E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(4): 287-290
Received: 14-01-2024
Accepted: 20-02-2024

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Investigating ground water recharge potential through various analytical methodologies: A case study at Babina block, Bundelkhand region

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i4Sd.624

Abstract
This study has been carried out at Babina Block, Bundelkhand region presented to estimate the ground water recharge potential of a shallow dug well by applying rainfall-infiltration factor (RIF) and water table fluctuation (WTF) methodologies. The research area's chosen wells provided the data, which was then used to determine the yearly water withdrawals for domestic and irrigation purposes, which came out to be 0.091 million m^3 and 0.339 million m^3, respectively. These investigations led to the observations that WTF and RIF had net annual ground water availability of 1.193 million m^3 and 1.209 million m^3, respectively.

Keywords: Groundwater, rainfall, water table fluctuation and irrigation

Introduction

These days, groundwater plays a significant role in the nation's water supply system as a natural resource. About 60% of India's irrigation needs and 80% of its drinking water needs are met by groundwater [1]. Different techniques are used in different places to determine the potential for ground water recharge [3]. Lack of water poses a serious threat to daily activities like drinking, irrigation, and textile production. Water needs to be rejuvenated in order to be met, and this is conceptualised by geological data and recharge mechanics, both of which are significant in the research domain.

About 15% of India's land area is experiencing an alarming pace of water table decline as a result of an over-reliance on and rapid development of ground water irrigation [5]. Few well-established techniques for the quantitative assessment of recharge may be effectively used in the field, despite the existence of numerous such techniques. It is crucial to start with a solid understanding of the various recharge mechanisms and their significance in the research area when evaluating groundwater recharge [6]. In addition to this perspective, the study's goals, the resources and data at hand, and the potential for acquiring additional data should influence the choice of recharge-estimation techniques [7]. This paper's primary goal is to examine the likelihood and possibilities of groundwater availability as well as the potential for rains to replenish shallow dug wells in the Bundelkhand region.

Materials and Methods

General Description of the Study Area

The Babina block in the Bundelkhand region, which is situated between 25^0 23' 47.6" and 25^0 27' 05.1" latitude and 78^0 20' 06.5" and 78^0 22'33.0" longitude, was the study's location. The study area has a warm, humid rainy season, a cold winter with sporadic showers of precipitation, and a dry, scorching summer. The average summer temperature (April-May-June) is 34 °C, with a high temperature of 46 to 49 °C possible in May and June. The average winter temperature (December, January, and February) is 16 °C, with December and January potentially seeing lows of 3–5 °C.

The Bundelkhand region receives between 800 and 1300 mm of rainfall annually, with the majority of that falling during the South-West monsoon season [8]. The Jhansi station's long-term weather data indicates that the location receives an average of 877 mm of rainfall year, with roughly 85% of the total falling between June and September. There are, on average, 42 wet days during the monsoon and 13 during the non-monsoon periods. The region experiences an average of 37 rainy days per year, with a range of 30-45.

The majority of the crystalline igneous and metamorphic rocks in the study area's geology are hard rocks like archaen granite and gneiss, and the aquifers are either perched or unconfined having insufficient storage (0.01-0.5% porosity). In such rough rock aquifers with inadequate Because of transmissibility, the only major sources of water for home and agricultural use in this area are shallow dug wells that range in depth from 5 to 15 metres. The region's agricultural productivity is extremely low (0.5-1.5 t/ha) because to its undulating topography, weak groundwater potential, high temperatures, and inconsistent and insufficient rainfall.Depending on temperature and rainfall patter ns, Bundelkhand's growing season can last anywhere from 90 to 150 days. The research area's soils are easily divided into two main categories: red soils and black soils.

Black soils are heavy soils, and red soils are upland soils with coarse grains. These soils are further divided into four different series based on their texture and colour: Kabar and Mar in black soils, and Rakar and Parwa in red soils. The rocky ridge soils that make up type 1A Rakar soils are unimportant for agriculture. The second type I B is shallow (10–50 cm), reddish to brownish red in colour, and has immature profile development (Alfisols and Entisols). Its coarse gravelly, light-textured texture and low water-holding capacity are its defining characteristics.

For the purpose of determining the ground water availability throughout the Babina Block watershed, thirty wells were constructed and proposed. These were chosen based on the area's lithology, geomorphology, slope, drainage network, and land use. Every day before and after the monsoon, the water level of a few chosen wells was checked to estimate groundwater recharge. The ground water table fluctuation method during and after the monsoon, along with the well-established specific yield method, are used to estimate ground water recharge in specific wells within the watershed. Of the yearly recharge of ground water, natural discharges and other losses were estimated to account for 45% [1]. Annual Ground Water Recharge = * Area * Average Water Table Fluctuation * Specific Yield.

Specific Yield = P*Rg/HW*(P-Rs)

Where P is the annual rainfall, Rg is the annual groundwater runoff, Rs is the annual surface runoff and Hw is the water table fluctuation.

According to the GEC Report of 1997, a rainfall infiltration factor of 10-15% of average rainfall is recommended for worn and cracked hard rock terrains, semi-consolidated sandstones, and sandy places. A 20–25% infiltration factor may be used to calculate the potential for groundwater recharge. Here, we've taken into account an average yearly ground water recharge of 15% due to rainfall infiltration.

Annual ground water recharge = area * average rainfall * infiltration factor

The CGWB's Ground Water Assessment Report from 1997 took into account each person's daily use of 70 litres. 10% of domestic consumption was estimated for the return flow from irrigation to ground water and other losses, which were estimated to account for 20% of the total irrigation draft and consumption by the cattle population.

Results and Discussion

The study's findings show that wells had a minimum water level of 5.14 m during the pre-monsoon and a maximum water level of 13.86 m. During the post-monsoon season, well water levels ranged from 2.13 metres to 9.52 metres. Availability of water at the conclusion of the monsoon depended on groundwater recharge in the particular year. In pre- and post-monsoon, the hydraulic head (difference in water level) of the wells was 8.72 m and 7.39 m, respectively, and the average water level was 8.607 m and 5.382 m. According to Table 1, there was an average fluctuation of 3.224 metres, with minimum and maximum fluctuations of 0.57 and 6.12 metres, respectively, in the water level in the wells.

For the Garhkundar watershed in the Bundelkhand region, Singh *et al*. [9] found that the hydraulic head in open wells before and during the monsoon season varied by an average of 4.0 m. In the Kothapalli watershed of the semi-arid tropics, Garg and Wani [2] also recorded a 4.5 m variation in hydraulic head (difference in water label) in open wells before and after the monsoon period. The ground water level fluctuation method was used to assess the change in ground water storage volume during the pre- and post-monsoon period. Numerous factors, such as terrain, local hydrogeology, daily rainfall data throughout the monsoon season, and the kinds of facilities available for artificial replenishment of groundwater by rainwater collection, among others, contributed to the fluctuations in water levels in wells during the pre- and post-monsoon period.

The average rainfall is 877 mm, however it can range from 800 to 1300 mm. Surface runoff was measured at 225.36 mm and ground water runoff at 105.24 mm, respectively. In the research region, there were 3200 recorded human occupants. Since the Bundelkhand region lies in the semi-arid tropical region, an infiltration factor of 0.15 was taken into account while estimating the area's yearly ground water recharge using the rainfall-infiltration factor approach. Table 2 lists the various characteristics used to estimate the availability of ground water using various analytical techniques. Well 16 recorded the highest water level behaviour during the pre-monsoon at 13.6 m, while Well 22 recorded the lowest at 5.14 m. After monsoon, well-15 reported a high water level of 9.52 metres, while well-08 recorded a minimum of 2.13 metres. The maximum fluctuation in water level was found 6.12m inwell-08 and minimum 0.57 m in well-24.

Table 1: Water level fluctuation at different location of Babina block in Bundelkhand Region

Well No.	Location	Pre-monsoon (m)	Post-monsoon (m)	Fluctuation (m)
1	25o 25’ 28.1” N 78o 21’ 29.5” E	7.18	2.53	4.65
2	25o 25’ 29.7” N 78o 21’ 43.0” E	7.98	6.15	1.83
3	25o 25’ 27.2” N 78o 21’ 42.4” E	10.15	7.1	3.05
4	25o 25’ 21.3” N 78o 21’ 40.9” E	8.55	3.45	5.1
5	25o 25’ 19.3” N 78o 21’ 47.7” E	8.06	4	4.06
6	25o 25’ 17.3” N 78o 21’ 48.5” E	7.55	2.93	4.62
7	25o 25’ 15.4” N 78o 21’ 49.0” E	6.95	3.65	3.3
8	25o 25’ 12.7” N 78o 21’ 49.5” E	8.25	2.13	6.12
9	25o 25’ 17.3” N 78o 21’ 51.8” E	8.84	2.83	6.01
10	25o 25’ 22.2” N 78o 21’ 48.2” E	9.25	5.1	4.15
11	25o 24’ 37.6” N 78o 21’ 22.3” E	8.15	4.93	3.22
12	25o 24’ 39.2” N 78o 21’ 23.5” E	7.82	6.69	1.13
13	25o 24’ 42.4” N 78o 21’ 26.2” E	11.85	8.36	3.49
14	25o 24’ 45.2” N 78o 21’ 31.6” E	10.75	8.3	2.45
15	25o 24’ 43.9” N 78o 21’ 33.8” E	11.94	9.52	2.42
16	25o 24’ 41.1” N 78o 21’ 35.3” E	13.86	8.96	4.9
17	25o 24’ 39.2” N 78o 21’ 40.5” E	13.38	8.6	4.78
18	25o 24’ 42.8” N 78o 21’ 44.1” E	10.86	8.68	2.18
19	26o 24’ 57.6” N 78o 21’ 44.8” E	7.81	4.36	3.45
20	26o 24’ 53.5” N 78o 21’ 42.0” E	10.44	7.15	3.29
21	26o 26’ 26.6” N 78o 21’ 18.3” E	6.29	3.72	2.57
22	26o 26’ 27.5” N 78o 21’ 16.7” E	5.96	4.3	1.66
23	26o 26’ 29.1” N 78o 21’ 11.6” E	5.66	3.47	2.19
24	26o 26’ 30.0” N 78o 21’ 18.3” E	5.14	4.57	0.57
25	25o 26’ 22.0” N 78o 21’ 33.4” E	8.35	4.7	3.65
26	25o 26’ 23.0” N 78o 21’ 30.6” E	7.59	5.6	1.99
27	25o 26’ 27.5” N 78o 21’ 35.1” E	9.22	7.1	2.12
28	25o 26’ 28.0” N 78o 21’ 31.6” E	7.32	4.2	3.12
29	25o 26’ 28.7” N 78o 21’ 25.3” E	5.88	3.9	1.98
30	25o 26’ 29.1” N 78o 21’ 23.0” E	7.18	4.5	2.68
Minimum water level		5.14	2.13	0.57
Maximum water level		13.86	9.52	6.12
Hydraulic head		8.72	7.39	1.33
Average water level		8.607	5.382	3.224

Table 2: Different parameters for estimation of ground water availability in Babina block

S. No.	Parameters		Pre-monsoon	Post-monsoon	Fluctuation
1	Area	12.46 km2	-	-	-
2	Average Rainfall	877 mm	-	-	-
3	Average water level	-	8.607 m	5.382 m	3.224 m
4	Ground water runoff	105.24 mm		-	-
5	Surface runoff	225.36 mm		-	-
6	Infiltration factor	0.15	-		-
7	Human population	3200	-		-

Table 3: Estimating net annual ground water availability in Babina block

Methods	Specific yield (m)	Annual ground water recharge (Million m3)	Irrigation Uses (Million m3)	Domestic uses (Million m3)	Net annual ground water availability (Million m3)
Water table fluctuation	0.039	1.623	0.339	0.091	1.193
Rainfall-infiltration factor		1.639	0.339	0.091	1.209

Conclusion

In contrast, for the annual ground water withdrawal, two major subunits, such as (i) Annual water withdrawal for irrigation uses and (ii) Domestic withdrawal, have been taken into account. Based on these results, Net Annual Ground Water Availability has been estimated as 1.193 million m3 and 1.209 million m3, which seems to be quite high and is sufficient to meet the people's needs. The total annual ground water recharge, measured in million m3 per year, has been calculated as 1.623 million m3 and 1.639 million m3 by water table fluctuation (WTF) and rainfall-infiltration factor (RIF) methods.

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