GIS MAPPING OF SUB-SURFACE WATER RESERVOIRS: A CASE STUDY OF RECHNA DOAB

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ABSTRACT: Water is basic necessity of life and is used for drinking, cleaning, production of food and energy. Increasing population, urbanization and industrialization are leading to a water scarce world. Water resource management and optimal planning is one of the most crucial global issues. Once Pakistan was regarded as water surplus country but now it is facing water shortage. This water scarcity is not only because of lack of water availability but also a result of ineffective and poorly managed policies, as groundwater is not sheltered under any legislation. Study was carried out at Rechna Doab, being located in arid and semi-arid climate experiences very low rainfall. In this situation groundwater deserves attention from planners and policy maker. This research was dedicated for assessment of groundwater potential zones. Data sets for study include Landsat 8 image, ASTER GDEM. Key factors considered in mapping groundwater potential zones are soil type, land cover, lineaments, slope, aspect, drainage density and rainfall. GIS and RS techniques were collectively used to map out potential groundwater zones at Rechna Doab on basis of above-mentioned parameters. Suitable weights were assigned to all factors and weighted overlay analysis in ArcMap was carried out. Suitability map shows least suitable, slightly suitable and highly suitable for groundwater recharge. For accuracy assessment tube wells data was acquired by local government which showed good correlation. Remote sensing and GIS are cost effective and efficient method for site identification for groundwater potential zones, it is also recommended to follow these methods for other parts of country.

1. INTRODUCTION

Water scarcity is burning global issue of the time. There is an inverse relation between demand and supply of water. Water shortage is anticipated to cause food shortage too. Food mainly comes from agriculture. Agricultural sector is facing a tough competition for this limiting resource with domestic and industrial sectors. Surface water sources are unable to fulfil water needs hence pressure has shifted to groundwater (Rosegrant et al., 2002). Groundwater not only acts as a natural resource to fulfil human water needs but also supports ecosystem. World is in dire need to manage this vital resource (Llamas and Custodio, 2002).

Ground water is significant natural resource and plays important role in human well-being. Groundwater is responsible for provision of nearly 34% of annual water supply. With increased demand for water pressure on groundwater is also augmented. Groundwater has become a topic of great interest for policy makers and researchers globally. Previously conventional approaches for groundwater potential mapping were used, these methods included extensive field surveys. With introduction of techniques like remote sensing and geographic information system field of groundwater mapping has been revolutionized. Researchers in the field of groundwater are encouraged to make use of remote sensing and GIS based practices. These methods help in minimizing budget as well as time period to carry out a particular research (Toleti et al., 2000).

Presence or absence of groundwater in any area depends on various parameters including lithology, geology, elevation, and precipitation (El-Naqa et al., 2009). The importance of drainage pattern can be understood by the relevant information it gives on geological formation in an area. Different types of drainage pattern are observed because of the influence of slope, lithology and structure. For example, dendritic pattern is observed in drainage basins which are composed of homogenous rocks (Pareta and Pareta, 2011).

Arid and semi-arid countries like Pakistan experience huge utility conflicts for water usage among domestic, industrial and agricultural sectors. Available resources of countries are declining while demand is higher therefore it is suggested to judiciously use this precious resource among all the sectors (Ahmad et al., 1998). If the present trend continues it is expected that one third of developing world will get severely affected from water scarcity by the year 2025 (Seckler et al., 2009).

Pakistan is an agricultural state and is dominated by arid and semi-arid zones therefore depend on water reservoirs and irrigation system. The graph of available water for the country is narrowing down rapidly, while the difference between population expansion and demand for resource with that of availability is broadening.

Present study is carried out at Rechna Doab, being located in arid and semi-arid climate experiences very low rainfall. One third of the gross area of upper Rechna is under perennial canal water supplies hence the dependence on groundwater is high. Moreover, Rechna Doab is covering highly urbanized and industrialized cities as a result quality of water is being affected by untreated domestic and industrial recharge. In this situation groundwater deserves attention from planners and policy maker. This research is dedicated for valuation of groundwater potential zones.

2. MATERIALS AND METHODS

2.1 Study Area

The study area consisted of Rechna Doab. Doab refers to the land between two rivers. Rechna doab is the land between River Ravi and Cheenab. It is a part of the alluvium-filled Indo Gangetic plane. Out of 2.98 million hectares of gross area, about 2.3 million hectares is cultivated and classified as the irrigated croplands (Jehangir et al., 2002). Rechna doab comprises eight districts namely Sialkot, Gujranwala, Sheikupura, Faisalabad, Toba Tek Singh, Jhang, Narowal and Hafizabad. Sharing some part of 8 populated districts with major industrial and agricultural activities increases significance of study area. Area provides shelter to about 21.1 million people as per government of Punjab statistics population density is 599 persons per square kilometers. 25 percent of total population of rechna doab resides in district Faisalabad, which is countries important agro-industrial zone.

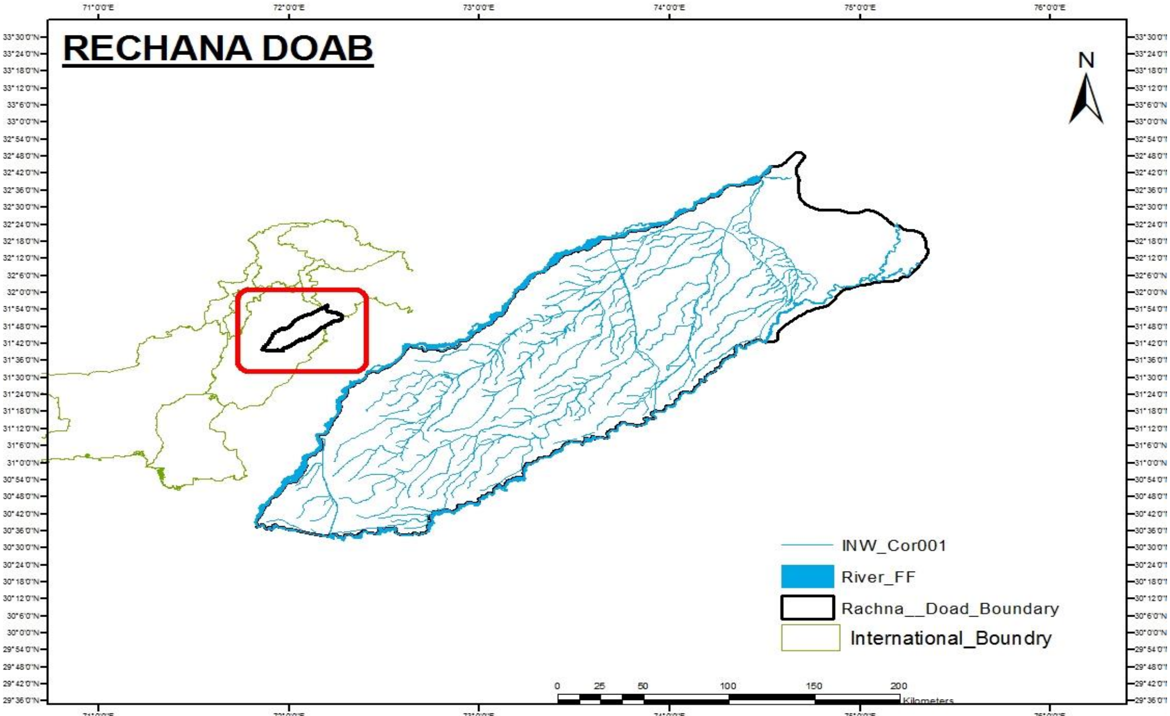

Figure:1 Map of Study Area Rechna Doab

2.2 Data set

- Landsat8 images were downloaded from USGS of year 2019.USGS is a science organization with a broad scope, cover almost all of the life aspects including ecosystem health, natural hazards and resources and impacts of climate change.
- ASTER GDEM of 30-meter resolution was downloaded from USGS.
- Rainfall data for five years from 2009 to 2013 was acquired from Pakistan Meteorological Department (PMD).
- Soil type map acquired by Geological survey of Pakistan

2.3 Processing

Landsat 8 imagery was classified using supervised classification method to produce a land cover map of study area. Panchromatic band of landsat 8 was used extract lineaments. Automatic lineament extraction algorithm from PCI GEOMATICA was used to produce lineaments map. Lineaments were converted to shapefile and used to produce lineament density map in ARCMAP. ASTER GDEM was processed in ArcMap to produce slope and aspect. With the help of hydrology tools drainage network was extracted and from the network drainage density of study area was calculated. Soil type map and rainfall map of study area were also generated in arcmap. Study area contains sandy, loamy and clayey soils. Soil is the most important indicator for determining presence of groundwater.

Suitable weights were assigned to different factors in the study area, which directly or indirectly influences the water infiltration into the ground are shown in table. The identification of potential groundwater recharge zones is dependent upon different factors like soil type, slope, lineaments, drainage density, and land cover as they control the water infiltration in the ground. Below is the list of weights assigned.

Table 1: weights assigned to individual features

Parameter	Class	Groundwater prospect	Weight of parameter out of hundred
Lithology	Sandy soil Loamy soil Clayey soil	Suitable Moderately suitable Poor	24
Land cover	Barren land Water bodies Vegetation Built up	Highly suitable Suitable Moderately suitable Least suitable	21
Lineament Density	< 1.191 1.191-1.787 1.787-2.383	Suitable Moderately suitable Poor	19
Drainage Density	< 1.758 1.758-2.102 2.102-3.134	Suitable Moderately suitable Poor	13
Slope	<15 15-24 24-56	Suitable Moderately suitable Poor	13
Rainfall	<34 34-45 45-53	Suitable Moderately suitable Poor	10

3. RESULT AND DISCUSSION

For land cover classification of the study area, satellite image of LANDSAT 8 was used. The classification results showed a mixture of four different classes i-e vegetation, water body, barren land and urban land. In addition, area for each class was also calculated in ArcMAP 10.5.

The classified map of Rechna Doab of year 2015 showed that the largest area is covered by built area and makes up-to 46% of the total area. Vegetation constitutes the second largest area of Rechna Doab covering 34% of total area. Out of remaining total area, 14% of the area is covered by barren land and water bodies cover 6% of the total area.

Land cover is an important determinant of groundwater potential as it has direct impact water penetration to the ground (Sener *et al.*, 2005). Various researchers used land cover/ land use as vital element in hydro-geological studies. Owing to its importance in mapping groundwater potential zones this factor was given an overall weight of 21.

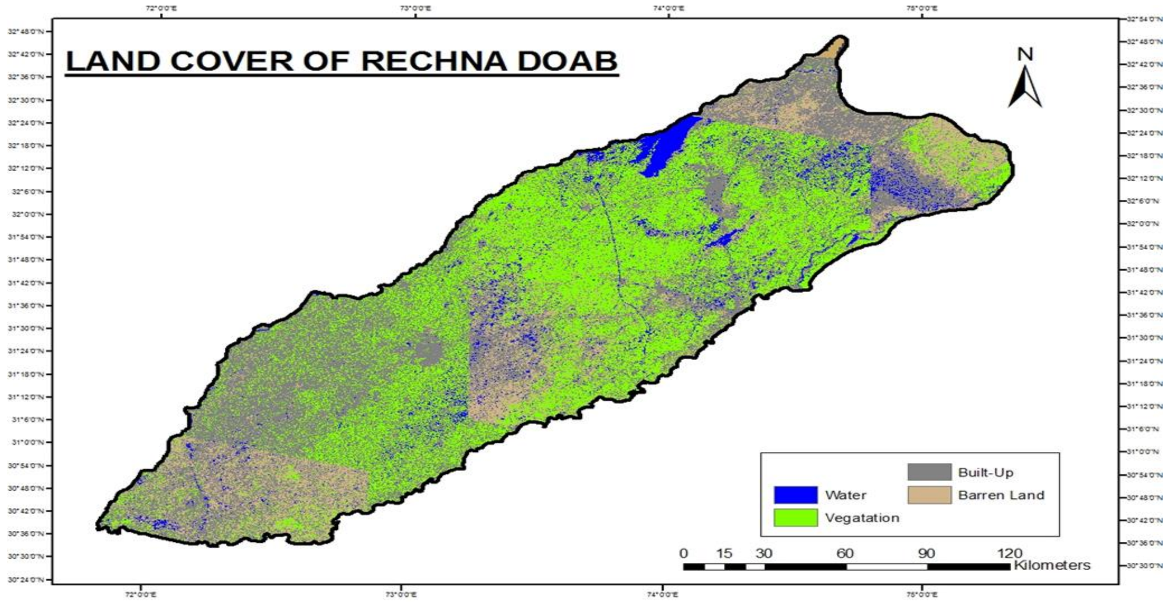

Figure 2: Classified Map of Rechna Doab in 2019 Using LANDSAT 8 Satellite Imagery

Main soil types discovered in study area include clayey soils, loamy soils and silty soils. Soil type plays significant role in groundwater presence as clayey soils are less permeable hence chances of groundwater are lesser. While silty soils are more permeable and therefore it was given the highest weight for groundwater potential (Taniguchi and Hiyama, 2014). Due to its significance maximum overall weight was assigned to this parameter.

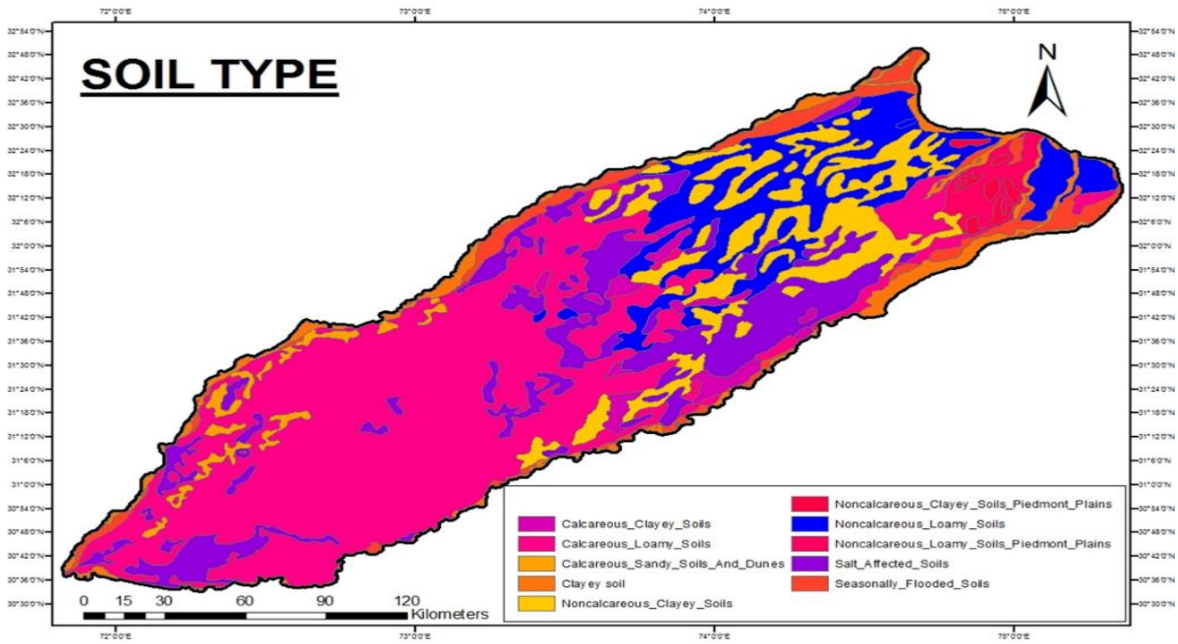

Figure 3: Map showing soil types of the study area

About 70% of the total area has gentle and moderate slopes ranging between 0-150 which favors the water infiltration into ground. The slope of an area is essential in site assessment and application of all ground-based water storage systems (Isioye et al., 2012).

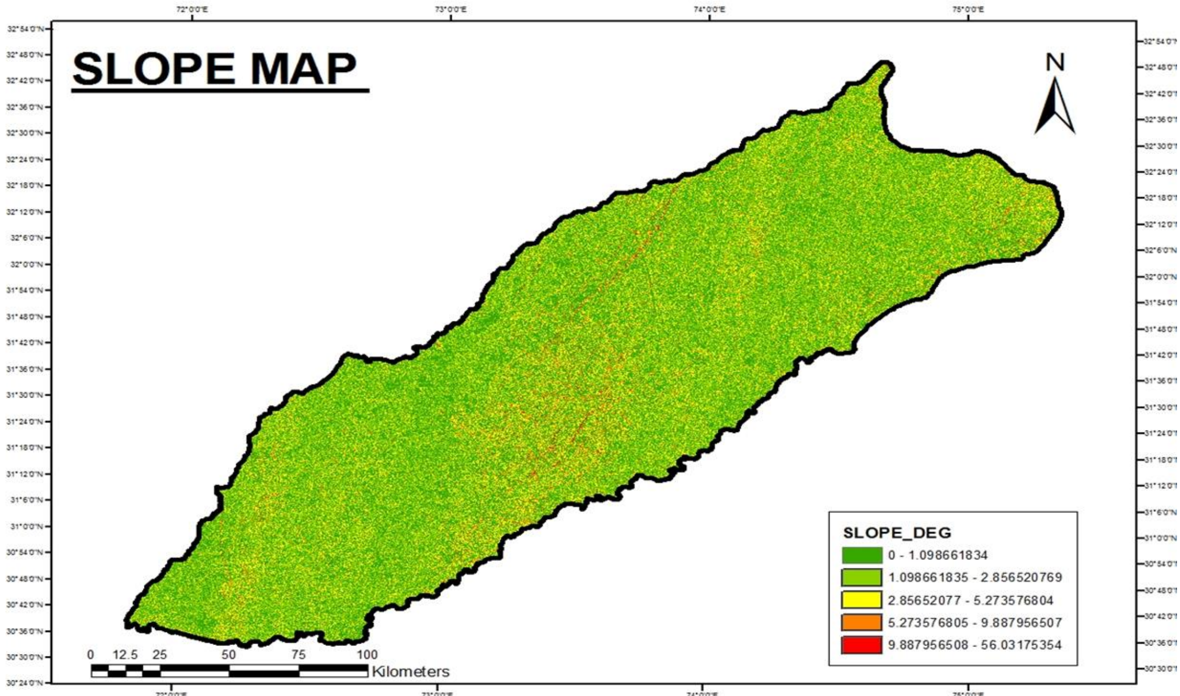

Figure 4: Map showing slope in degrees and the contour of the Rechna Doab

Lineament density of any region is an indicator of its ground water potential. This is why the presence of lineament is considered as a signal for porous region. Low lineament density categories less significant zones and vice versa (Haridas et al., 1998). Overall weight of 19 was assigned to lineament density.

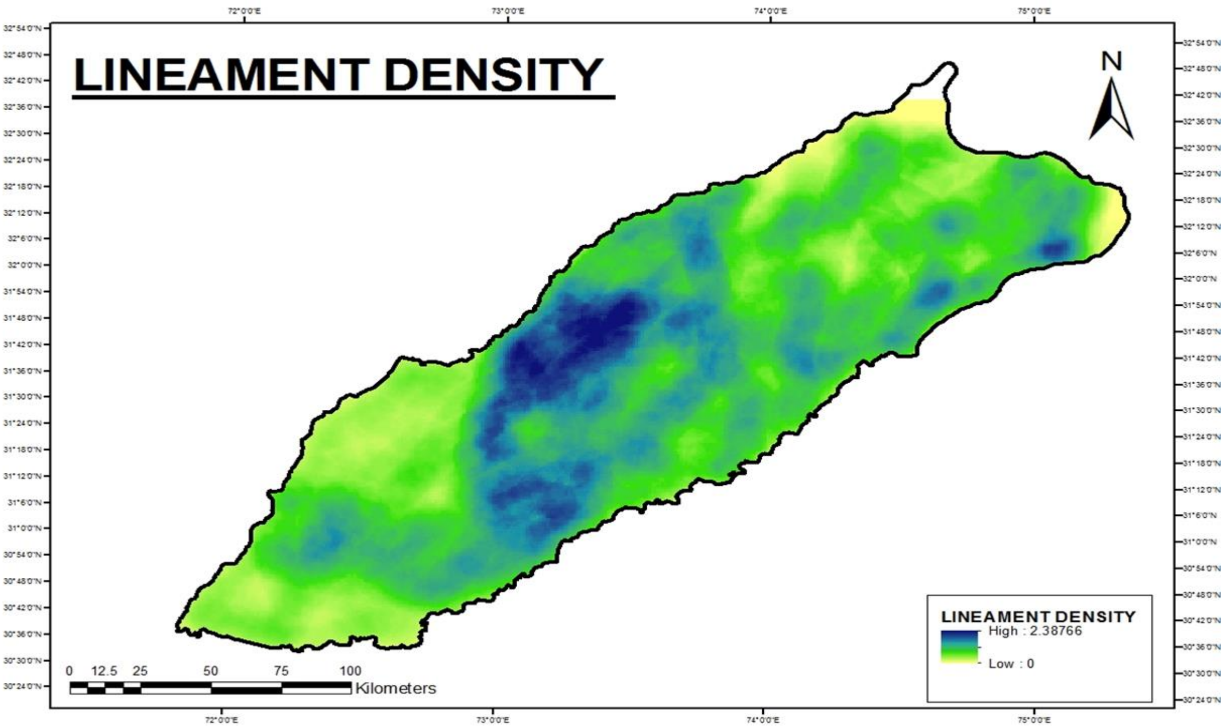

Figure 5: Map showing the lineament density of the study area

Suitable weights were assigned to different factors in the study area, which directly or indirectly influences the water infiltration into the ground are shown in table 2.1. while initial weights assigned are presented in table 2

Table 2: Table showing weights assigned to parameters for groundwater potential mapping

THEME	WEIGHT
Lithology	6
Land cover	5
Lineaments	4
Drainage density	3
Slope	2
Rainfall	1

Using these initial parameter weights pairwise comparison matrix of parameters was carried as shown in table below.

Table 3: pairwise comparison matrix of parameters

	Lithology	Land cover	Lineaments	Drainage density	Slope	Rain	Mean	Normalized weight
Lithology	6.0/6.0	6.0/5.0	6.0/4.0	6.0/3.0	6.0/2.0	6.0/1.0	2.45	0.3
land cover	5.0/6.0	5.0/5.0	5.0/4.0	5.0/3.0	5.0/2.0	5.0/1.0	2.04	0.23
Lineaments	4.0/6.0	4.0/5.0	4.0/4.0	4.0/3.0	4.0/2.0	4.0/1.0	1.63	0.19
drainage density	3.0/6.0	3.0/5.0	3.0/4.0	3.0/3.0	3.0/2.0	3.0/1.0	1.22	0.15
Slope	2.0/6.0	2.0/5.0	2.0/4.0	2.0/3.0	2.0/2.0	2.0/1.0	0.81	0.09
rain fall	1.0/6.0	1.0/5.0	1.0/4.0	1.0/3.0	1.0/2.0	1.0/1.0	0.4	0.04
Total							8.55	1

After determination of normalized weights through pairwise matrix overall weights were assigned as per table:1 and used in weighted overlay analysis process. The identification of potential groundwater recharge zones is dependent upon different factors like soil type, slope, lineaments, drainage density, and land cover as they control the water infiltration in the ground. For identifying such zones, the weighted overlay analysis of the above-mentioned layers was done in

ARCMAP 10.1, using 1 by 3 by 1 scale. The resultant layer was then classified into 3 classes based upon suitability scale i-e Suitable, moderately suitable, and Unsuitable as shown in figure.

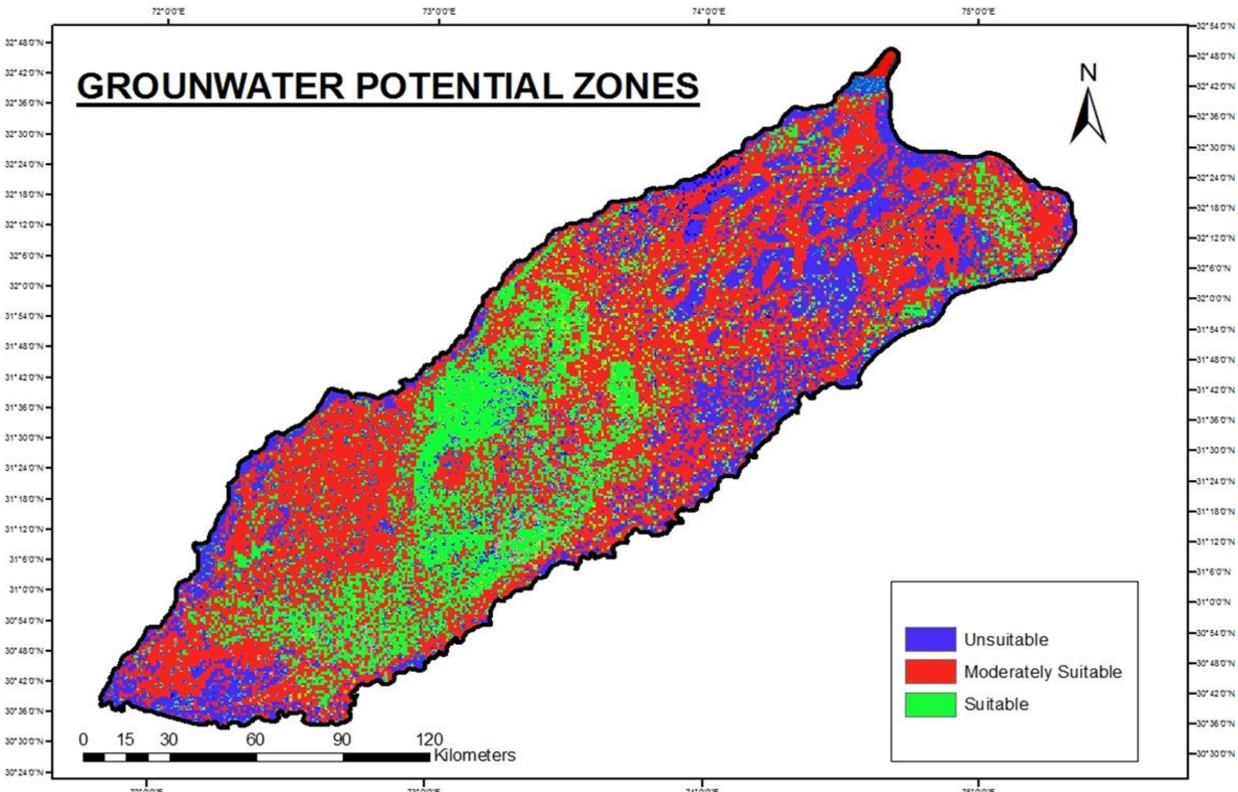

Figure 6: Map Showing Groundwater Potential of Rechna Doab

On comparison with field tube wells data it was found that most suitable sites lie in regions were water table is higher than the rest.

4.CONCLUSION

Water, the fundamental source of life, is depleting at a rapid rate. Groundwater has gained much fame as a substitute of surface water. Suitable site identification for groundwater exploration is dependent on various factors. Previously the operations to abstract groundwater were either by random digging or by using the conventional methods of deep study area analysis. Following study is based on advanced remote sensing and GIS techniques. These techniques are recognized to be highly cost and time effective. Research based on Rechna Doab focused on parameters that have a significant role in presence or absence of groundwater. These factors included lithology, land cover, lineaments, slope, drainage density, and rainfall. All parameters were assigned suitable weights to produce final map showing suitable, moderately suitable, and unsuitable sites for groundwater exploration. Similar studies if carried out at other parts of country too will be helpful in significant groundwater exploration.

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