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Research Paper

Estimation of Groundwater Recharge and Draft of Arwal District Watershed based on Changing Trend of Rainfall and Population Forecasting

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ABSTRACT
Increasing demand of fresh water is not only an issue in India but across the world. Rapid growth of population is a major cause of harassing the natural resources and groundwater is one of them. The methodology for groundwater resources assessment in India is mainly based on Ground Water Resources Estimation Committee,1997 and it involves assessment of annual groundwater resources recharge, annual groundwater draft (utilization) and the percentage of utilization with respect to recharge (stage of development). The assessment units (blocks/watersheds) are categorized based on stage of groundwater development (utilization) and the long term water level trend. This study estimates the recharge and draft of Groundwater in Arwal District due to uses for irrigation, domestic and industrial uses, etc. The characteristic of annual rainfall, monsoon rainfall and non-monsoon rainfall were analyzed. The average annual rainfall of Arwal district is 743.05 mm, monsoon rainfall as 654.18 mm and non-monsoon rainfall was recorded as 66.87 mm. Groundwater recharge was estimated at 49766.15 ha-m and draft was determined as 52973.15 ha-m. Population study of district was forecasted using Geographical Increased method. Based on this study results, the total annual demand of water for Domestic purposes was estimated at 41.09 MCM. Draft of groundwater was observed more than recharge of groundwater. This needs proper planning and management of existing groundwater resources.

Keywords: Rainfall infiltration factor method; GEC-1997; Recharge; Draft of groundwater; Rainfall; Population forecasting.

INTRODUCTION
Water is one of the important crucial renewable natural resources and no one can survive without it either humans or animals. Water availability varies from the region to region depending upon the rainfall and geological formation, etc. Groundwater is a primary source of fresh water in many parts of the world. The crucial role of groundwater as a decentralized source of drinking water for millions of rural and urban families cannot be overstated. According to estimates, it accounts for nearly 90% of the rural domestic water needs, and 50% of the urban water needs in India (GEC, 2015). More amount of water is used for purpose of Agriculture. Sectors like domestic, livestock and industrial water demand are being met by using the groundwater. In India, agricultural sector is the biggest user of groundwater. For industrial purposes, surface

water is the major source of water (41%) followed by groundwater (35%) and municipal water (24%). The water demand for the industrial sector is on rise and will account for 8.5 and 10.1 percent of the total freshwater abstraction in 2025 and 2050, respectively (FICCI, 2019). Due to climate change, rainfall is gradually being affected in different parts of region of world which finally influence the groundwater recharge. Fresh water availability is less than 1% for drinking from total source of water availability. Increasing population and more demand of water is great challenge for next generation. Extraction of more and improper management of water is major cause of depletion of groundwater in the world. Some parts of the country are becoming overly dependent on it, consuming groundwater faster than it is naturally replenished and causing water tables to decline unremittingly. Groundwater is being depleted at a mean rate of 4.0±1.0 cm per year equivalent height of water (17.7±4.5 km^3 per yr) over the Indian states of Rajasthan, Punjab and Haryana (including Delhi) (Rodell et al., 2009).

MATERIALS AND METHODS

Study Area

Arwal district is located in the state of Bihar, India and was formed in August 2001. It was earlier part of Jehanabad district. According to 2011 census report, the total population of Arwal district is 700843. The rural population share is 648994 and urban population accounts for 51849. Arwal town is situated on the right side of bank of the Son river which is the tributary of the Ganga river. Total Area of Arwal district is 637km^2. The five blocks of Arwal district are Arwal, Kaler, Karpi, Kurtha and Sonbhadra banshi suryapur. Arwal district is predominantly agricultural district with highly fertile soil. The total land available in the district is 195966.08 acres and forest cover area is small. The net shown area available for cultivation is 129166.39 acres, which is 65.91% of the total available land. The district falls under Punpun sub-basin of Ganga basin. The drainage network in the district is represented by river Punpun emanating from southern palteau (Plamu district of Jharkhand). Continental monsoon type of climate is observed in the district owing to its far distance from the sea. The climate is extreme and comprises three broad seasons the summer, the monsoon, and the winter. The actual average rainfall of July is 147.6 mm and of August is 168.2 mm, respectively. The annual rainfall of the district (1901-1970) is 1027.3 mm. Water bearing formation of the district known by vast tract of flate Indo Gangetic Alluvium of quaternary edge. The alluvial sediments are made of gravel sand, silk and clay. The graval and the sand layers are good groundwater repositories. Thickness of the alluvial deposit is not mentioned due to lack of exploratory drilling. However, the thickness of the alluvium is found to be more than 140 m as per as exploratory drilling in adjacent Jehanabad district is concerned. The potential of tube-wells within 50 m bgl is expected to be 15-20 meter cube/hr. The yields potential of tube-wells deeper aquifer in 140m bgl is expected to be around 80 meter cube/hr. The drilling information from the surrounding areas and the skate agencies reveal that shallow thin aquifers exist within 50 m depth which may yield around 20m cube/hr. Depth of water table in order to get the temporal and spatial behavior of groundwater was monitor during pre-monsoon and post-monsoon period (District Irrigation Plan, 2018). District profile of Arwal District is given in Table 1.

Table1:- District profile of Arwal District

District code as per department of agriculture	1038
Geographical Area	637 km2
Latitude and Longitude	25.24?N/84.67?E
Net sown area	17903 ha
Gross cropped Area	21946.26 ha
Net irrigated(Rabi/kharif)	11318.65 ha
Net rainfed	12027.9 ha
Total number of blocks	5
Total number of Panchayat	68
Total number of Villages	322
Total population	754511

Rainfall Analysis

There are five rain-gauge stations in the study area such as Arwal, Kaler, Karpi, Kurtha and Banshi Block. **A** 10 years rainfall data i.e. from 2009-2019 of 5 rain-gauge stations were collected for rainfall study in Arwal district. As per the 10 years of analyzed rainfall data, average annual rainfall is accounted as 743.05 mm (Table 2), average monsoon rainfall is 654.18 mm (Table 3) and Non-monsoon rainfall was determined as 88.87 mm (Table 4). Since the average non-monsoon rainfall is more than 10% of average annual rainfall, the non-monsoon rainfall is accounted for the assessment of groundwater recharge by rainfall infiltration method during non-monsoon season. As per the guidelines, the rainfall infiltration percentage is considered as 11% for the assessment of groundwater recharge through rainfall infiltration factor (GEC, 1997).

Table 2 :- Monthly Rainfall (mm) of Arwal district from 2009 to 2019

Month	Year										
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
January	0.00	0.00	0.00	16.80	0.00	23.18	10.92	3.04	0.00	0.00	9.90
February	0.00	4.30	0.00	0.00	29.80	90.50	0.00	0.00	0.00	0.00	6.80
March	0.00	0.00	19.40	6.00	0.00	0.00	14.34	0.00	6.00	0.00	0.90
April	0.00	0.00	2.60	22.20	3.40	0.00	14.84	0.0	5.40	0.00	0.90
May	122.80	12.20	32.10	1.70	60.10	6.00	0.00	4.90	11.80	0.00	5.80
June	67.80	8.60	264.3	70.58	111.7	46.05	177.13	108.4	25.30	47.80	20.60
July	179.20	147.6	115.5	234.66	62.00	97.24	241.01	373	253.1	227.7	199.3
August	290.50	168.9	389.4	254.60	164.0	154.18	211.56	263.2	149.9	218.9	88.76
September	141.50	111.1	284.0	146.18	91.22	131.04	76.18	386.7	113.8	80.90	200.6

October	21.00	80.20	1.60	17.60	142.7	10.40	0.00	100.6	6.60	0.00	19.12
November	5.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.40
Total	828.60	532.9	1108.9	770.32	664.3	558.59	746.06	1239.4	571.9	575.3	576.14
Average annual rainfall 743.05 mm											

Table 3 :- Monsoon Season Rainfall (mm) from 2009 to 2019

Month	Year										
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
June	67.80	8.60	264.30	70.58	11.70	46.05	177.14	108.40	25.30	47.80	20.60
July	179.20	147.7	115.50	234.66	62.00	57.24	241.08	373.09	253.10	227.70	199.36
August	290.50	168.90	389.40	254.60	164.00	154.18	211.56	263.20	149.90	218.90	88.76
September	141.50	111.10	284.00	146.18	91.22	131.06	76.18	386.70	113.80	80.90	200.60
TOTAL	679	436.3	1053.2	706.02	428.92	428.51	705.96	1131.39	542.10	575.30	509.32
Average monsoon rainfall 654.26 mm											

Table 4 :- Non-monsoon rainfall (mm) from 2009 to 2019

Month	Year										
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
January	0.00	0.00	0.00	16.80	0.00	23.18	10.92	3.04	0.00	0.00	9.90
February	0.00	4.30	0.00	0.00	29.80	90.50	0.00	0.00	0.00	0.00	6.80
March	0.00	0.00	19.40	6.00	0.00	0.00	14.34	0.00	6.00	0.00	0.90
April	0.00	0.00	2.60	22.20	3.40	0.00	14.84	0.00	5.40	0.00	0.90
May	122.80	12.20	32.10	1.70	60.10	6.00	0.00	4.90	11.80	0.00	5.80
October	21.00	80.20	1.60	17.60	142.70	10.40	0.00	100.60	6.60	0.00	19.12
November	5.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.40
Total	149.6	96.70	55.70	64.30	236	130.08	40.1	108.54	29.8	0.00	66.82
Average non-monsoon rainfall 88.87mm											

Water Table Fluctuation

The water table fluctuation (WTF) has several advantages in estimating recharge rates mechanism by which water moves through the unsaturated zone (Healy and Cook, 2002; USGS, 2007). During the study period, five observation wells in every blocks monitored groundwater level through dug wells in the study area (Table 5 and Table 6).

Table 5 :- Groundwater level observation in wells of Arwal district (District Agriculture Department)

Name of blocks	Coordinates	status	Geology	Elevation of groundwater (m)
Arwal	25.1643°N84.6688°E	Non-command area	Alluvial	73
Kaler	25.1223°N84.4996°E	Non command area	Alluvial	71.30
Karpi	25.1678°N84.7351°E	Non command area	Alluvial	69
Kurtha	25.1227°N84.7955°E	Non command area	Alluvial	45.73
Banshi	25.1143°N84.7285°E	Non command area	Alluvial	41.20

Table6 :- Water table fluctuation in Arwal district (CGWB, 2018)

Name of the blocks	Year									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Arwal	1.14	1.52	1.92	2.58	2.49	1.72	0.58	2.2	2.12	1.53
Kaler	2.01	1.10	-0.12	2.12	2.14	1.82	2.14	1.7	0.98	1.2
Karpi	1.64	1.98	3.84	2.87	0.13	2.25	3.66	0.57	0.57	0.81
kurtha	2.33	-0.14	-2.58	2.30	0.00	0.53	-2.94	0.00	-0.40	1.53
Banshi	1.31	-0.74	2.64	2.96	1.19	1.15	1	3.27	2.32	1.12
Yearly Total	8.432	3.72	5.7	12.82	5.95	7.47	4.44	7.74	5.59	4.66
Avg fluctuation	1.686	1.488	1.14	2.56	1.19	1.494	0.89	1.74	1.11	1.23
Total district fluctuation =1.2936 m										

Groundwater Recharge

Wells data was collected from Central Groundwater Board of India which shows the level of groundwater table in post-monsoon and pre-monsoon season. There are number of dug wells cum bore wells present in the study area. As per the GEC (1997) guidelines, unit draft for borewell is 1.00 ha-m, for dugwell it is 0.60 ha-m and for dug cum borewell, it is 0.80 ha-m. A 30% of total annual groundwater draft is considered as a groundwater draft during monsoon period and remaining 70% is considered as a groundwater draft during Non-monsoon period. For study of groundwater recharge, Groundwater Estimation Committee (1997) mentions the quantification of water resources of any basin involves the

application of principle of conservation of mass, to account for quantitative changes occurring in various components of hydrologic cycle as applied to the basin. The quantitative changes may be expressed as water balance equation in which the inflow-outflow and changes in storage in a period of time are represented by individual components. The recharge and draft affecting the groundwater reservoir have been worked out as:

$$I - O = \pm \Delta S \quad (1)$$

where,
I = Inflow
O = Outflow
ΔS = Change in storage

Rainfall infiltration factor method is used for actual field conditions for groundwater study.

$$R_{rf} = RFIF \times A \times (R-a)/1000 \quad (2)$$

where,
R_{rf} = Rainfall recharge
RFIF = Rainfall factor
A = Area in ha
a = Threshold factor

Population Estimation of District Arwal, Bihar

The estimation of water discharge from the groundwater and different resources depends on how much water consumption from existing population and growth rate of population in future. In the case of Arwal district of Bihar, according to the census of 2011 population is 700843 and growth rate of population per decade was worked out to be as 19.01%. For forecasting of population of Arwal district, Geometrical Increase method it is assumed average percentage increase in population is constant from decade to decade. Average percentage increase in date from census of 2011 of India.

$$Pn = P(1+r/100)^n \quad .(3)$$

where,
Pn = Future population after n decade
P = Present population
n = no of decades
r = average % increase population per decade

Table7 :- Population forecast (lakh) for year 2021

Year	Population	Increase population	% increase in population
2001	589476	……	……
2011	700843	111367	18.89 (or) 19.01
2021	834073	133230	19.01

Daily demand of water for domestic purposes as per IS;1992:1993 is 135 lpcd.

Average daily per capita demand = Quantity required in 12 month/(365×Population)
Average daily per capita demand = Quantity required in 12 months/ (365×834073)
Quantity required in 12 month = Average daily demand in 12 month × 365×834073
=135×365×834073
$=4.10\times10^{10}$
=41.09 MCM
So in 2021 water required for Arwal district is 41.09 MCM.

Table 8 :- Domestic water demand

Blocks	**Population in 2015**	**Water demand in 2015**	**Projected population in 2020**	**Gross water demand 2020 (MCM)**
Arwal	158431	7.81	172182	8.48
Kaler	192056	9.46	208727	10.29
Karpi	249666	12.3	271337	13.37
Kurtha	124449	6.13	135251	6.66
Bansi	101625	5.01	110446	5.44
Total	8226227	40.71	897944	44.24

Table 9 :- Present water demand of Arwal district for various sectors

S.No	Block	Components				Total (MCM)
		Domestic	Crop	Livestock	Industrial	
1	Arwal	7.81	150.3	1.1	0.0121	159.21
2	Kaler	9.46	148.5	0.9	0	158.86
3	Karpi	12.3	179.8	1.03	0.00009	193.13
4	Kurtha	6.13	127	1.51	0	134.64
5	Banshi	5.01	91	0.72	0	96.73
Total		40.71	696.6	5.26	0.01219	742.57

Table 10 :- Projected water demand of the district for various sectors

S. No	Block	Components				Total (MCM)
		Domestic	Crop	Livestock	Industrial	
1	Arwal	8.84	180.36	1.26	0.0139	190.12
2	Kaler	10.29	178.2	1.04	0	189.52
3	Karpi	13.37	215.76	1.18	0.0001	230.32
4	Kurtha	6.66	152.4	1.74	0	160.8
5	Banshi	5.44	109.2	0.83	0	115.47
Total		44.24	835.92	6.05	0.014	886.23

RESULTS AND DISCUSSION

Annual rainfall variation

Rainfall analysis was carried out for the period from 2009 to 2019 in terms of Annual, Monsoon and Non-monsoon season. The average annual rainfall was determined at 743.05mm. Annual rainfall variation from 2016 to 2019 is shown in Fig. 1. During the observation of the monsoon data, rainfall is rapidly changing in the district within 2016 to 2019. Rainfall even decreases to 509.32 mm which affect the recharge amount of the aquifer during monsoon season. Monsoon and Non-monsoon rainfall were estimated at 386.46 mm (Fig. 2) and 88.87(Fig. 3), respectively. Non-monsoon variation is also going to fluctuate between from 2013 to 2019 but after 2016, rainfall was observed to be rapidly changing.

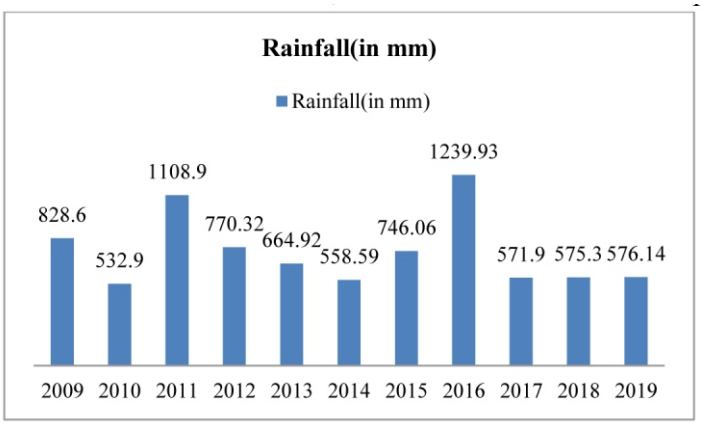

Fig. 1 Variation of rainfall (mm) from 2009 to 2019

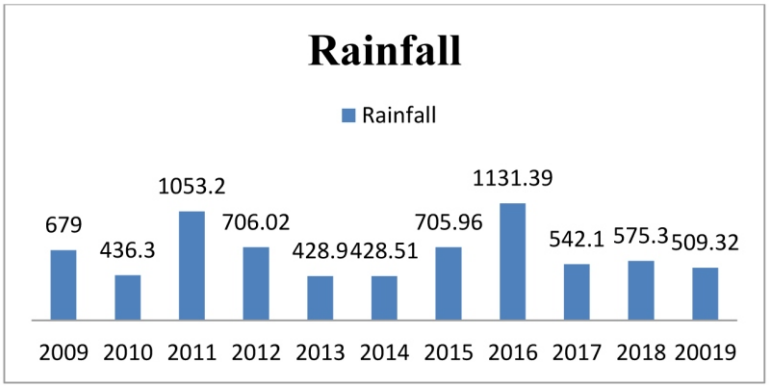

Fig. 2 Monsoon rainfall variation during period of 2009 to 2019

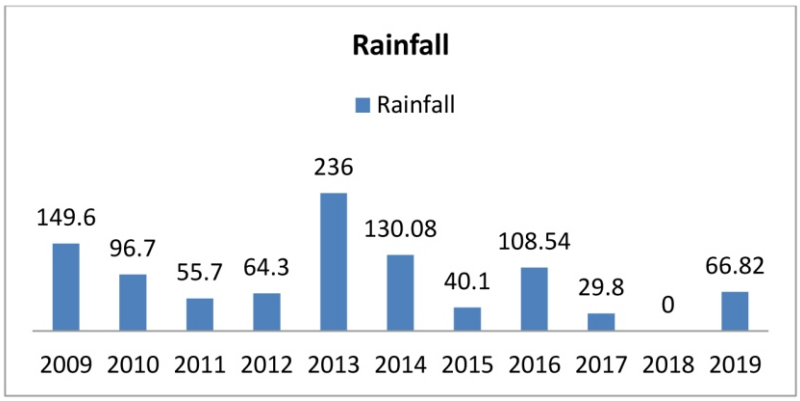

Fig. 3 Non-monsoon rainfall variation from 2009 to 2019

Groundwater Table Fluctuation

Fig. 4 shows the water table fluctuation over the years and average groundwater table variation is 1.2936 m. The natural discharge during non monsoon season is 10% of the annual groundwater recharge as per GWREC 1997. The existing stage of groundwater development is accounted as safe.

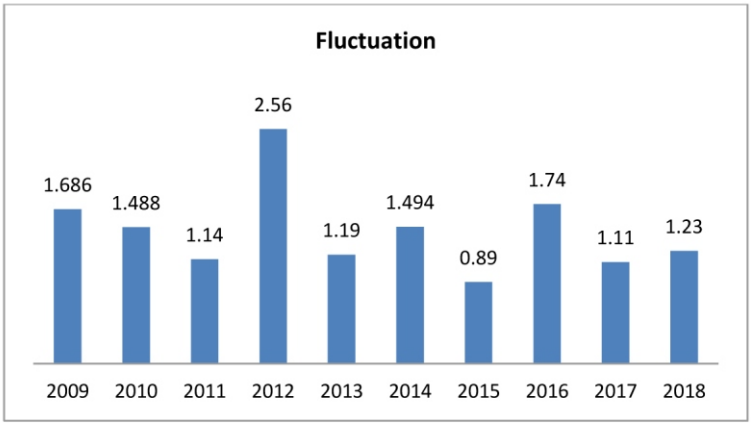

Fig. 4 Fluctuation chart of groundwater

Table11:- Groundwater condition of Arwal district

Name of the block	Status of blocks as per CGWB	Groundwater (MCM)		
		Draft	Recharge	Gap
Arwal	Safe	1.026	1.207	0.181
Kaler	Safe	0.98	10.37	0.057
Banshi	Safe	1.039	1.063	0.024
Karpi	Safe	0.977	1.096	0.119
Kurtha	Safe	1.017	1.067	0.05
Total		5.039	5.47	0.431

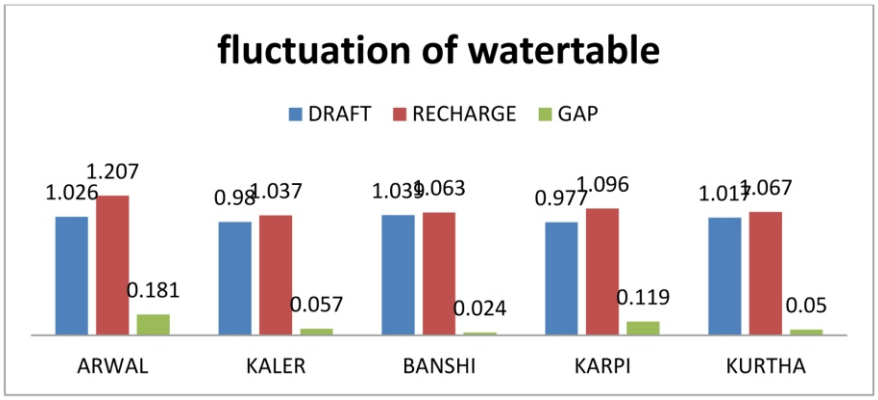

Fig. 5 Groundwater fluctuation

If population growth at rate of the 19.01% is considered, then population in 2021 are 834073 lakh which are going to draft the groundwater. As per Central Ground Water Board, rate of increasing draft of groundwater projected for Domestic, irrigation, livestocks and industries are 44.24, 835.92, 6.05, 0.014 and total is 886.23(MCM), respectively.

Total Annual recharge of ground water =49766.155 ha-m
Total draft of groundwater =52973.6 ha-m
Fluctuation = ±3207.445 ha-m

CONCLUSIONS

Due to change in expected climate change, rainfall in Arwal district shall decrease continuously. Further, rapid increase in population and variation in rainfall may pose a serious scarcity of water in general and drinking water in particular. Average water table fluctuation was observed to be as 1.2936 m (2020) whereas total estimated population in 2021 was 834073. Based on study of different parameters, total recharge is 49766.155 ha-m and draft is 52973.6 ha-m where fluctuation in groundwater table is expected to be ±3207.445 ha-m. Fluctuation rate of groundwater is going to increase day by day due to more withdrawal of water. Therefore, proper assessment of groundwater abstraction and extraction is required and groundwater recharge should be emphasized in suitable areas.

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