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RESEARCH ARTICLE

HYDROGEOMORPHOLOGICAL MAPPING IN PARTS OF MAHENDERGARH DISTRICT, HARYANA: REMOTE SENSING APPROACH

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ABSTRACT

Remote Sensing (RS) plays a significant role in Groundwater investigations. Hydrogeomorphological mapping which emphasizes on study of Groundwater potential on the basis of landforms and underlying geology has proved beyond doubt. Satellite remote sensing has the capabilities of permanent record, synoptic coverage, repetivity, viewing over larger spectrum beyond visible range, unbiased information, stereoscopic coverage, cheap and speedy over larger areas and stereoscopic coverage. These characteristics of the satellite data have continuously increased the potential of this technique in Ground water studies. Present paper mainly deals with the preparation of hydrogeomorphological map in parts of Mahendergarh district, Haryana State, India. Hydrogeomorphological map has been prepared by employing visual image interpretation techniques by considering various image interpretation elements. Ground truth was conducted in selected areas for checking and verifying the prefield interpreted map. The prefield map thus prepared was updated by keeping field observation into consideration. The final map was assessed in terms of groundwater prospects. The main hydrogeomorphic units mapped in the study area are fluvio-aeolian plain, alluvial plain, sand dunes, structural hills, residual hills and buried pediments. Each geomorphic unit is assessed for groundwater potentiality.

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INTRODUCTION

Groundwater is one of the most important natural resources available to the humanity and it constitutes an important component of the earth's water circulatory system known as hydrologic cycle as well as of human life cycle. But the issue of use, abuse and misuse of water is continuously been the burning topic from last more than a decade. Although, water is a more dynamic renewable natural resource, its availability with good quality and proper quantity is of significant importance. The pressure on the availability of water increases globally because of its increasing demand due to industrialization, urbanization, population explosion, increased agricultural requirements etc. Several countries situated in arid regions already face the problem of more surface/ groundwater use than replenished annually. Continuous pressure on this precious gift of nature is increasing day by day. Due to over drafting and less recharge, water table is decreasing at many places. However due to poor groundwater quality and flood irrigations the water level is having upcoming trend, resulting in water logging and salinization. In India more than 90% of rural and nearly 30% of the urban population depend upon groundwater for meeting their drinking/domestic requirements. It also accounts for about 60% of the total irrigation potential in the country (Reddy *et al*., 1996). Haryana state forms a divide between Ganges and Indus water catchments. The alluvial plain including western desertic terrain of sand dunes covers more than 90% of the area of the state. Despite this Haryana state is suffering from adverse hydrogeological conditions in almost 65% of the area. The northern and southern parts of the state are facing the problem of water level decline due to over drafting of groundwater whereas the central part along Rohtak, Jind, and Sirsa axis is facing the problem of rise in water table leading to problems of water logging and salinization. The southern part of Haryana and specifically the study area is facing lot of problem related to groundwater. This is due to less rainfall resulting into less recharge than exploitation. The situation is further worsened due to non-availability of surface irrigation. This is the basic reason for selecting the study area for groundwater potential areas demarcation.

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Review of Literature

Groundwater potential in any area depends upon the type of landforms and the underlying geology. Hence study of the

geomorphology as well as geology is essential before making any inference about the availability of groundwater. The geology of an area must be mapped since various rock units and structures govern the occurrence & movement of groundwater. Landforms and relief also play an important role in altering runoff/ recharge and groundwater movement. Many authors have successfully carried out groundwater prospects areas mapping using remote sensing approach (Roy, 1979; Perumal and Roy, 1983; Roy, 1984; Singh, 1992; Mangrulkar *et al*, 1993; Haldar *et al*, 1994; Thomas *et al*, 1995; Chaudhary *et al,* 1996; Roy, 1996; Singh 1999; Chaudhary 2003 and Gopinath and Seralathan 2004; Chaudhary and Agarwal, 2009; Toleti *et al.,* 2000; Rani and Chaudhary, 2015). Such maps depicting prospective zones for groundwater targeting, are essential as base, for planning and implementation of groundwater exploration in the following manner:

- Select likely areas for groundwater exploration.
- Progressively narrow down the target areas in pin pointing of well drilling sites.
- Find the indicators of the presence of groundwater.
- Identify regions of recharge/ discharge.
- Indicate the quality of groundwater.
- Monitor aquifer changes as groundwater development proceeds.
- To acquire certain remote sensing based parameters of use in hydrological equations for assessment of groundwater resource potential.

The importance of satellite imagery in hydrogeological investigation is based on the principle, that, the multispectral images help the Hydrogeologists and water resources Engineers in locating structural, morphological and vegetation features as possible keys that govern groundwater flow in aquifers. The water on the surface, which has a bearing on groundwater circulation underground, can be distinguished in the near infrared region owing to low reflection of water. Synoptic view, repetitive coverage and capability to view the scene in several spectral bands, some lying beyond the visible part of the electromagnetic spectrum, are some of the special characteristics that have made remote sensing an effective tool in groundwater search. The clue to groundwater search is the premise that sub-surface geologic elements forming aquifers have almost invariably surface expressions that can be discerned by remote sensing techniques.

Brief description of study area

Study area comprises of Nangal Chaudhary and Narnaul blocks are the southern part of Mahendergarh district in south Haryana with a total geographical area of 649.58 sq. kms. It extends from 27^{o} 46' north to 28^{o} 12' north latitudes and 75^{o} 55' east to 76^{o} 15' east longitudes. Physiographically the study area consists of fluvio-aeolian plain, aeolian plain, flood plain, sand dunes, pediment zone and hills of Aravalli series. Since the sandy area is associated mostly with the Aravalli hills, it may be inferred that sand, which constitute the plain, was probably transported across the low relief Aravalli ranges or through the gapes in the hills and then it settled due to loss of wind speed in the leeward side. Rocky outcrops traverse through most part of the area in roughly southwest northeast direction. The hills are longer than wide forming roughly parallel series of ridges. Dohan and Krishnawati are the Streams/ Rivers flowing in the area, which are non-perennial in nature and originate from the Rajasthan Portion of Aravalli hills near Nim Ka Thana. Location map of the area is shown in **Figure 1.**

Geologically the study area is a part of Indo Gangetic system of quaternary age, which rests on the basement rocks of Delhi system. The area contains small exposures at various places in the form of hillocks. These belong to Aravalli hills. There are only two major geologic units present in the area: one representing alluvium and wind blown sand comprising of various proportions of sand, silt and clay whereas the other is the hills formed of quartzite, shale, slate and schist etc with granites, aplites & quartz veins as intrusive. The soils in the area qualifies "Ustic soil moisture regime". The mean annual temperature of the area is more than 22°C and the mean summer temperature and mean winter temperature differ by more than 5°C. Hence the area qualifies for "Hyperthermic" soil temperature regime (Arya and Kumar 1994). The soils of the district falls into two major soil orders i.e. Antisols and Inceptisols. In Antisols order, the soils are very young and no profile development was observed whereas in case of Inceptisols some changes in the profile were observed. The district is inadequately wooded and the xerophyte type of flora dominates in the area. The climate, except during the monsoon is characterized by the dryness of air, a hot summer and cold winter. About 75% of annual rainfall is received during the southwest monsoon months i.e. July to September and July and August are the rainiest months in the year. Temperature begins to rise from March to June and June is the hottest month, When the mean daily maximum temperature varies from 41°C to 45°C and mean daily temperature is about 27°C. Maximum temperature may go up to 47°C. After October, there is decrease in both day and night temperature, the decrease being more steep after middle of November. January is the coldest month with daily mean temperature 11°C. The area is quite interesting from groundwater study point f view as it comprises of a variation in the terrain and hence numbers of different landforms are available.

Objectives

The sole objective of the present study is preparation of hydrogeomorphological map depicting groundwater prospects of different geomorphic units.

Database and Methodology

Satellite Data IRS 1D LISS IIII of 20th April 1998 and IRS 1B LISS II of Nov. 1992 geo-coded standard FCC paper print on 1: 50, 000 scale were used for interpreting various geomorphic units. Previous literature, ancillary data available on groundwater depth & quality, climate (rainfall and temperature etc) and district census handbook and district gazetteer along with Survey of India topographical sheets numbering 53 D/4, 54 A/1, 45 M/13 and 44 P/16 (scale: 1: 50, 000) were used as ancillary information. Before starting the interpretation, familiarity with a legend showing various hydrogeomorphological features in the study area is desirable. Hence a detailed study was carried out of various guidelines available from different agencies for groundwater mapping such as NRSA, Hyderabad, SAC, Ahmedabad, DST, GOI and Agriculture Department, GOI and other institutions working in this filed. Guidelines of various international agencies involved in the groundwater research and monitoring like FAO, UNEP and UNDP were also perused. Visual Image interpretation techniques have been employed in the present study to prepare

the hydrogeomorphological map on 1:50,000 scale. Base maps have been prepared on 1:50,000 scale with the help of survey of India toposheets. Summer data IRS 1D LISS III geo-coded standard FCC on 1: 50, 000 scale of 20th April 1998 has been used for hydrogeomorphological mapping. Major geomorphic units such as aeolian plain, fluvio-aeolian plain, alluvial plain, flood plain, hills and pediments etc have been demarcated on the base map. Lineaments and various structural features were also marked. Enough care is taken to delete/ omit linear features corresponding to cultural features like roads, railway, canals, etc. The pre-field interpreted map, thus prepared was randomly checked in the field for various geomorphic features and associated geology. The pre-field map was corrected taking in to consideration field observations. Detailed legend was prepared to indicate nature, properties and the potential of each unit mapped. This map was digitised and put in to Arc/Info GIS environment. After digitisation, and error removal, attributes were attached to various geomorphic units and thus a groundwater potential map was generated.

The stratigraphic sequence of the rocks lying in the area and general geology is given in Table 1. There are only two major geologic units present in the area: one representing alluvium and wind blown sand comprising of various proportions of sand, silt and clay whereas the other is the hills formed of quartzite, shale, slate and schist etc with granites, aplites & quartz veins as intrusive.

Hydrogeomorphological Description of Various Units

Hydrogeomorphologically the district has varied conditions due to its location, geology and topography. The major part of the study area is occupied with fluvio-aeolian plain and aeolian plain consisting of quaternary alluvium and wind blown sands. The hill areas belong to Precambrian meta-sediments of Delhi systems and have poor groundwater prospects due to less number of lineaments and basically being a zone of surface runoff. Availability of groundwater in fluvio-aeolian plain and aeolian plain is good to moderate. Groundwater availability in

Table 1. General Geology of the area

Formation	Composition
Recent	Alluvium & wind blown sand
Igneous intrusive	Acid volcanic (Malani), granites, aplites & quartz veins
	---------- Unconformity ----------
Ajabgarh series	Shale, slate, quartzite, schist, calcschist, calcgneiss calc-amphibolites, calc-silicate, rocks associated with calcareous magniferous shale
Heron stone Breccia	Breccia with ferruginous matrix.
Kushalgarh lime stone	Crystalline lime stone and associated Breccia
Alwar series	Massive schistose quartz, carboniferous phyllite and calc-amphibolites and quartzite.
	---------- Unconformity ----------
Rialo series	Marble, dolomite and quartzite

(Source: G W Cell, Agric. Dept. Haryana)

Table 2. Groundwater (GW) prospects of the area

Geomorphic unit	*Description*	GW prospects	Area (Sq. kms)	% of total area
Aeolian origin				
Aeolian Plain	Quaternary/ recent unconsolidated fine to coarse sand and silt spreading over vast area	Moderate	50.98	7.85
Sand Dunes	Isolated sand dune comprising of wind blown sand	Poor	0.79	0.12
Fluvio-Aeolian origin				
Fluvio Aeolian Plain	Quaternary fluvial deposits of fine to medium size sand silt and clay along with wind blown sands.	Moderate	283.55	43.65
Fluvial origin				
Alluvial Plain	Gently undulating plain consisting of clay, silt, fine to coarse sand of Quaternary deposits with intense Cultivation	Good	209.44	32.24
Flood Plain	Recent deposits of unconsolidated fine sand, silt, clay occurring in fluvio-aeolian plain.	Good	5.25	0.81
Dry River Channel	Recent deposits of pebbles, sand and silt occurring in fluvio-aeolian plain	Very good	8.34	1.28
Palaeochannel	Abandoned river channels which are burried and the surface covered with aeolian sand	Very good	6.5	1.00
Denudational origin	Isolated low relief hill formed due to differential weathering consisting of meta-sediments	Poor	9.38	1.44
Residual hills	Residual isolated hill standing above the ground level of surrounding plain	Poor	0.93	0.14
Inselberg	Gently sloping smooth surface of erosional bedrock between hill and plain mostly covered with aeolian sand deposits.	Moderate to poor	60.83	9.37
Pediment				
Structural origin	Linear to arcuate hills associated with folding and faulting in meta sediments of Delhi super group	Poor	13.3	2.05
Structural hills				
Total			649.58	100

RESULTS AND DISCUSSION

Geological setup of the area

The study area is a part of Indo Gangetic system of quaternary age, which rests on the basement rocks of Delhi system. The area contains small exposures at various places in the form of hillocks. These exposures in the area belong to Aravalli hills. dry river channels and flood plains of Dohan and Krishnawati rivers is good in quality as well as quantity. The groundwater exploration activity can be carried out in Palaeochannels, flood plains and dry river courses for fresh water. Groundwater prospects and geographical area under different geomorphic units is given in Table 2. Hydrogeomorphological map, showing groundwater prospects in various units is shown in Figure 2.

Fluvio-Aeolian Plain

These are essentially developed by fluvio-aeolian activity. There is Aeolian sand deposition over the alluvium. This is constituted of quaternary fluvial deposits of fine to medium size sand, silt and clay along with wind blown light brown to tan-buff colored sand. This unit occupies second major part of the study area. Groundwater potential in these units is moderate to good. Total area under this category is 283.55 sq kms. It is 43.65 percent of the total geographical area under study. This mostly occupies the eastern part of Krishnawati river.

Aeolian Plain

In arid/ semi-arid climatic conditions, the Aeolian phenomenon plays a dominant role in shaping the landscape. This area is no exception to that. Some parts in the northwestern portion of the study area and in the eastern part are covered by Aeolian plain. This unit also covers some areas in the southeastern part. The colour of the sand deposited by Aeolian action varies from light brown to tan-buff. This unit is composed of finer sand mixed with little proportions of silt & clay. Sparse cultivation is practiced in this unit. There is no perennial drain in the area. This unit is good from groundwater recharge point of view. This unit is having moderate potential of groundwater. Total area under this category is 50.98 and constitutes 7.85 % of the total study area.

Alluvial Plain

This unit covers vast area running the south up to the north through the central part. The groundwater prospects are good in this unit. Alluvial plain may be formed by the fluvial activities of Dohan & Krishnawati river. These are level or gently undulating plains consisting of clay, silt, fine to coarse sand and gravel. Total area under this category is 209.44 sq kms, which constitute 32.24 % of the total study area.

Sand Dune

Only one sand dune of comparable size is found in the area in the west of Nangal. This feature is called so due to deposition of large heaps of medium to fine sand. This is not good from groundwater potential point of view. Hence it comes under poor groundwater availability conditions. This unit covers 0.79 sq kms of the area, which is only 0.12 % of the total geographical area under study.

Flood Plain

This unit is composed of recent deposits of unconsolidated fine sand, silt and clay occurring in fluvio-aeolian plain. The wells tapping the flood plains are high yielding and with good quality. Total area covered under flood plain is 5.25 sq kms constituting 0.81% of the total area. Small areas along the river course falls under this category.

Palaeochannels

Abandoned channels, which are buried under the aeolian/ alluvial sand, are called palaeochannels. These are excellent from groundwater potential as well as quality point of view. These are comprised of fluvial deposits of varying lithology. Four palaeochannels have been demarcated in the area at different places. These are in the alluvial plain area. Total area under this category is 6.5 sq kms, which is almost one percent of the total geographical area under study. These can be seen in the field as slightly low lying areas having sinuous pattern which seem to be surrounded by eroded low height natural levees.

Residual Hills

These are isolated low relief hills formed due to differential weathering. The more resistant formation stand as residue like small hills. Presence of joints, fractures etc are observed in the field. These are of varying lithology. This unit acts as a zone of surface runoff hence groundwater potential is very poor. These cover a total area of 9.38 sq kms constituting 1.44 %of the total area.

Pediment

Gently sloping smooth surface of erosional bedrock between hill and plain with thin veneer weathered material. This is overlaid by a thick cover of aeolian sand, hence may be called buried pediment. This unit covers an area of 60.83 sq kms, which is 9.37 % of the total geographical area. GW potential in this unit is poor. Moderate potential of groundwater may be found along the lineaments. There is a thick deposition of aeolian sand over pediment areas in the west side of the hills. This unit is found almost all around the hills.

Inselberg

These are isolated hills standing above the surface of the earth and are surrounded by plain areas. As these are basically zone of surface runoff, GW potential in these areas is poor. Total area under this unit is 0.93 sq kms almost 0.14 % of the total geographical area. Insignificant fracturing/ jointing was observed in the field in these areas.

Structural Hills

These are linear to arcuate hills associated with folding and faulting in meta-sediments of Delhi super group with definite trend line marks on these. The groundwater potential is poor as these are basically zones of surface runoff. GW prospects are poor in this zone but may be moderate along the fault plain. These are mostly present in the southern part of the study area. Total area under this category is 13.3 sq kms, which constitutes 2.05 % of the total study area. The highly jointed quartzite form local pockets of good groundwater zones and may support shallow dug wells or tube wells. Before installation of any tube well in the area, geophysical survey at selected point should be conducted for better accuracy at the selected point.

Conclusion

Authors conclude that Remote Sensing and GIS are powerful tools in groundwater potential areas mapping. Remote sensing technology along with other ancillary data is quite useful in narrowing down the target areas for groundwater exploration. It also helps in pictorial representation of the areal extent of various zones at a glance. It will be of immense use for the planners and decision makers in the formulation of scientifically based management of groundwater resources of the area.

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