Pradesh. Based on the incorporated studies, it has been observed that the lithology, geomorphology, lineaments, slope and land use/land cover was generated from IRS P6 LISS III data and Survey of India, toposheet on 1:50,000 scale and incorporated data with raster based Geographical Information System (GIS) to identify the groundwater potential zones. The assessment of satellite images, topographic maps supported by ground truth survey revealed that the area has a network of interlinked subsurface features. For surface water resources and ground water resources, the appropriate assessment of water potential helps in additional exploration at voluntary level. To formulize the proper management programme, a reliable and up to date information about various factors, viz. size and shape of river basin, topography, slope, elevation and their characteristics, land use/land cover, and drainage parameters are required. The incorporated map generated was further classified according to spatial variation of the ground water potential. Seven categories of groundwater potential zones availability namely: Excellent (0.011%), Very Good to Good (0.027%), Good (10.773%), Good to Moderate (81.371%), Moderate to Poor (0.365%), Poor (6.949%) and River (0.501%) were delineated and identified. In this system used a subsistence plan for optimum development of the water resources and for finding solution for different management problem related to natural resources. The final result represents the favorable groundwater potential zones and this information could be used to reduce the water shortage and quality risks for public health.*

Keywords: *DEM, GIS, Geomorphology, Remote Sensing*

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I. Introduction

Ground water is a vital resource for both industrial and livelihood purpose, due to increasing demand of fresh water supply has bought awareness among us to save water resources which is a primary source. The value of using water was never undermined, but it's about time that even its exchange value is given due importance. Fresh water, at present is a limited resource, and it is being flowed over the world (Khan et al., 2013). More than 2000 million people would stay alive under conditions of high shortage of water by the year 2050, according to the UNEP (United Nations Environment Programme), which urge water could bear out to be a limiting factor for development in various regions of the world. About one-fifth of the world total population lack access to safe drinking water and with the present way of utilization; two out of every three persons on the earth will live in water-scarcity conditions by 2025. One-third of the world total population at present live in countries with moderate to high water shortage—where water utilization is more than threshold of the renewable unsullied water supply, said by GEO (Global Environment Outlook) 2000, the UNEP's millennium report. Pollution, scarcity of water resources, and global climate change will be the prime forthcoming challenge in the next century, said by the report (Janaki and Subramani, 2016). The continuously changing the global climate and environment makes it necessary to realize and compute various hydrological components for competent water resource management (Saha et al., 2017). The reality of water calamity cannot be ignored. India has been outrageous of being poor management of water resources. The requirement of clean water is already outstrip, the adequate supply. Majority of the population in hi-tech cities today depends on groundwater.

Use of remote sensing and geographical information system for potential groundwater zones investigation is an conventional and effective procedure (Raghu and Swamy, 2009). Remote sensing in concurrence with the current studies like geo-hydrological and geo-physical analysis is developing increasingly as a dominant resource to target potential ground water zones (Jose et al., 2012). Geo-physical inspections enable us in identification of groundwater aquifers and evaluation of their movements whereas, GIS enables user specific management and incorporation of multi-thematic data (Janaki and Subramani, 2016). Proved that remote sensing technique combined with Geographical Information System (GIS) procedure are very proficient in identification of groundwater capability of any area (Murthy et al., 2003; Prakash Ravi and Singh, 2004). In this study IRS IA, LISS II data has been used to identify and classify seven groundwater potential zones by integrating diverse thematic maps. The study reveals that incorporation of thematic maps prepared from conventional remote sensing techniques using GIS and rectified ground truth survey, established the base line information for potential ground water zones (Manikandan et al., 2014). Integration of GIS and remote sensing techniques have proved to be an proficient tools in groundwater studies (Krishnamurthy et al., 2007; Sander et al., 1996; Adhikari and Kumar, 2006), satellite data serves as groundwork inventory method to understand the ground water prospects / condition and GIS enabled assimilation and management of multi thematic layers. Hence, the present study in endeavor to identify and understand the ground water prediction zone of Karwi block, in a part of Uttar Pradesh, Chitrakoot district, North Central India by an incorporated approach of advanced remotely sensed data, GIS, field survey, and lab technologies.

II. Study Area

The present study focused to assess the probable ground water predicts zone of defined area as Karwi Block part of Chitrakoot District, Uttar Pradesh, India. The study area lies between latitude 25°5’58.383” to 25°25’17.889‖” N and longitude 80°41’40.233’’ to 81°1’52.613’’E covering an area of 51879.52Ha. Chitrakoot Dham (Karwi) is serving as a district headquarters and a municipal corporation in Chitrakoot district of Uttar Pradesh, India. Since, Karwi block was a tehsil in Banda district. On May 6th, 1997 Government of Uttar Pradesh carved out a new district Chitrakoot (Initially named as Chhatrapati Shahuji Mahraj- Nagar) from Banda district. Since then the block is serving as district headquarter. The town named Karwee, in New Zealand's Canterbury region was named after Karwi by a retired British Army colonel. As of 2001, India census, Chitrakoot Dham (Karwi) had a population of 48,853. Males constitute 54% of the population and females 46%. Chitrakoot Dham (Karwi) falls on National Highway 76 (NH-76) stretched from Pindar to Allahabad via Udaipur, Chittaurgarh, Kota, Shivpuri, Jhansi, and Banda. Chitakoot Dham (Karwi) is a railway station on Manikpur - Jhansi/Kanpur main railway track, served by the North-Central division of Indian Railways.

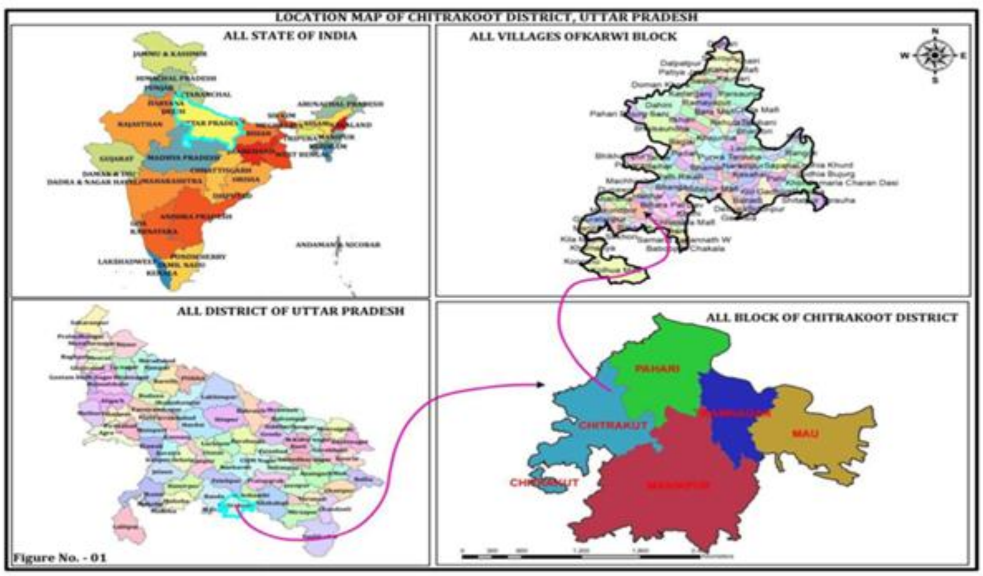

Figure 1: Study area map of Karwi Block, Chitrakoot, U.P.

III. Materials And Data Used

For the present study, diverse datasets and software resources comprised of imagery details and analysis tools have been used. The Shuttle Radar Topography Mission (SRTM) DEM of 90 m resolution was used. The use of Digital Elevation Model (DEM) in specific has made watershed demarcation a comparatively a smooth process (Saha and Singh, 2017). The LISS III satellite data is used for the year 2016. The Linear Imaging Self Scanning Sensor (LISS-III) is a multi-spectral sensor operating in four spectral bands, in which three bands are in visible and near infrared and one in SWIR region, as in the case of IRS-1C/1D.

Table 1: Data Used in the present work

Types of data/software	Details of data/software	Sources
SRTM DEM	90 m, Year 2004	http://srtm.csi.cgiar.org/
LISS III satellite imagery	Dated 30/01/2016 and 02/03/2016	https://earthexplorer.usgs.gov/
ArcGIS software	ArcMap 10.3	http://desktop.arcgis.com/

IV. Methodology

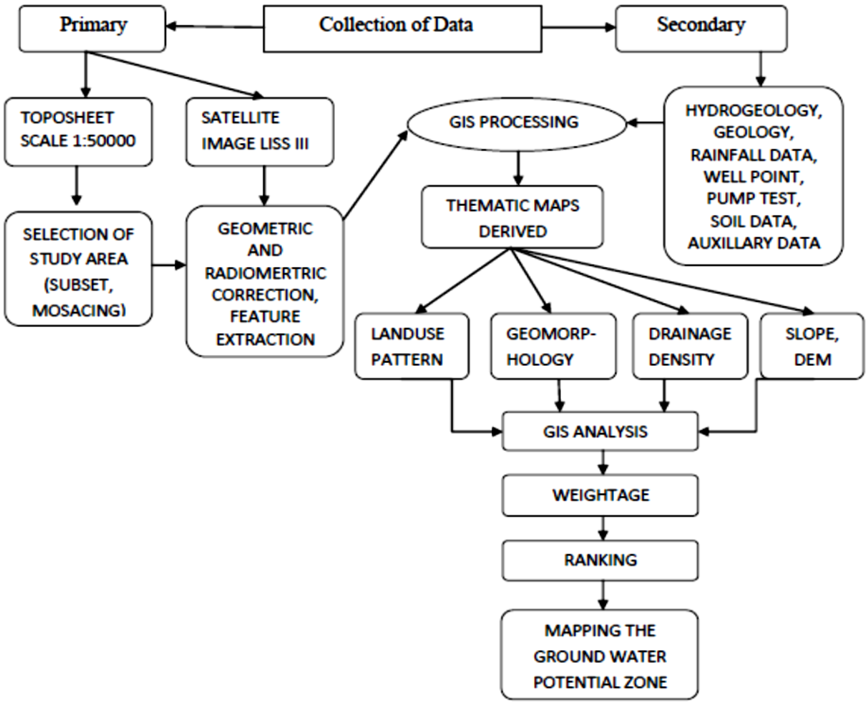

Figure 2: Flowchart of Groundwater Potential Zone mapping

The methodology adopted for the present study is shown in above figure. The base map of Karwi block was prepared based on topographic maps from Survey of India on a 1:50,000 scale. The drainage network for the study area is processed in ArcGIS 10.3 platform. The slope maps were prepared from SRTM DEM data in ArcGIS spatial analyst module (Manikandan et al., 2014). The rainfall map has been prepared using the data obtained from the Indian Meteorological Department (IMD) gauge stations. These data were then spatially interpolated using Inverse Distance Weighted (IDW) method to obtain the rainfall circulation map. This interpolation method combines the concepts of intimacy to follow thiessen polygons with plodding change of the trend surface (Magesh et al., 2012). The drainage density and lineament density maps were prepared using the line density analysis tool in ArcGIS (Magesh et al., 2012) Satellite images from IRS-P6, LISS-III sensor, on a scale of 1:50,000 (geo-coded, with UTM projection, spheroid and datum WGS 84, Zone 44 North) have been used for delineation of thematic layers such as land-use, lithology, lineament, and soil types. These thematic layers were converted into a raster format (30 m resolution) before they were brought into GIS environment. The groundwater potential zones were obtained by overlaying all the thematic maps in terms of weighted overlay methods using the spatial analysis tool in ArcGIS 10.3 (Nagarajan and Singh, 2009). During weighted overlay analysis, the ranking was given for each individual parameter of each thematic map, and weights were assigned according to the multi-influencing factor (MIF) of that particular feature on the hydro-geological environment of the study area.

Seven influencing factors, such as lithology, slope, land-use, lineament, drainage density, soil, and rainfall have been acknowledged to delineate the groundwater potential zones. Interrelationship between these factors with their effect is shown. Each relationship is weighted according to its potency. The representative weights of a factor of the potential zone are the sum of all weights from each factor. A factor with a superior weight value shows a larger impact and a factor with an inferior weight value shows a smaller impact on groundwater potential zones. Assimilation of these factors with their potential weights are computed throughout weighted overlay analysis in ArcGIS.

Geomorphological map can be well thought-out as graphical inventory of scenery depicting landforms, surface as well as sub-surface materials. Sketches and maps of landscapes and landforms (e.g. Dykes, 2008) have been elementary methods to analyze and visualize earth’s surface features continually ever since geomorphological research. The prevalent distribution and comprehensive graphical capabilities of geographic information systems (GIS) seeing that the availability of high-resolution remote sensing data such as airborne and satellite imagery and surface elevation models has led to the recent renovation of the method (Lee et al., 2001, Paron and Claessens, 2011, Smith et al., 2013).

Lithological map can be well thought-out the study area rock types as massive sandstones and granitic rocks occupy whole mountainous range and hills. Geologically, the study area consists of hard quartzite rocks mainly granite and charnockite of the Precambrian age. A few secluded granite bodies located in the reserve forest areas of north-east of kalua mafi are well thought-out as closet granite, pink and grey in color, being intrusive in to the peninsular gneissic complex, the sargur supracrustals and charnockite, chamundi granite, exposed south of study area.

V. Results And Discussion

The different type of thematic layers resulting the analysis for groundwater potential zones and result of the composite map obtained in (Figs.), are discuss below in details:

Geomorphology:

The Geomorphic surface can be considered as outer indicators for the identification of ground water conditions. Geomorphology is well depicted in satellite imagery. False color composites of the original bands and principal component images have been used for the interpretation of the geomorphic features. Geomorphic features and structural information from satellite images are interpreted to identify ground water and assisted the site of recharge zones and ground water situations. Assorted geomorphic features have been identified in the images using remote sensing techniques (Kumar et al., 2013). Geomorphic unit of the study area have been identified on the basis of satellite data and followed by ground truth validation. Two types of landforms dwell in the study area of Karwi block area, a part of Mandakini river basin in Chitrakoot district of Uttar Pradesh. First type of denudational landforms (Hill, Plateau), and other second types of fluvial landforms of Alluvial plain, Pedi Plain, Striped Plain, Flood Plain etc. The quantitative assessment of Karwi block area carries out with the help of research literature review, deduce geology, satellite data and ground surveys so as to discriminate difference in landform features of the area. For example- Alluvial Plain, Pedi Plain, Striped Plain, Plateau etc (Kumar and Dev, 2014). The annotation of the alluvial plain is found to be excellent for ground water potential zone of Karwi block area.

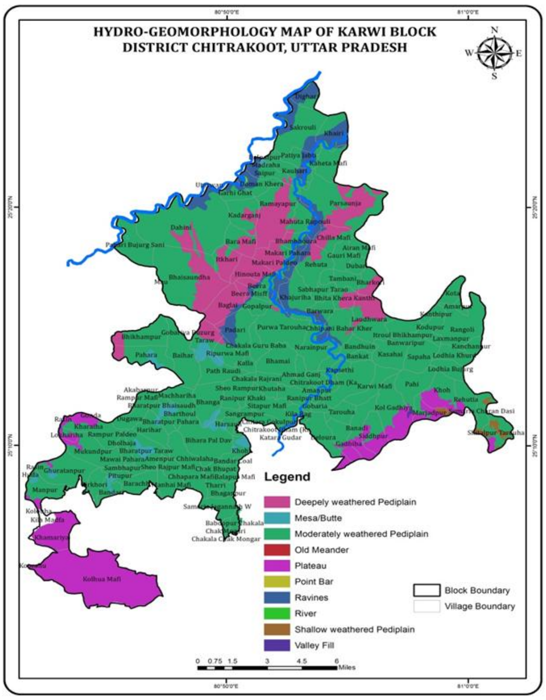

Figure 3: Hydro-Geomorphological Map of Karwi Block

Lithology:

The study area consists of rock types having massive sandstones; granitic rocks which occupies whole ranges and hills. Geologically, the study area consists of hard quartzite rocks mainly granite and charnockite of the Precambrian age. A few isolated granite bodies located in the reserve forest in northeast of kalua mafi are considered as closepet granite, pink and yellow in color, being intrusive in to the peninsular gneissic complex, thick bedded massive sandstone, and charnockites, chamundi granite, exposed to the south of study area. These rocks are intruded by dolerite dykes of proterozoic age. Gneiss is medium grained with yellow and pink colors and occupies north-west part. They have secondary porosity such as fractures, joints, faults, etc. Granite rocks occupy south-eastern part forming the hill ranges with less primary porosity as well as high secondary porosity.

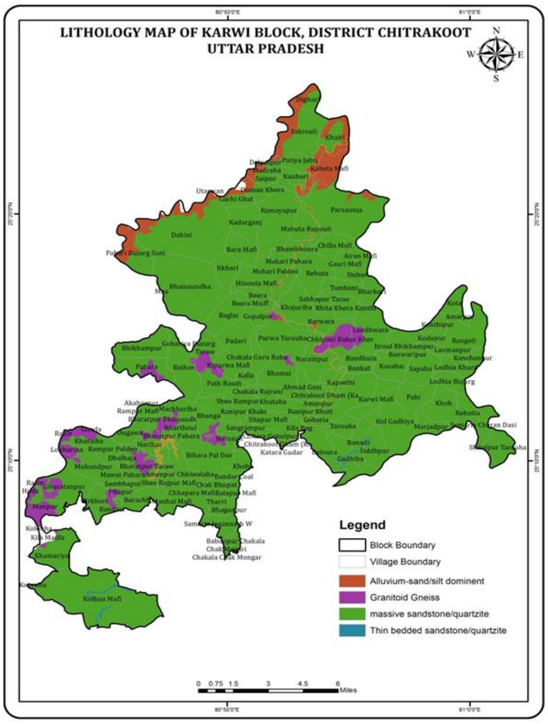

Figure 4: Lithological Map

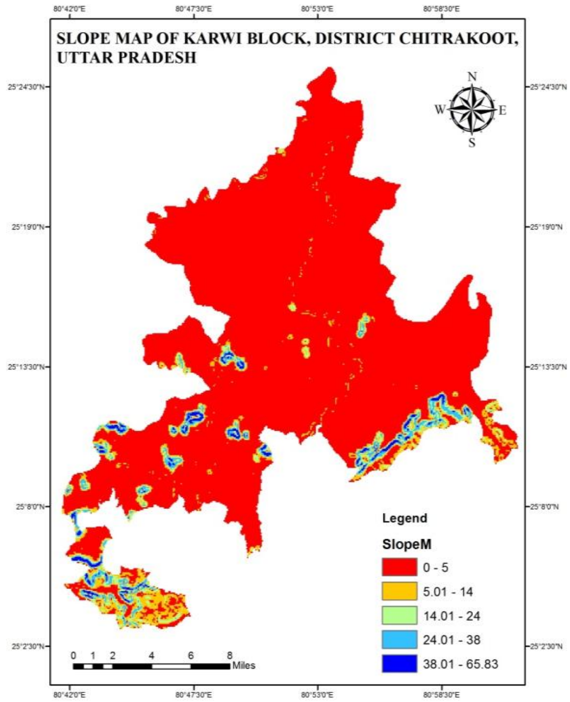

Figure 5: Slope Map

Slope:

Slope/gradient is a rate of change of elevation and well thought-out as the principal factor of the sacrificial water flow seeing as it determines the effect of gravity on the water movement. The slope is directly proportional to runoff, thus ground water recharge will be lesser in the area with vertical slope. The water flow over the smoothly undulating plains is slow and sufficient time is accessible to enhance the penetration rate of water to the underlying splintered aquifer. The slope was estimated from SRTM data, using 3D Analyst tools of ArcGIS 10.3 software. The slope was estimated from the digital elevation model (DEM), which was obtained from the contour lines in the topographical map.

Drainage:

Mandakini River is the foremost river with widespread drainage system, draining the water to the whole area and responsible for biodiversity, habitation, agro-economic growth and livelihood. The Mandakini river basin a complete drainage system is found to be 1st order to the main river (Kumar and Dev, 2014). The drainage pattern of the area is dendritic and drainage texture of the study area is medium. The interconnected nature of land and water resource calls for a holistic approach toward the urban and rural areas development and watershed management. The enlargement of stream segments is mainly affected by the slope and local relief which may fabricate distinction in drainage density from place to place. This drainage system is expressive for river basin and watershed management. The drainage system is formed with different streams and streamlets.

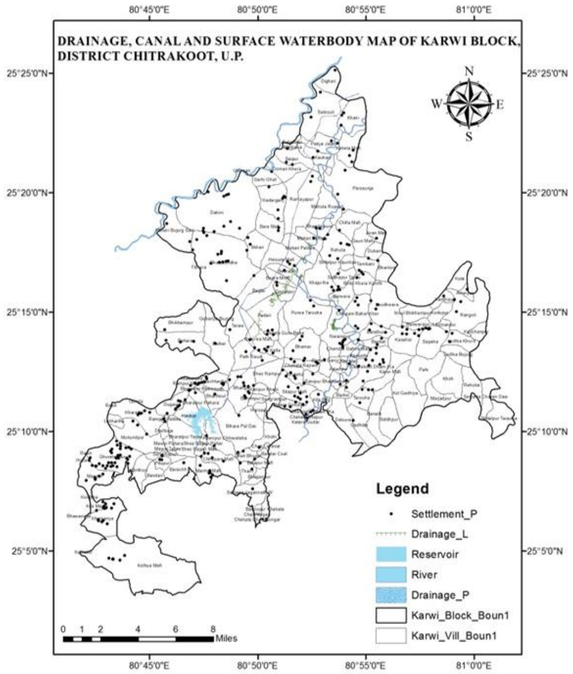

Figure 6: Water body Map

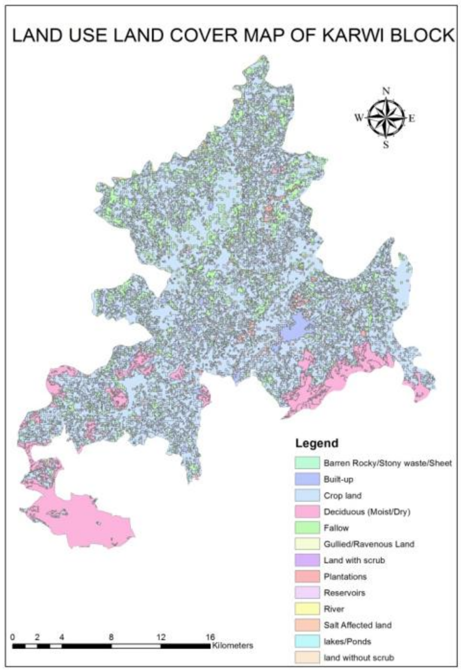

Figure 7: Land Use and Land Cover Map

Land use / Land cover:

Apprehending the importance of Land use/Land cover in ground water potentiality, Land use/Land cover maps was prepared using geocoded LISS III images and field data. The various Land use/Land cover classes delineated by employing the slandered methods of visual interpretation and the identified features includes crop land, forest/plantation, waste land, hills, built-up, fallow/open land, deciduous, lakes/pond, barren, rocky, road network and river/water bodies. In this majority of the area is used for scrubs land followed by crop land. The Karwi Block area in a part of Uttar Pradesh, classified from satellite data covers an total area of 51879.52 ha. Out of total classified area obtained from satellite data yields to Crop land of 71.4%, deciduous 12.06%, fallow/open land of 12.19%, Built Up area of 1.95%, river/water body area of 0.52%, Plantation 1.76% and barren rocky land of 0.28% of the interpreted of satellite data.

Table 2: Land use/Land cover Statistics Based on Visual Image Interpretation

Sl No.	Class Name	Area (in Ha)	Area (in %)
1	Barren Rocky/Stony Waste	148.78	0.28
2	Built Up	1012.23	1.95
3	Crop Land	36909.27	71.14
4	Deciduous	6256.42	12.06
5	Fallow	6325.8	12.19
6	Gullied/Ravenous Land	0.05	0.00009
7	Land with Scrub	0.580	0.0001
8	Plantation	913.71	1.76
9	Reservoirs	0.06	0.00009
10	River	272.54	0.52
11	Salt affected land	0.045	0.00008
12	Lakes/Pond	38.85	0.07
13	Land without scrub	0.254	0.0001
14	**Total**	**51879.52**	

Groundwater Potential Zones:

For the Block area was conducted with objective to outline the areas with capable ground water zones and fused map of groundwater potential zones recapitulate the results. In this study, process involves raster superimpose analysis and is known as multi-criteria evaluation techniques (MCE), which gives linear permutation of portability weight for different themes taken for the study. The incorporated final map (Fig. 8) has generated the distribution of ground water potential zones provide an imminent to the management of ground water resources. The map has been categorized into seven zones namely, poor to excellent groundwater potential zones. The area under various ground water prediction zones labeled with the study area are computed and is shown in the table no. 2 based on thematic layers assimilation techniques.

Table 3: Predictable Potentiality Statistics of the Karwi Block part of Uttar Pradesh

Sl No.	Class Name	Area (in Ha)	Area (in %)
1	Excellent	5.911637	0.011
2	Very Good to Good	14.044034	0.027
3	Good	5589.388852	10.773
4	Good to Moderate	42214.981011	81.371
5	Moderate to Poor	189.678225	0.365
6	Poor	3605.430207	6.949
7	River	260.085734	0.501
	Total	51879.52	

Out of the total area, 3605.43 ha were classified as poor potential zone, 189.68 ha having moderate to poor potential zone, which total accounts for almost 7.38% of the total area. Good potential zone occupy 10.773% of total predicted potential zones, while very good to good potential zone accounts to 14.04% of the area. The good to moderate potential zone occupy 42214.98 ha, which accounts for almost 81.371% of the total area and the excellent zone covers 0.011% of the basin. Almost whole of Karwi block area is in Good to Moderate condition for ground water potential zone. Field check has been done through the yield data of dug wells and tube wells which persuade the above analysis (Sharma et al., 2002).

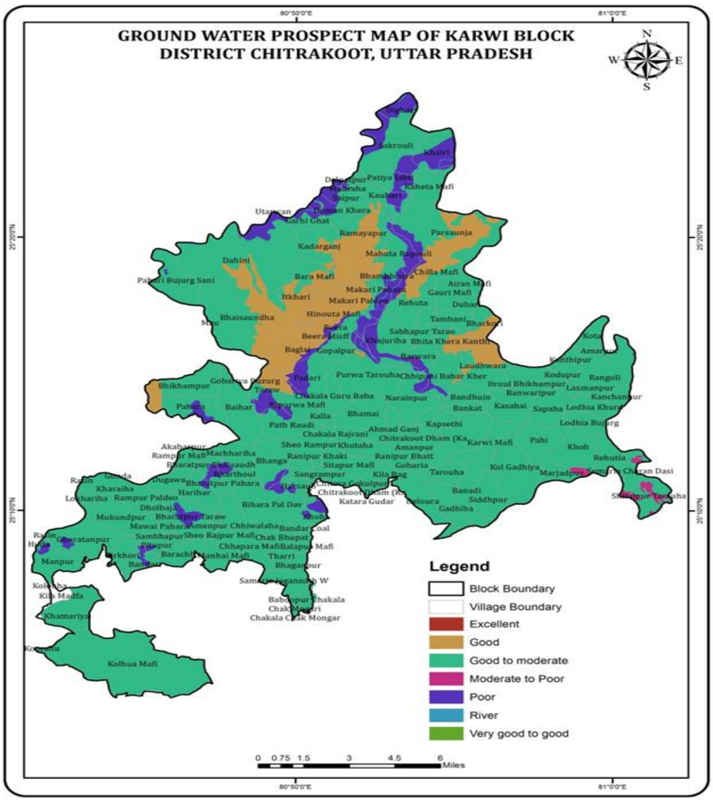

Figure 8: Ground Water Potential Zone Map of Karwi Block

VI. Conclusion

In the present study, an endeavor has been made to generate ground water potential zone maps through multi-criteria evaluation techniques using the raster based GIS assessment and also to appraise the incessant variation of ground water prospects availability in the area (Kumar and Dev, 2014). In this, exploration can be incorporated into Karwi block management plan aimed at improving the life style of humans and protecting the natural environment. It forms a complete water potential zones system which provides an expressive role in agriculture, rural and urban areas development of study area. It has been observed from ground water potential that the smooth slope has more potential for ground water than the rough slope (Kumar and Dev, 2014). The incorporated ground water potential zones map has been categorized into seven classes on the basis of the increasing weightage to different features of the thematic maps. The poor zone indicates the least favorable area for groundwater prospect; whereas excellent zone indicates the most favorable area for groundwater prospect (Murasingh et al., 2014). The total area of ground water prospects zones is 51879.52 ha. And excellent ground water potential zone area is 0.011% of the total area and from Good to Moderate ground water potential zone covers an area of 81.371%. The ground survey has been made through the data of dug wells and tube wells which satisfy the above scrutiny. Therefore, appropriate management interventions and amicable salutations for drinking water supply, irrigation tube wells, wells of basin better developments and management need to be initiated without further delay. This vital information could be used effectively for the identification of suitable locations or extraction of drinkable water. The current approach using GIS and remote sensing is holistic in nature and will Minimize the effect of time and cost especially, for identifying ground water-potential zones and suitable site-specific recharge structures in hard rock terrain on a regional as well as local scale, thus enabling quick decision-making for water management.

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