Identification of Appropriate Sites for Artificial Ground Water Recharging using Geospatial Techniques

Dhiraj Khalkho[1], M. P. Tripathi[2], Prafull Katre[3], A. K. Pali[4]

[1,3] Scientist, AICRP on IWM, Department of Soil and Water Engineering,
SV CAET&RS, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur
dkhalkho[at]rediffmail.com
prafullkatre[at]rediffmail.com

[2] Professor and Head, Department of Soil and Water Engineering, SV CAET&RS, Faculty of Agricultural Engineering,
Indira Gandhi Krishi Vishwavidyalaya, Raipur
mktripathi64[at]gmail.com

[4] Professor, Department of Soil and Water Engineering, SV CAET&RS, Faculty of Agricultural Engineering,
Indira Gandhi Krishi Vishwavidyalaya, Raipur
akpali[at]hotmail.com

Abstract: ***Groundwater is a precious resource of limited extend. However over exploitation has depleted groundwater availability. The increased demand for water has increased awareness towards the use of artificial recharge. The lack of effective groundwater recharge structures in a region usually brings about adverse effect on groundwater utilization. Bilha block of Bilaspur district comes under semi-critical stage (89.19%) of ground water development. Looking to the need of groundwater recharge plan for this semi-critical block of the district a study on groundwater recharge planning was carried out in the Department of Soil and Water Engineering, Faculty of Agricultural Engineering, IGKV, Raipur. Various thematic maps including Block boundaries, drainage, slope, soil texture, lineaments, geology and water level depth were generated in the environment of GIS. Satellite image IRS P6 LISS III, was classified using supervised classification method to generated Land use map of the area. The total geographical area of the block is 189.85 km^2 in which 62.17% (22251.1 ha) is available for agriculture. The geology map has been generated with shale and limestone as the formations in the area. The upper, middle and lower reaches of drainage lines were considered for different sizes of check dam. Finally 21 locations were identified for check dams whereas 13 locations were identified for percolation tanks in the Bilha block of Bilaspur district.***

Keywords: Groundwater; Artificial Recharge; Geospatial; Lineament

1. Introduction

Water resource of earth can be classified as surface water and ground water source. The total volume of ground water is only 0.65% of the total water availability of the globe [1]. Ground water is one of the important natural resource of the earth which is required for drinking, irrigation, industrialization etc. [2]. In order to ensure a sensible use of ground water its proper evaluation and management is required. Ground water development has occupied an important place in Indian economy because of its role in stabilizing agriculture and as a means for drought management. Over the years, particularly since the launching of Five Year Plans, there have been continued efforts in India for development of ground water resources to meet the increasing demands of water supply for various sectors. The prevailing scenario of ground water development and management in India calls for urgent steps for augmentation of ground water resources to ensure their long-term sustainability. Artificial recharge aims at augmenting the natural replenishment of ground water storage by some method of construction, spreading of water, or by artificially changing natural conditions.

Chhattisgarh state receives adequate rainfall (average annual rainfall is 1324 mm). About 87 % area of the state is covered by hard rocks. Groundwater availability is largely influenced in these rocks by the topography and rainfall. Because of varied topography and hydrogeological condition in the state, the groundwater potential is not uniform and it changes from one area to another. Out of 146 blocks in the state, 24 have been categorized as semi-critical from groundwater development point of view as the stage of groundwater development is more than 70% but less than or equal to 90 %. Out of these 24 blocks 3 fall in Dhamtari, 2 in Bemetara, Balod, Durg, Jashpur, Karwardha, Raigarh, Rajnandgaon and one each in Gariaband, Janjgir, Champa, Korba, Raipur, Sarguja and Bilaspur District. Bilha block of Bilaspur district falls in the semi-critical stage of groundwater development. The stage of the ground water development in the district is 46.71% and the Bilha block (89.19%) has the highest stage of ground water development. The lack of effective ground water recharge structure in a region usually brings about adverse effect. The relentless increase in population and resulting spurt in the demand for water requirement, carefully planning and management of this limited water resources is urgently needed [3].

Conventionally, remote sensing and GIS methods are deployed to select favorable sites for implementation of artificial recharge scheme. Remote Sensing (RS) and Geographical Information System (GIS) are modern techniques which can effectively be used for groundwater management, such as location of suitable sites for artificial recharge. Some researchers have used varying number of thematic layers, such as geology, geomorphology, drainage density, slope, aquifer transmissivity, water table fluctuations or depth to groundwater level, lineament density etc., for identification of artificial recharge sites. A set of weights for the different themes are decided based on personal judgment, considering their relative importance from the artificial recharge viewpoint. These thematic layers can be integrated in a GIS framework to identify suitable zones for artificial recharge. Other researchers have attempted to select suitable sites for artificial recharge as well as to suggest site specific recharge structures.

2. Materials and Method

Bilaspur district is located between 81°14' to 82°15' E longitude and 21°47' to 23°08 'N latitude and covers an area of 6377 km^2. The average altitude of the Bilaspur district is about 262 m above mean sea level (MSL). The district is bounded by Korea district on the north, Anuppur and Dindori District of Madhya Pradesh state on the West, Kawardha on the southwest, Durg and Raipur on the south and Korba and Janjgir-Champa district on the East.

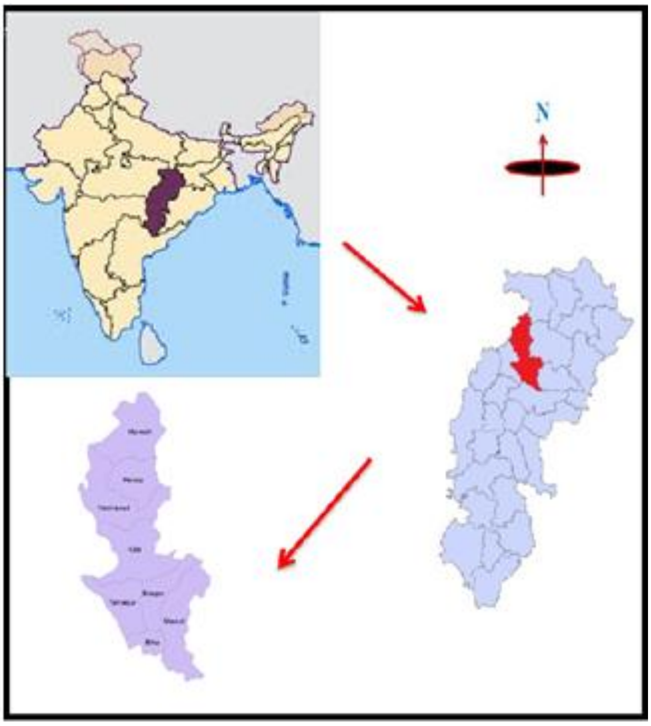


Figure 1: Location of the study area in India and Chhattisgarh

2.1 Agroclimate of Bilaspur district

The climate of Bilaspur district is sub-tropical, semi arid, and monsoon type. Thus, it has hot summers, cool winters and small rainy season. The winter season starts towards the latter half of November and extends till about the middle of March followed by summer, which continues till about the end of June when maximum temperature reaches up to 45ºC. After it, southwest monsoon arrives. The rainy season remains between Julys to September. The post monsoon months October and November constitute a transitional period from monsoon to winter season. The Bilaspur district receives average rainfall of 1296 mm

2.2 Soil resource data

Generally, soils are classified on the basis of texture, mineral content and presence of salts and alkalis. However, in present context the classification and distribution is adopted as per the soil orders in US soil taxonomy and their Indian equivalents. There are 12 orders in US soil taxonomy but only four orders are found in these districts. They are given in Table 1

Table 1: Soil texture classification of study area

S. No	US Soil Taxonomy	Indian Equivalents
1	Ultisols	Lateristic Soil
2	Alfisols	Red Loamy Soil
3	Vertisols	Deep Black Soil
		Medium Black Soil
4	Inseptisols	Humic Gray Soil

2.3 Satellite data

IRS P6 Linear Imaging and Self Scanning-III (LISS III) images acquired on 15 November 2014. The satellite data for preparing the land use/land cover map was procured from National Remote Sensing Centre Agency, Hyderabad in the form of CD-ROM format. LISS III sensor considered for this study. The resolution, path, row and date of pass are given in Table 2.

Table 2: Detail of satellite image used in this study

Satellite	Sensor	Reso. (m)	Path	Row	Date of Pass
IRS-P6	LISS III	23.5	102	056	15/11/14

2.4 Categorization of assessment units

There are four categories namely "Safe "areas which have groundwater potential for development, "Semi-critical" areas where cautious groundwater development is recommended, "Critical-areas" and "Over-exploited" areas where there should be intensive monitoring and evaluation and future groundwater development be linked with water conservation measures. The details of Criteria for categorization of assessment units are given in Table 3

Table 3: Criteria for categorization of assessment units

S. No	Stage of ground water development	Significant long term decline		Categorization
		Pre-monsoon	Post-monsoon	
1	Upto 70%	No	No	Safe
2	>70% to ≤ 90 %	No	No	Safe
		Yes/No	Yes/No	Semi-critical
3	>90% to ≤ 100%	Yes/No	Yes/No	Semi-critical
		Yes	Yes	Critical
4	>100%	Yes/No	Yes/No	Over-exploited
		Yes	Yes	Over-exploited

Results and Discussions

The geographical area of Bilaspur district is 6377 km². The boundary of Bilaspur district is digitized as described previously. The maps of district boundaries are shown in Fig. 2. There are total 7 blocks in Bilaspur district in which only Bilha block comes under semi-critical stage.

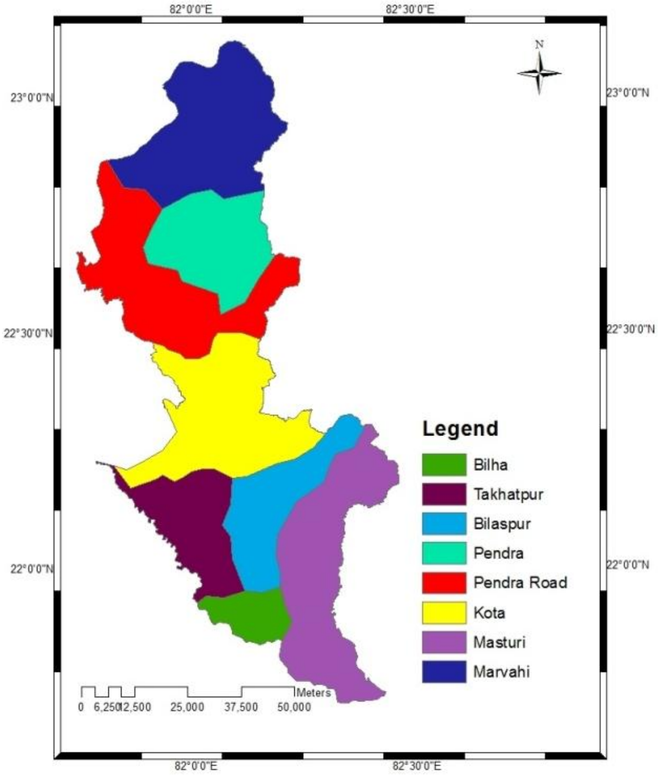


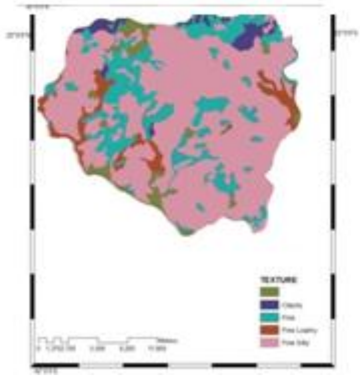
Figure 2: Different blocks of the Bilaspur district

Table 4: Area of Different bocks of Bilaspur district

S.No	Block Name	Area in km²
1	Bilaspur	498.41
2	Bilha	189.85
3	Kota	871.32
4	Masturi	880.08
5	Marwahi	905.33
6	Takhatpur	473.10
7	Pendra	570.44
8	Pendra road	885.37
	Total	5818.49

3.1 Drainage map

Drainage density of the area is found to be 1.62 km/km^2 which was indicate low runoff potential of the study area. Similarly, stream frequency (the total number of the channel required to drain a unit area of watershed) of the area was found to be 0.054, which is also low showing more or less plain topography of the area and lack of structural control. The drainage map of Bilha block is shown in Fig 3.



3.2 Lineament Map

Lineaments are the linear, rectilinear, curvilinear features of tectonic origin observed in satellite data. These lineaments normally show tonal, textural, soil tonal, relief, drainage and vegetation linearity and curvilinerities in satellite data. All these linear features were interpreted from the satellite data and the lineament map of the study area was prepared. Most of these lineaments were attributed either to faults or to fracture systems that were controlled by joints (fractures without relative offsets)

3.3 Soil Texture map

Soil texture map of the Bilha block of Bilaspur district is shown in the Figure which was prepared through GIS using available soil resource data of the area. The area occupied by the soil texture identified in the study areas can be related with the legends of the map.

3.4 Land use/cover map

The cloud free geo-coded digital data of IRS- P6 (LISS-III) in CD ROM was obtained from the NRSC Data Centre, Hyderabad. The imagery, which covers Bilaspur district, was used in this study. Area under different land use classes are given in Table 5. Area under different land use classes of Bilha block are shown in Table 5.

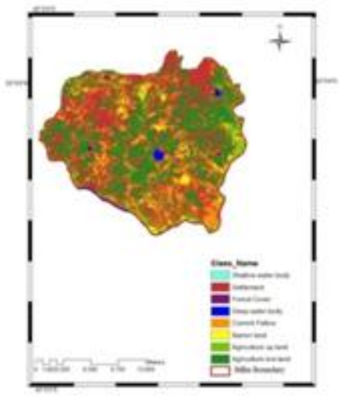
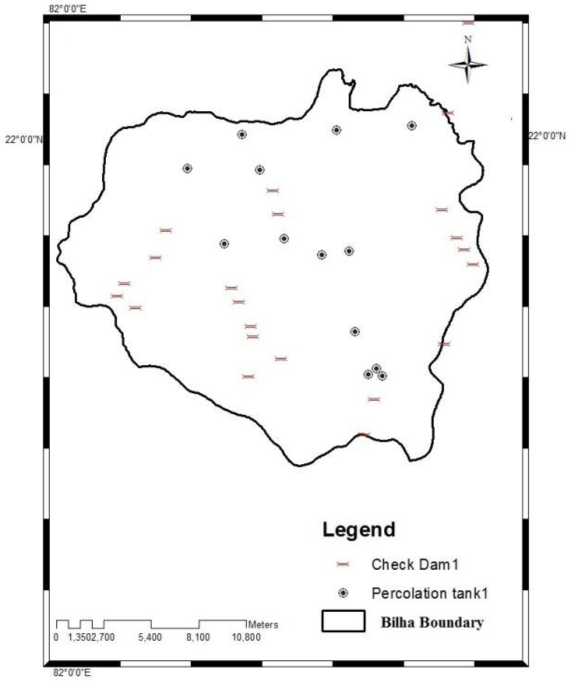


Table 5: Area under different land use classes in the Bilha block

S. No	Class	Area in ha	Percentage Area
1	Agricultural up land	5453.91	15.23
2	Agricultural low land	16797.1	46.94
3	Barren land	2137.51	5.96
4	Settlement	4617.2	12.8
5	Deep water body	584.2828	1.63
6	Shallow water body	5355.013	14.95

4. Conclusions

Thematic map including drainage, geology, lineament, soil and slope maps were considered to identify the location of groundwater recharges structures. The suitable recharge sites were suggested accordingly fo Bilha Block of Bilaspur district.



In Bilha Block, check dam and percolation tank were found to be 17 and 6, 3 and 4, 1 and 3 numbers of small, medium and large size, respectively. Various thematic map including slope, land use/land cover, drainage, soil texture, lineament, geology and depth to water level (pre and post monsoon) can be generated using GIS techniques and image processing software which can be further utilized for groundwater recharge planning and management. Overlay technique is proved to be useful for identification of location for different groundwater recharge structures. Overlay of the drainage map, slop map, land use/cover map, drainage map, soil map, lineament map. Geology map and depth to water level map resulted in identification of fairly accurate location for artificial groundwater recharge. 364 and 34 numbers of groundwater recharge structure can be constructed in the Bilaspur and Bilha block respectively. Total 868.36 Mm^3 water is available for recharge in Bilaspur district respectively.

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Author Profile

Er Dhiraj Khalkho has completed his B.Tech. in Agril. Engg. from JNKVV, Jabalpur and thereafter completed his M.Tech. in Soil and Water Conservation Engg. from IIT Kharagpur in 2004. He joined Indira Gandhi Krishi Vishwavidyalaya, Raipur in 2005 and has worked at Jagdalpur campus till 2011 for many national projects like NAIP, AICRP for Dryland Agriculture. He has worked for IWMP, DPAP, BRGF, NREGA as project officer and Engineer. Under his supervision more than 250 water harvesting structures were constructed in the Bastar zone and for his effort he was Conferred with the ***Jaal Doot Samman*** by the Soil Conservation Society of India, C.G. Chapter in 2012. He has expertise on Geospatial techniques, hydrological modeling, Irrigation and Drainage, SWCE. He has got more than 20 research publication in his name. Presently he is working as Scientist in AICRP on Irrigation Water Management scheme and is the Principal Investigator of Mega Project entitled Development of Land use plan at Cadastral level for Chhattisgarh using Geospatial techniques. He is pursuing his PhD. From Dept. of Soil and Water Engg., FAE, IGKV, Raipur.