International Journal of Applied Research 2015; 1(13): 586-591


**ISSN Print:** 2394-7500
**ISSN Online:** 2394-5869
**Impact Factor:** 5.2
IJAR 2015; 1(13): 586-591
www.allresearchjournal.com
Received: 21-10-2015
Accepted: 22-11-2015

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# Assessment of groundwater potential zones in Allahabad district by using remote sensing & GIS techniques

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**Abstract**
The current study was conducted to identify potential ground water zone in Allahabad district using remotely sensed data and GIS techniques. In the current study, remotely sensed land use and DEM data were utilized to assess ground water potential zones. The land use data was derived by USGS (United States Geological Survey) using SPOT 4 satellite images. DEM (Digital Elevation Model) data used in current study also obtained from USGS. The presence of ground water in a given area is a result of many hydro geological factors such as land use pattern and slope. The assessment of ground water potential zone is done by taking in account an impact of land use and slope on ground water after assigning ranks and weightage to these factors. Various land use classes were given weight and ranks according to their potential towards ground water. Similarly slope of study area was weighted and ranked according to its impact on ground water potential for e.g.- areas with steep slopes were weighted and rank least because the surface water would stand long enough to get infiltrated and subsurface water in these areas will tend to less slope or to the level areas.
It is found that the ground water potential zones information analyzed for Allahabad district can be used for effective utility of ground water for domestic and other purposes. It is also useful for identification of suitable wells location for extraction of water and it's a convenient and time saving method as compare to field methods.
The ground water potential zones map of study area were classified into four zones viz. excellent, good, moderate and poor zones gave a more realistic view to understand potential ground water areas and can be used for groundwater development & management.
Overall, this study focused on the assessment of groundwater potential zones in Allahabad district for getting the holistic view on planning, utilization, administration and management of groundwater resources.

**Keywords:** Arc GIS, Remotely sensed data, Groundwater potential zone, DEM

## 1. Introduction
Ground water is one of the most precious resources which is a dynamic and replenish in nature. It is one of the economic sources of portable water supply in urban and rural environment. It is the water located beneath the ground surface in soil pores and in the fracture of rock formation. Due to uneven distribution of rainfall, the surface water resources are unevenly distributed as well as increasing intensities of irrigation from surface water resulted in increased emphasis on development of ground water resources.
The observation wells are indicators to measure the periodical changes in ground water level and potential. India has 10,715 dug wells, 4,398 piezo metric wells. The total numbers of wells analyzed are 15,653 in India. Uttar Pradesh has 818 dug wells, 247 piezo metric wells. The total numbers of wells are 1,065 in U.P. (CGWB, 2013).
The present study area was Allahabad district located between $25.45^0$ North latitude and $81.85^0$ East longitude at elevation of 98 m above mean sea level. In Allahabad district, number of dug wells monitored are 26. Out of 26 wells, only 20 dug wells are in working condition. Major problems of groundwater in Allahabad are prone to water logging, groundwater pollution due to large amount of iron, nitric acid in water.
Remedial measures to above stated groundwater problems are:
i) Construction of check dams is quite feasible and useful in Trans-Ganga area.
ii) Aquifer should be tapped for irrigation purposes.
iii) There should be conjunctive use of both surface and sub-surface groundwater.

Monitoring groundwater potential zones by using GIS is convenient and time saving method for identifying groundwater potential zones than field methods. In field methods, depth of wells are measured and on the basis of water table level, groundwater potential zones are classified but remote sensing and GIS techniques use satellite data like land use map, slope, soil map for assessment of groundwater potential zones.

Ground water mapping is used in monitoring groundwater occurrence and its distribution by using GIS and remote sensing. Groundwater map is a graphical representation of occurrence and distribution of ground water within geographical relationship. Its purpose is to provide information on occurrence and distribution of ground water and also to provide basis for understanding the relationship between ground water, geological and hydrological environment.

GIS and remote sensing tools are widely used for management of various natural resources. Geographic information system (GIS) is a computer system designed to capture, store manipulate, analyze, manage and present all type of geographical data. It provides special data entry, retrieval, management, analysis and visualization functions.

Remote sensing is the science art and technology of acquiring information (spectral, spatial, and temporal) about material objects, area or phenomenon without coming into physical contact with the object, area or phenomenon under investigation.

Keeping above points in view this study was conducted with the objectives given below:

This study was conducted to assess ground water potential zones in different areas of Allahabad district including metropolitan city areas by GIS. Advanced remote sensing and GIS technology was used in assessing groundwater potential zones by utilizing land use and slope information in study area. It was also useful for identification of suitable wells location for extraction of water and it's a convenient and time saving method as compare to field methods. Therefore this study focused on the assessment of groundwater potential zones in Allahabad district for planning utilization, administration and management of groundwater resources.

### 1.1 Objectives of the study

- To assess groundwater potential zones based on land use and slope information by using remote sensing & GIS.
- To prepare thematic map of groundwater potential zone for Allahabad district by using GIS.

## 2. Background of the study

During the last various few years, various studies have been conducted for effective groundwater potential zones exploration and its management by researchers that are summarized below:

Das *et al*. (2000) [2] identified groundwater exploration and artificial recharge area in Sali river basin, Bankura district of West Bengal using the GIS software's ARC/Info and ILWS 2.1. They found that spatial integration using GIS is very useful in assessing the groundwater resources. Geologic, landform, drainage and geomorphic condition of the area are analyzed. The IRS IB 11 FCC data and SOI topographic sheets are used as base maps. Weighted overlay analysis was done for delineating the recharge suitable areas in the catchment.

Srinivasa and Jugran (2003) [12] assessed that remote sensing and GIS had been used for groundwater potential zones exploration, along with zones of water quality suitable for domestic purposes in Chittor town. Results indicated that for Chittor, 1.64% of area was classified to have very high groundwater potential with groundwater quality moderately suitable for domestic purposes and 31.68% of the area was classified as high potential with over 31% being suitable. Most (62.05%) of the area was of moderate groundwater potential with water quality most suitable for domestic purposes.

Sener *et al.* (2005) found that remote sensing and the GIS have been used for investigation of springs which are an important groundwater source. The chemical composition of groundwater is not of drinking water quality in Burdur city and water in the Burdur residential area is being obtained from the Cine plain. The purpose of this study was to investigate new water sources by using remote sensing and GIS methods. Geology. Lineament and land use maps of the research area were prepared using Landsat TM satellite image composed of different analyses on the TM 7-4-1 band.

Vijith *et al.* (2007) [13] carried out a study of identify and delineate the groundwater information potential areas in parts of Western Ghats, Kottayam, covering upper catchment of Meenachil river. The information of lithology, geomorphology, lineaments, slope and landuse/land cover was generated using the remote sensing data and Survey of India topographic sheets an integrated them with raster based GIS to identify the groundwater potential of the area. Thus, GIS based model which takes account of local conditions/variations have been developed specially for mapping groundwater potential. On the basis of hydro-geomorphology, three categories of groundwater zones namely good, moderate and poor were identified and delineated. It was found that the high potential zones corresponds to fracture valleys, valley fills, pediments and denudation slope, which coincide with the low slope and high lineament density areas.

Sathian *et al*. (2007) [11] conducted a study to estimate the recharge and discharge of groundwater in laterite soils of the KCAET campus. Groundwater recharge was estimated using water table fluctuation method and rainfall infiltration factor artificial recharge structures like percolation ponds, pitting, an echelon dams, induced recharge and battery of wells.

Imran *et al.* (2010) [4] studied the groundwater conditions in Mamundiyar basin, Tamil Nadu by combining remote sensing, evaluation of digital elevation models (DEM), GIS and fieldwork techniques. DEM was used for lineament and geomorphologic mapping. All thematic layers were integrated and analyzed in GIS. The overall results demonstrate that the use of remote sensing and GIS provide potentially powerful tools to study groundwater resources and design a suitable exploration plan.

Kumar *et al.* (2014) conducted a study to find out groundwater potential zones in Lekkur sub basin of Mangalur block Cuddore district, Tamil Nadu. All thematic maps were converted into grid (raster format) and superimposed by weighted overlay method (ranks and weightage wise thematic maps) prepared. From the analysis, groundwater were grouped into excellent, very good, good, moderate and poor prospects.

## 3. Materials and Methods

### 3.1 Description of study area

Allahabad is a metropolitan city of Uttar Pradesh in India. The location of Allahabad district is between the coordinates $25.45^0$ North latitude and $81.85^0$ East longitudes. The geographical area of Allahabad district is 5,246 $km^2$. Allahabad has a humid subtropical climate. There are three seasons in Allahabad: hot dry summer, cool dry winter and warm humid monsoon. The mean maximum temperature is $42.9^0$C and mean minimum temperature is $9.30^0$C in year 2009. (Groundwater Brochure, 2009).

There are two methods of monitoring groundwater potential zones:

a) Field Method: In this method, depth of ground water table level from dug wells and tube wells in pre monsoon and post monsoon is measured and then ground water potential zones are analyzed on the basis of water level of wells in different regions.

b) Ground water mapping: It is used in monitoring groundwater occurrence and its distribution by remote sensing & GIS. The purpose of groundwater mapping is to provide information on occurrence and distribution of ground water and also to provide basis for understanding the relationship between ground water, geological and hydrological environment.


**Fig 3.1:** Location map of Study Area

**3.2 Data Used:** The satellite data used were USGS(United States Geological Survey) SPOT 4 with spatial resolution of 1000 m for Land use/Land cover map and Shuttle Radar Topographic Mission (SRTM) data for Digital Elevation Model (DEM) map acquired from(United States Geological Survey) USGS site produced by NASA with spatial resolution of 90 m.

### 3.3 Software Used:

**3.3.1 ERDAS Imagine 9.2:-** This software was used in various steps of satellite image processing. It was developed by ERADAS in USA for geospatial applications. The input data was satellite image in the form of raster (grid) that was processed in software to get land use map.

**3.3.2 Arc GIS 9.3:-** This software was used in data analysis and map composition. Arc GIS is a geographic information system (GIS) used for working with maps and geographic information. It was developed by ESRI Software Company in USA. The input data used was satellite image in the form of raster or vector (polygon) form that was processed in Arc GIS to DEM map.

### 3.4 Methodology

**3.4.1 Land Use: -**Land use map was prepared by using ERDAS 9.2 and Arc GIS 9.3. The major land use of the areas were grouped into different categories or classes like water bodies, irrigated agriculture, mixed agriculture/settlement, dry vegetation/forest, scrubs/thorn forest, barren and highly urbanized.

Various land use classes were given weight and ranks according to impact they have on presence of groundwater influencing groundwater potential zones. The highest rank i.e. seventh rank was given to water bodies because there was seven land use classifications and among seven land use classifications seventh rank was assigned to water bodies. It means opportunity time for water present to infiltrate into soil was high so water bodies have high infiltration rate. Similarly, least i.e. first rank was given to highly urbanized regions because of low infiltration rate due to absence of water or less opportunity time for water to infiltrate into land. The other land use patterns also ranked on the basis of infiltration capacity of different regions.

**3.4.2 Digital Elevation Model (DEM):-** Digital Elevation Model (DEM) could store varying variables like elevation, slope, ground water depth etc. The accuracy and efficiency of DEM is depends upon details of elevations which were digitized to find slope. The DEM map was prepared by using Arc GIS 9.3. The slopes were grouped into five classes: level, moderate level, gentle, moderate gentle and steep on the basis of degree of slope.
Lesser is the slope, higher will be infiltration rate. It means opportunity time for water to infiltrate into soil is high so infiltration rate is high resulting good ground water potential zones. Similarly, higher is the slope, lesser will be infiltration rate resulting poor ground water potential zones. It means lesser opportunity time for water to infiltrate into ground. Level areas were given highest rank i.e. fifth rank as slope classes were grouped up to five classes that's why fifth rank rank was assigned to level areas, moderate level areas were given fourth rank and steep areas were given least rank i.e. first rank depending upon infiltration rate and its impact on groundwater potential.

**3.4.3 Assigning Ranks & Weights to the classes and maps:-** Ranks and weights were assigned to the classes and maps to show the importance of a hydrologic parameter or parametric map or ground water potentiality.
It determined the impact of each parameter on the potential of groundwater. Each class of a particular map such as land use map and DEM map was assigned ranks according to their infiltration rate and suitability. Each parametric map i.e. land use map and digital elevation model map was given certain weightage. Land use map was given 45% weight and DEM map was given 55 % weight based on its influence on ground water availability. Higher ranks were given to most suitable class and ranks decrease as per decrease in suitability. The product of rank and weight as given as index value of each map. The indexed values were used to reclassify the area into four classes: excellent, good, moderate and poor potential zones.

**3.4.4 Techniques Used**
The preparation of satellite data involves land use map and DEM map for generation of Ground water potential zones map.

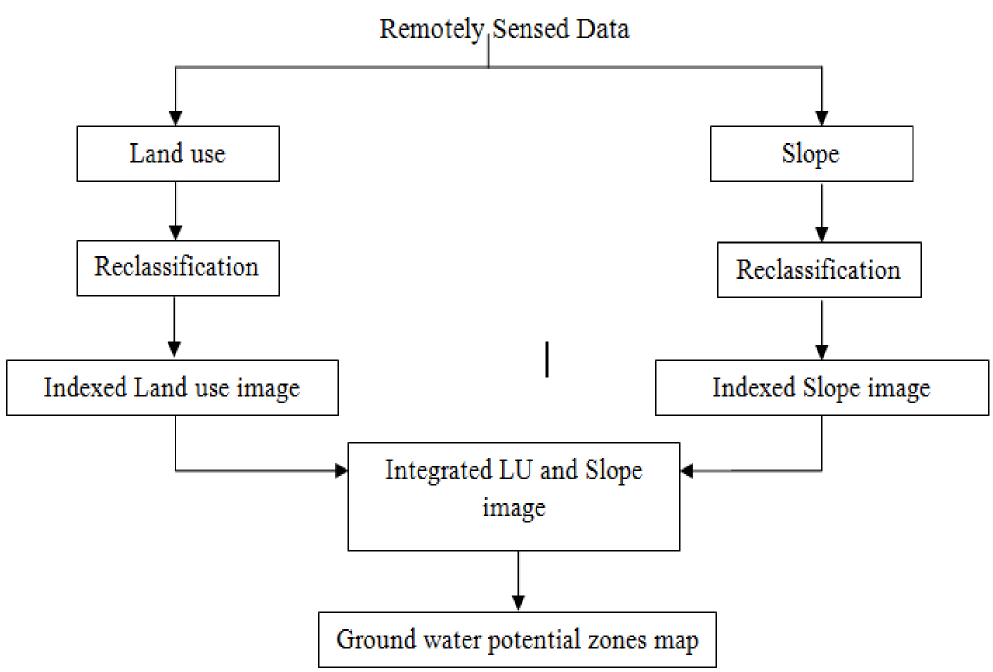


**Fig 3.4:** Flow chart delineating groundwater potential zones

**4. Results**
An assessment of ground water potential areas were consisting of some influencing factors like slope of land and land cover over the area. Using the GIS software, the data was analyzed and results were viewed as maps which provide an easy way for assessment of groundwater potential zones in Allahabad district was covering area of 3,424 km$^2$. The elevation of study area was 98m. The salient findings of the detailed spatial analysis of the Allahabad area using remote sensing and Arc GIS were given below:

**4.1 Land use map:** Land use map was developed by USGS using SPOT 4 satellite data was classified into different land use layers. The major land use of the areas were grouped into different categories or classes like water bodies, irrigated agriculture, mixed agriculture/settlement, dry vegetation/forest, scrubs/thorn forest, barren and highly urbanized.

Agriculture fields had more ground water potential zones because of regular irrigation and infiltration consequently so they have given fifth and sixth ranks. Water bodies showed high groundwater potentiality due to highest infiltration rate so they ranked highest i.e. seventh among others classes. Hence high weightage and rank was given to water bodies. Barren land and highly urbanized area was given least rank as there was no water available so infiltration capacity was not there. In the same way other land use classes were ranked like dry vegetation and thorn forest were ranked third and fourth based on infiltration rate and its impact on groundwater potential. Weightage given and ranks assigned are shown in Table 4.1 and the map is shown in fig 4.1.

**Table 4.1:** Weightage and rank assigned to land use classes:

| Sl. No. | Land use | Rank | Weight | Index |
|---|---|---|---|---|
| 1 | Water Bodies | 7 | 45 | 315 |
| 2 | Irrigated Agriculture | 6 | | 270 |
| 3 | Mixed Agriculture/Settlement | 5 | | 225 |
| 4 | Dry Vegetation/Forest | 4 | | 180 |
| 5 | Scrubs/Thorn Forest | 3 | | 135 |
| 6 | Barren | 2 | | 90 |
| 7 | Highly Urbanized | 1 | | 45 |

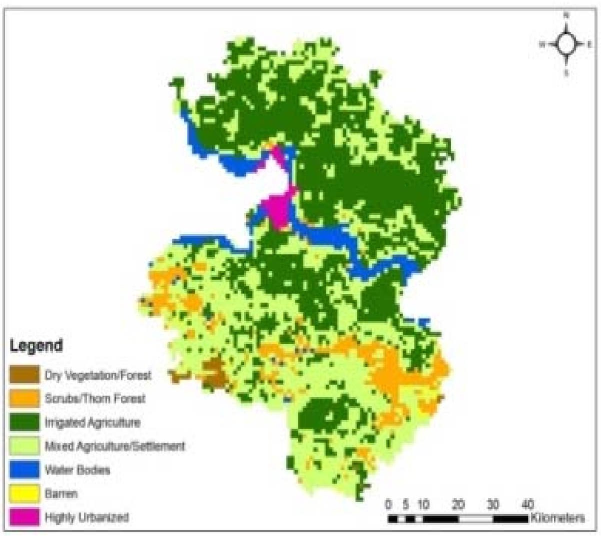


**Fig 4.1:** Land use map

**4.2 Digital Elevation Model (DEM):** A DEM SRTM satellite data was downloaded from USGS site and processed in Arc GIS environment shown in fig 3. Slope is an important factor in assessing ground water potential zone that has been derived from DEM map. High degree of slope is between 1$^o$ to 6$^o$ showing steep areas can result in rapid runoff therefore infiltration rate can be ultimately reducing ground water level. Steep areas were given lowest rank i.e. first. Similarly, when degree of slope is less i.e. between 0$^o$ to 0.25$^o$.It means areas are leveled and infiltration rate is high so leveled areas ranked high fifth. Moderate level and gentle areas were given ranks fourth and third respectively based on infiltration rate. The slopes were grouped into five classes like level, moderate level, gentle, moderate gentle and steep on the basis of degree of slope. Weightage given and ranks assigned are shown in Table 4.2 and the map is shown in fig 4.2.

**Table 4.2:** Weightage and ranks assigned to slope classes:

| Sl. No. | Class name | Slope in degree | Rank | Weight | Index |
|---|---|---|---|---|---|
| 1 | Level | 0 - 0.125 | 5 | 55 | 275 |
| 2 | Moderate Level | 0.125 – 0.25 | 4 | | 220 |
| 3 | Gentle | 0.25 – 0.5 | 3 | | 165 |
| 4 | Moderate Gentle | 0.5 – 1.0 | 2 | | 110 |
| 5 | Steep | 1.0 – 6.0 | 1 | | 55 |

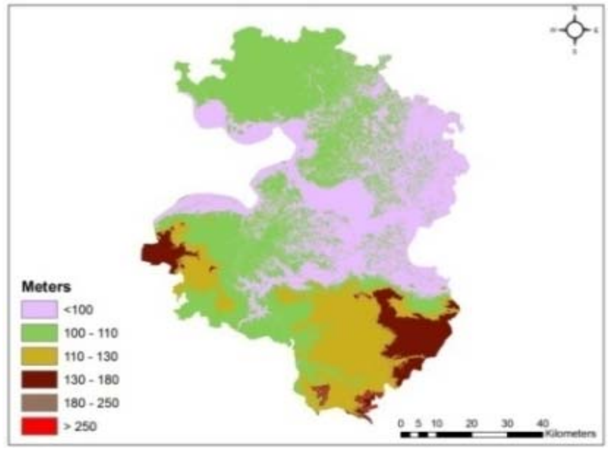


**Fig 4.2:** Digital elevation model (DEM) map

**4.3 Groundwater potential zones:** The ground water potential zones were delineated based on the total score obtained by integrating slope and land use maps. Total weighted index had been worked out for groundwater potential zones map and based on it map classes were divided into four zones-excellent, good, moderate and poor zones. They were excellent zones (<=315 index values), good zones (270-315), moderate zones (180-225) and poor (45-135 index values).

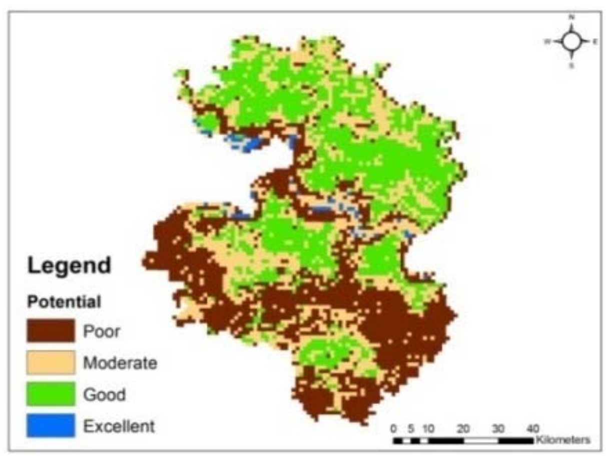


**Fig 4.3:** Output map (Ground water potential zones map)

**4.3.1 Excellent zones:** The excellent ground water potential zones were delineated by grouping the areas, which had index values more than or equal to 315. Land use pattern have leveled water bodies and some intensively irrigated areas around water bodies comes in these zones. There were also leveled so infiltration rate was high due to opportunity time for water was high to infiltrate into land created excellent potential groundwater areas.

**4.3.2 Good zones:** Good zones were those areas having index values ranging between 270-315 with irrigated agricultural regions and having slope between levels to moderately level.

**4.3.3 Moderate zones:** The moderate ground water potential zones index values ranged from 180-225 includes mixed agriculture, settlement, dry vegetation, forest with some areas having gentle or moderately gentle slope comes under this category.

**4.3.4 Poor zones:** The areas having index values ranging between 45-135 were grouped as poor ground water potential zones. The scrubs, thorn forest, barren land and highly urbanized regions with higher slopes were classified in these areas. In these areas infiltration rate was least due to land use type and slope. There were barren lands and scrubs with less or no water presence so ground water potential would be least in these zones. In the absence of rainfall with low infiltration capacity, contribution of such areas will be least towards ground water.

## 5. Summary and Conclusion

The present study was done to identify potential groundwater zones in Allahabad district. Remotely sensed data which included land use and DEM were used in this study. Land use and Digital Elevation Model (DEM) were ranked according to the impact they may have on the presence of ground water. e.g. - Highly urbanized areas were ranked least and water bodies were ranked high for presence of groundwater also influences groundwater potential zones. Irrigated agriculture field and settlements around agricultural field had good water potential than barren lands because of regular irrigation and infiltration resulting from irrigation. Information on slope of these aforementioned areas was also utilized in the delineation of potential ground water zones. The potential groundwater zones identified in the study were classified into four categories: excellent, good, moderate and poor zones.

The excellent ground water potential zones had water bodies and some intensively irrigated areas around water bodies. These were also leveled so infiltration rate was high due to water opportunity time to infiltrate into ground was high made excellent potential ground water areas. Good zones were the areas with irrigated agriculture and having slope between levels to moderately level.

The moderate ground water potential zones include mixed agriculture system, settlement, dry vegetation, forest with areas having gentle or moderately gentle slope.

The scrubs, thorn forest, barren land and highly urbanized regions with higher slopes were classified under poor ground water potential areas. In these areas infiltration rate was least due to land use type and slope. There were barren lands and scrubs with less or no water presence so ground water potential would be least in these zones. In the absence of rainfall with low infiltration capacity, contribution of such areas will be least towards ground water.

It was useful for identification of suitable wells location for extraction of water and it's a convenient and time saving method as compare to field methods. These results were verified and correlated with actual groundwater level reports of Allahabad district. In Yamuna river basin, Bari and Ladiri Bazar regions of Allahabad district compatibly were identified as the region of maximum and minimum ground water potential. Moreover, Allahabad city zone had moderate groundwater potential. Overall, this study focused on the assessment of groundwater potential zones in Allahabad district for planning utilization, administration and management of groundwater resources.

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