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Enhancing Groundwater Recharge by Implementations of various Agricultural Water Intervention Structures-A Case Study in Bundelkhand Region, Central India

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ABSTRACT: Water has been, is and will be most important natural resource for mankind. Such natural resource management becomes an important concern for 21st century due to high demand of water by rapidly increasing human population. Bundelkhand region is a hub of drought in Central India due to its erratic rainfall, hard rock terrains of archaen granite, absence of water interventions, undulating and rugged topography, dissected land, multidirectional slopes, highly eroded and shallow soil depth (25-150 cm). The study of last 20 years (2000-2019) reveals that 10 are severe drought years, 5 normal and 5 excess rainfall years. Most of the rainfall portion around >90% is received between June to September. Thus lack of agricultural water intervention structures, it was converted into runoff and generated drought for remaining period of the year. Around 85-90 % wells were dried in the region due to absence of groundwater recharge. In this way, this study was carried out for assessing the effect of various agricultural water intervention structures on enhancing groundwater recharge in Garhkundar-Dabar (GKD) watershed located in Semi-Arid Tropics, Bundelkhand region, Central India. Adopting water management interventions are include checkdams, spillways, gabions, nalla plugs, and bunding. These interventions were implemented under RS and GIS environment for doing most effective. Water table fluctuation (WTF) method which is a well-accepted and convenient technique for estimating groundwater recharge for the region was used. All agricultural interventions were generate approximately 25 thousand cubic m water resulting reduced number of dry wells to 2% from 86% and supports water supply whole the year.

Keywords: GKD watershed, RS and GIS, Rainfall, water interventions.

INTRODUCTION

Water has been, is and will be most important natural resource for mankind and its availability for producing a balance diet for increasing human population is an important concern. Conservation of such type of natural resource has become a huge challenge for the 21st century especially in arid and semi-arid tropics. Water is considered as one of the major constitute of living plant tissues comprising about 80-90% water of the plant's total weight (https://courses.lumenlearning.com). The physical, chemical and biological processes of soils are mainly depending on availability of water. Bundelkhand region is a hub of drought in Central India due to its erratic rainfall, hard rock terrains of archaen granite, absence of water interventions, undulating and rugged topography, dissected land, multidirectional slopes, highly eroded and shallow soil depth (25-150 cm).

Most of the patches over 560 million in such type of regions are suffering from different kind of natural degradations i.e. undulating and rugged topography, hard rock terrains, highly eroded, fresh water availability, dissected land, low organic matters, scare groundwater resource and land degradation. The hard rock such as basalts, granite, quartzites, limestones etc. occupy nearly 65% of the total geographical area of country with low porosity (less than 5-6%) and very low permeability (10-1 to 10-5 m/day). India's agricultural land is 142 million ha with 135% cropping intensity (NAAS, 2009) and 60% is rainfed which is characterized by water scarcity, land degradation, low inputs use and low productivity. Agricultural productivity of these areas oscillates between 0.5 and 2.0 ton/ha with average of one ton per ha (Rockstrom *et al*., 2010; Wani *et al.*, 2011a, 2011b). Irrigated land which covers 40% of total agricultural area significantly contributes in satisfying 55% of total food requirement of the country (GOI, 2012) but on the other hand it consumes almost 70% of fresh water resources and has left limited scope for expanding irrigated area further (CWC, 2005). Thus achieving food security of the country in future is largely dependent on rainfed agriculture (Wani *et al.*, 2009, 2012).

Groundwater recharge is a part of the hydrologic cycle that has a significant share in the water balance at the local, regional or global scale (Surinaidu *et al*., 2016). It assumes that the semi-arid areas are critical parts of the complete water balance of the earth's sub-surface (Rahman *et al*., 2020). The recharge from precipitation to groundwater in semi-arid to arid conditions varies essentially in space, where the extreme climate of low and inconsistent precipitation and high annual temperature hampers the recharge (Lentswe *et al*., 2020). Groundwater is a renewable natural resource; however, this vital life-sustaining resource recharge has been dramatically decreased over the last 4–5 decades due to different forms of anthropogenic activities and distorted innovations and technologies (Arulbalaji *et al*., 2019).

Bundelkhand region is one of the most degraded, hard rock terrains, backward and disadvantaged region of the Country. Its total geographical area is 7.16 m ha supporting 15.62 million human and 8.36 million animal population with a forest cover of 1.24 m ha (Anon., 2005). Degraded land, hard rocks terrains, highly eroded and dissected land, annapratha, poor soil fertility, indiscriminate extraction of ground water resource, erratic distribution of rainfall, lack of irrigation facilities, large size of bundless fields, frequent crop failures resulting in scarcity of food, fodder and fuel are the major problems of this region. The overall aim of this study to assess the impact of agricultural water interventions on groundwater recharge and its availability for sufficient water supply whole the year.

MATERIAL AND METHODS

General description of the study area: The study was carried out in Garhkundar –Dabar watershed located at Tikamgarh district of Madhya Pradesh in Semi-Arid Tropics, Bundelkhand region of Central India (Fig. 1). Location of watershed is varying between 78° 52' 41" to 78° 54' 44" E longitude and 25° 26' 24" to 25° 28' 31" N latitude with its total geographical area of 850 ha. The altitude ranges from 208 to 285 m above mean sea level (MSL).

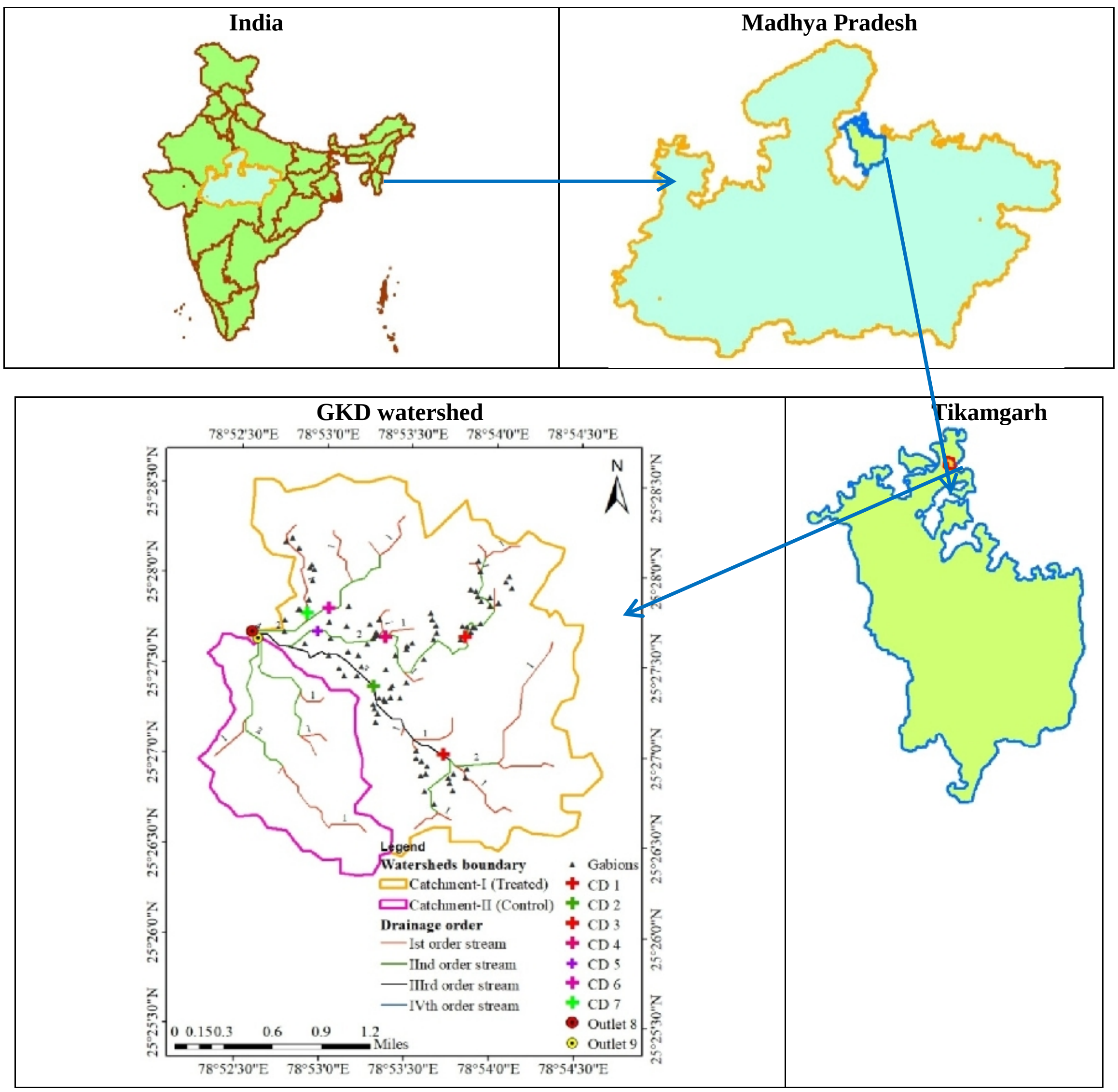

Fig. 1. Location map of study area along with agricultural water interventions at different locations in GKD watershed.

The agro-climate of watershed is characterized on monsoonal with three distinct seasons, *viz.* summer, rainy and winter. The mean summer (April-May-June) temperature starts from 34°C and rise up to a maximum of 46°C to 49°C during May and June while mean winter (December-January-February) temperature starts from 16°C and drop up to a minimum temperature of 3°C to 5°C in December and January.

Long term weather data (nearby site) was analysed and found that annual rainfall of the Bundelkhand region varies from 800 to 1300 mm in which about 85-90% rainfall receiving from South-West monsoon during the month of June to September while annual average rainfall in study region is 877 mm with standard deviation, σ = 251 mm. Last 20 years (2000-2019), 10 are severe drought years, 5 normal and 5 excess rainfalls year (Fig. 2).

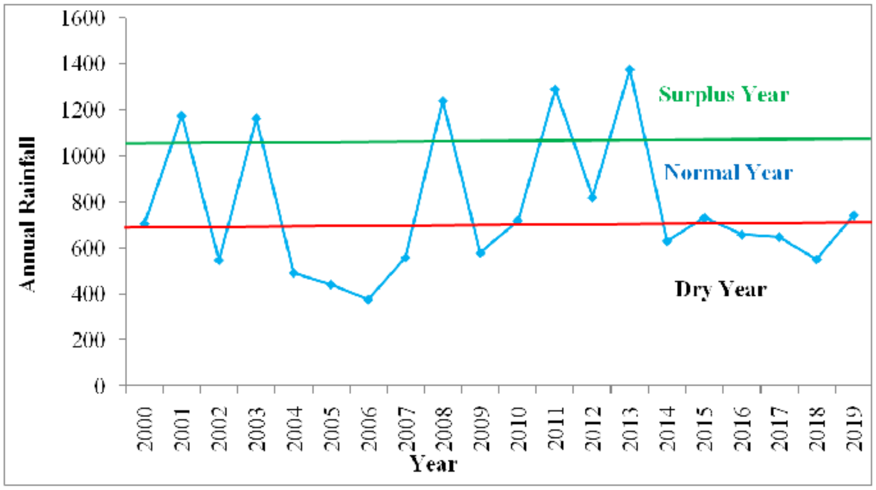

Fig. 2. Year classification (identification) based on erratic rainfall in GKD watershed.

Base map preparation for effective interventions: Base map for watershed boundary, number of streams, stream length, drainage network, village location, location of water harvesting structures and watershed boundary along water divided was prepared by RS and Arc GIS version 10.3 which identify the direction, length of channel, slope of area, location of conservation practices and the catchment area contributed by each intervention. Adopted interventions were listed in the Table 1 along with their construction costs and approximately water productivity in m^3.

Table 1: Adoptive water interventions along with their specifications.

Sr. No.	Type of structure	No.	Avg. Unit cost (Lakh)	Approx. Water harvested (000, m^3)
1.	Checkdam	7	2.35	17.7
2.	Checkdam (LC)	2	1.6	6.8
3.	Khadin	8	0.08	—
4.	Gabion (3 cum.)	150	0.01	—
5.	Spillways	15	0.01	—
6.	Bunding	3 km	Rs. 27/- per m.	—

Runoff yield and its role on groundwater recharge: Surface runoff, inflow and transportation of sediment, basically depends upon land use and land cover, generated from different locations in watershed. Flow data was recorded at various gauging station of watershed by using diver at 10 min interval. Diver is a device used for collecting runoff as well as flow data in the form of head and then these data are transferred into computer by data analoguer and process all data for analysis according to need (Fig. 3).

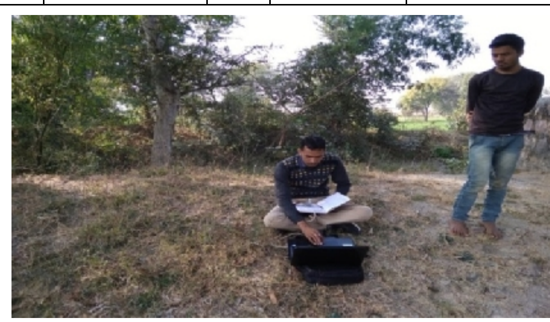

Fig. 3. Data transferred from Diver device with data analoger into the computer devices for processing and analysis.

Groundwater recharge estimation: Groundwater levels of the 107 open wells located at GKD watershed were monitored at monthly basis interval during pre and post monsoon seasons of three consecutive years. Average depth of wells are varies from 3 to 10 m with an average of 8 m. Water of these wells is being used mainly for agricultural purpose. The ground water recharge potential in the area was estimated by using water table fluctuation methods. Specific yield was estimated in range between 0.5 and 1.5 % with average value of 1.0 % for Bundelkhand hard rock region (Singh *et al.*, 2014).

Central Ground Water Board (CGWB, 2000) also reported specific yield of Bundelkhand hard rock region in the same range. Water table fluctuation (WTF) method is a well accepted and convenient technique for estimating groundwater recharge in hard-rock regions (Sharda *et al.*, 2006; Dewandel *et al.*, 2010; Glendenning and Vervoort 2010; Garg and Wani, 2012; Singh *et al.*, 2014).

This method was based on the premise that the rise in groundwater levels in unconfined aquifers due to recharging water arriving at the water table. Water balance captured by WTF method is defined by mass balance equation such as: Net groundwater recharge during monsoon = (change in hydraulic head before and after monsoon) × specific yield + water withdrawal during monsoon period + underlying deep drainage + evaporation losses from water table.

RESULTS AND DISCUSSION

Base map preparation for sustainable agricultural water interventions: Base map of a study area plays a vital role during implementing the interventions. It reveals various forms of topography and identifies the drainage channel. Base map was prepared under RS and GIS environment. Slope of the segments varies from 2.6 to 54.4 % which is due to rugged topography. Such difference of slope indicates that the topography of study area was undulated and maximum slope was indicate the dense forest as well as degraded forest.

Runoff contribution in groundwater recharge: In GKD watershed, distance of remotest point from outlet is 2.5 km and average velocity of runoff water was recorded 1.0 km per hour while time of concentration at different locations of checkdam was estimated as 0.5 to 2.5 hour. After interventions, a great difference was found in runoff amount between treated and control watershed. In treated watershed, runoff varies from 18 to 22 % of rainfall while in case of control watershed it was recorded as 31 to 39 % (Fig. 4) which supports to increase ground water recharge by generating base flow at different scales. Such runoff was found satisfactory for maintain the ecosystem services and watershed hydrology.

Impact on Groundwater recharge of agricultural water interventions: Rainfall is the major source of groundwater recharge. During study period (2007-2019), from 2016 to 2019 continuously deficit rainfall was received Table 2. In spite of such climatic pattern, enhancing the groundwater recharge due to implementation of agricultural structures supports the crop cultivation during both seasons. Rising of graph reveals the impact of interventions on groundwater recharge (Fig. 5) and portioning maximum amount of rainfall in the part of runoff and base flow. About 14% of rainfall was received as groundwater recharge during the study which was relevant and satisfactory because previous study of this region also stated the range of groundwater recharge as 13-16% (Singh *et al*., 2014). Availability of such groundwater recharge in the region is sufficient to water supply for livelihood security.

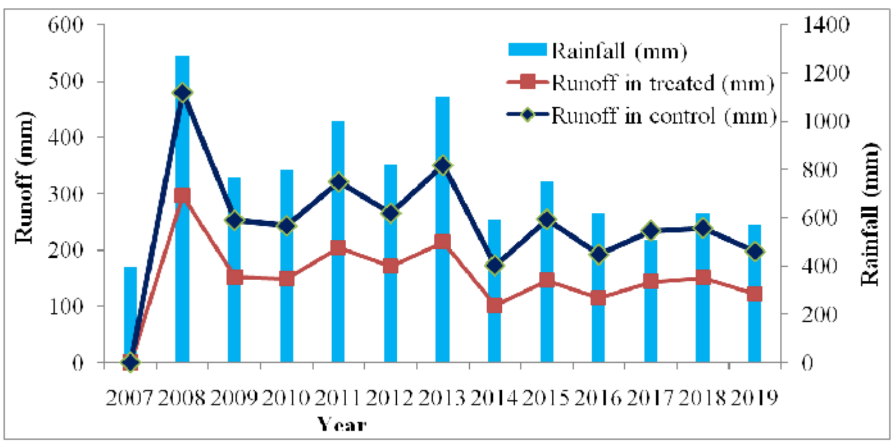

Fig. 4. Runoff assessment in GKD watershed.

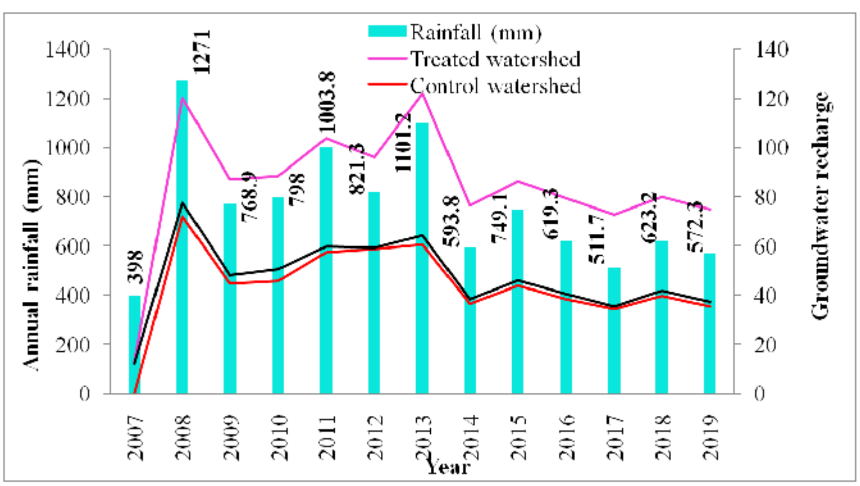

Fig. 5. Groundwater recharge in relation to rainfall received in watersheds.

Table 2: Groundwater recharge (mm) in wells located in treated, control and downstream of treated watershed.

Year	Rainfall (mm)	Treated watershed	Control watershed	Downstream of treated watershed
2007	398	24.12	0.00	6.20
2008	1271	145.21	76.93	97.45
2009	768.9	94.95	44.56	48.01
2010	798	88.51	45.71	46.54
2011	1003.8	125.67	57.44	59.74
2012	821.3	96.09	58.60	59.10
2013	1101.2	142.07	60.66	61.34
2014	593.8	76.49	36.51	38.35
2015	749.1	86.28	43.87	45.94
2016	619.3	79.35	38.35	40.42
2017	511.7	72.73	34.44	35.36
2018	623.2	80.06	39.73	41.80
2019	572.3	74.76	35.36	37.20

CONCLUSION

Remote sensing and GIS based agricultural water interventions were found most effective and sustainable due to suitable site selection. These interventions generated approximately 25000 m^3 water which was found sufficient for mankind and their activities. Adoptive method (Water table fluctuation) for groundwater recharge is a well accepted and convenient in hard-rock regions (Sharda *et al.*, 2006; Dewandel *et al.,* 2010; Glendenning and Vervoort 2010; Garg and Wani, 2012; Singh *et al.,* 2014). Result of groundwater recharge reveals that adoptive technology was relevant and also satisfactory which supports to enhance the groundwater recharge for fulfil the requirements of mankind. Thus, this technology and method will be supportive for researchers and hydrologist to assessing the water scarcity problems and their solutions. Hence, such interventions and technology should be scaled up in other drought prone and semi-arid regions.

Conflict of interest. There are neither conflictions nor any body take interest.

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