Comparative Analysis of Empirical Models Derived Groundwater Recharge Estimation in Venkatapura Watershed, Karnataka

Praveen G. Deshbhandari, C. Krishnaiah

Department of Marine Geology, Mangalore University, Mangalagangothri- 574 199, India

Abstract **- The quantification of water resources is very essentiaal to water resources management. The Venkatapura Watershed of Karnataka has been selected for the present study. The groundwater recharge is determined by using different empirical models proposed by Chaturvedi, Up Irrigation Research Institute, Bhattacharjee, Krishna Rao, Sehgal, Kumar and Sethapathi. According Sehgal formulae average maximum groundwater recharge of 34.27% observed and based on Chaturvedi formulae minimum groundwater recharge of 8.04% is observed. The correlation analysis reveals that Chaturvedi, UPRI and Kumar and Sethapathi formulas are nearly same. The present study helps to calculate groundwater recharge without hydrogeological methods.**

Key words **-Recharge, Rainfall, Venkatapura, Monsoon**

I. INTRODUCTION

The rain water is main source for groundwater recharge. West coast of Karnataka receives sufficient amount of rainfall during monsoon season. The large volume of water will be discharged to ocean during the flood. Estimation of groundwater recharge is necessary to assess hydrogeological conditions of the area.Groundwater recharge is defined as the fraction of total precipitation falling into a drainage basin, which eventually reaches the water table in the saturation zone of an aquifer (Juckik and Juckik , 2004) Quantifying recharge is important to sustain long-term groundwater use, make intelligent groundwater allocation decision and water management stratargies (Ebrahimi and Ghazavi, 2016)

Recent days most of the indirect methods like groundwater fluctuation method, soil water balance approach and tracer techniques are utilized to employ to determine the groundwater recharge. These techniques are necessary to required regular field monitoring. Some of the recharge determination techniques, data are required on temporal scales ranging from days to thousands of years (Adhikary et al. 2012). Estimation of groundwater recharge is difficult without availability of hydrological data. In this adequate situation empirical models are useful to quantify the groundwater recharge. The empirical methods, using simple mathematical relations, can give quick recharge value for water resource decision making process. Increasing demand for recharge estimation is forcing the researchers to develop new approaches through understanding of aquifer recharging process (Scanlon and Cook, 2002). The various researchers are proposed different formulas to calculate ground water recharge. For Indian climatic conditions, various models are generated by various workers. These empirical models are required only meteorological statistics as an input. In the present study empirical models proposed Chaturvedi, Up Irrigation Research Institute, Bhattacharjee, Krishna Rao, Sehgal, Kumar and Sethapathi are applied to determine groundwater recharge in Venkatapura watershed.

II. STUDY AREA

The Venkatapura watershed is located between 13058’48” to 14008’46”N latitude and 74028’48” to 74044’35”E longitude. The rivers flows about 15 km and joins the Arabian sea near Venkatapura village of Bhatkal Taluk with an catchment area of 363.45 Sq, Km. The watershed covers part of Uttara Kannada and Shimoga districts of Karnataka State. The river originates in western ghat near Kogar villages . The river confluences to Arabian ocean near Venkatapura village of Bhatkal Taluk. The metabasalt, laterite and Chlorite schists are main litho units of the study area. The study area comprises of sandy, gravelly clayey and clayey type of soils. Forest and agriculture are the major land use in the catchment (Karthik and Ramachandra 2007). The location map of the study area is shown in Fig 1.

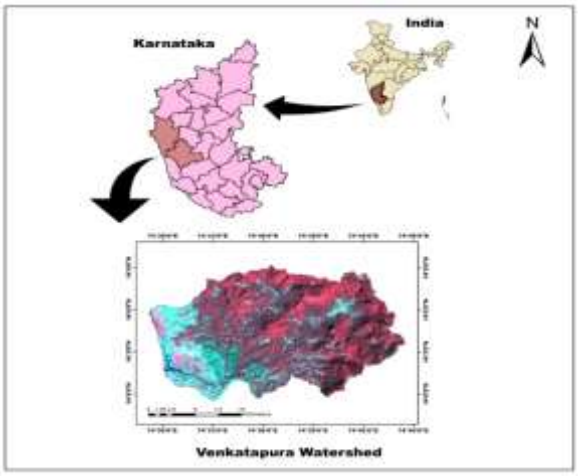

Fig. 1 Location Map

III. METHODOLOGY

The base map of the study area is prepared from SOI Toposheets. The three rain gauze stations namely Shirali, Nagavalli and kogar are located in the study area. The Bhatkal station is situated near to the watershed boundary. The rain guaze stations are shown in Figure The rainfall data four stations was collected from Department of Mines and Geology, Groundwater Division and Directorate of Economics and Statistics, Government of Karnataka. The average areal rainfall of the watershed is calculated by using arithmetic mean method. The natural groundwater recharge from rainfall estimated using empirical formulae proposed by various workers. The statistical techniques i.e. correlation analysis is applied to compare results obtained from various models**.**

Fig. 2 Location map of Rain gauze Stations

III. RESULTS AND DISCUSSIONS

A. Rainfall Statistics

The variation of average rainfall recorded in stations is shown in the Table 1. Descriptive Rainfall Statistics of Stations are shown in the table. The highest rainfall (7516.8mm) is recorded in Kogar station in the year 2006 and lowest rainfall (3025.7mm) is recorded in Shirali station in the Year 2015. The highest mean rainfall (6118.6mm) is observed in Kogar station.

TABLE 1
RAINFALL RECORDED IN GAUZING STATIONS

Year	Shirali	Bhatkal	Kogar	Nagavalli	Mean
1996	-	3626.9	5007.6	4189.3	4274.6
1997	-	4043.7	6195.8	5455.6	5231.7
1998	-	4924.8	6769.7	6650.7	6115.0
1999	-	6027.4	6456.9	6325.2	6269.8
2000	-	5960.2	7267.4	6004.2	6410.6
2001	-	4014.8	3781.0	3107.8	3634.5
2002	-	3471.2	4198.1	5132.0	4267.1
2003	-	4146.5	5645.0	5335.6	5042.3
2004	-	4916.6	5744.0	5520.2	5393.6
2005	-	4423.4	6278.8	6446.8	5716.3
2006	-	6148.0	7516.8	7140.9	6935.2
2007	-	5800.6	7084.8	6253.2	6379.5
2008	3395.0	3878.0	5013.1	3654.7	3985.2
2009	4392.0	4964.1	6630.4	5991.3	5494.4
2010	4363.9	5229.8	5884.6	6693.7	5543.0
2011	3765.0	4585.0	7004.0	4555.0	4977.2
2012	4148.0	3427.0	6283.0	5555.7	4853.4
2013	4444.0	4891.0	7419.4	6111.2	5716.4
2014	3695.3	3653.2	6074.4	4896.1	4579.7
2015	3025.7	3462.0	4582.1	3916.3	3746.5

TABLE 2:
DESCRIPTIVE RAINFALL STATISTICS OF STATIONS

Stations	Shirali	Nagavalli	Kogar	Bhatkal
N Valid	8	20	20	20
Missing	0	0	0	0
Mean	3903.6	5446.7	6118.6	4579.7
Median	3956.5	5537.9	6278.8	4504.2
Std. Deviation	520.1	1104.4	1042.7	910.0
Variance	270593.6	1219906.9	1087428.1	828187.2
Maximum	4444	7140.9	7516.8	6148
Minimum	3025.7	3107.8	3781	3427
Sum	31228.9	108935.5	116254.8	91594.2

B. Groundwater recharge Estimation

The results of various models are shown in Table 3 and are discussed below.

1) Chaturvedhi formula (1936):

Chaturvedhi derived a following empirical equation to calculate groundwater recharge.

$$R_g = 2(P - 15)^{0.4}$$

Where, P is the annual precipitation in Inches.

According to this formula the highest rainfall recharge is observed in 9.73 % in the year 2001 and lowest rainfall is observed in 6.75 % in the year 2006. The mean recharge of 8.04 % is observed in last 20 years.

2) Up Irrigation Research Institute Formula:

In 1954 Up Irrigation Research Institute modified equation as.

$$R_g = 1.35(P - 14)^{0.5}$$

Where, P is the annual precipitation in inches.

Based on this formula the estimated groundwater recharge ranges from 7.95 % to 10.71% for the year 2006 and 2001 respectively. The mean recharge of 9.17% is observed in the study period.

3) Bhattacharjee Formula (1954):

Bhattacharjee has proposed the following empirical formulae to calculate to groundwater recharge

$$R_g = 3.47(P - 38)^{0.4}$$

Where, P is the annual precipitation in centimeters.

The estimated lowest groundwater recharge (6.68) is noticed in 2001 and highest (9.63) is noticed in 2006. The average

rainfall induced recharge of 8.329 is observed in between the year 1996 to 2015.

4) Krishna Rao Formula (1970)

Krishna Rao developed the following empirical relation to calculate groundwater recharge based on climatic conditions.

$R_g = K (P-X)$

Where,

K is constant

P is the annual precipitation in millimeters.

X is number of point rainfall.

The following formulae is applied to different climatic conditions of Karnataka

Rr = 0.20 (P-400) – for areas with annual rainfall between 400 and 600mm

Rr = 0.25 (P-400) – for areas with annual rainfall between 600 and 1000mm

Rr = 0.35 (P-600) – for areas with annual rainfall above 2000mm

According to this formula Groundwater recharge is varies between 29.22 % (Year 2001) to 31.97% (Year 2006). The 30.84% of mean recharge is observed in last 20 years.

5) Sehgal Formula (1973)

Sehgal has developed the following empirical relation to calculate groundwater recharge.

$R_g = 2.5 (P-16)^{0.5}$

Where, P is the annual precipitation in inches.

According to Sehgal formulae the groundwater recharge varies in between 28.18 % to 40.08 % for the year 2001 and 2006 respectively. The average recharge of 34.27% is observed in 1996 to 2015.

6) Kumar and Seethapathi (2002)

The Kumar and Seethapathi developed empirical formula to determine the ground water recharge.

$R_g = 0.63 (P-15.28)^{0.76}$

Where, P is the annual precipitation in inches.

Based on above formulae groundwater recharge ranges from 15.69% to 17.56 % for the year 2001 and 2006 respectively. The average recharge of 16.57% is observed in 1996 to 2015.

TABLE 3:
ESTIMATION OF NATURAL RECHARGE FROM ANNUAL RAINFALL IN THE STUDY AREA

Si. No	Year	Rainfall (mm)	Groundwater Recharge in %						
			Chaturvedi	UPRI	Bhattach-arjee	Krishna Rao	Sehgal	Kumar & Sethapathi	Average
1	1996	4274.60	8.89	9.96	9.63	30.08	30.85	17.12	17.75
2	1997	5231.70	7.93	9.08	8.83	30.98	34.45	16.54	17.96
3	1998	6115.07	7.25	8.44	8.03	31.56	37.47	16.07	18.13
4	1999	6269.83	7.15	8.34	7.73	31.65	37.98	15.99	18.14
5	2000	6410.60	7.06	8.25	7.48	31.72	38.43	15.93	18.14
6	2001	3634.53	9.73	10.71	6.68	29.22	28.18	17.56	17.01
7	2002	4267.10	8.90	9.97	7.01	30.07	30.82	17.13	17.31
8	2003	5042.37	8.10	9.23	8.93	30.83	33.77	16.65	17.91
9	2004	5393.60	7.79	8.95	7.35	31.10	35.03	16.45	17.77
10	2005	5716.33	7.54	8.71	7.25	31.32	36.14	16.27	17.87
11	2006	6935.23	6.75	7.95	7.74	31.97	40.08	15.69	18.36
12	2007	6379.53	7.08	8.27	7.98	31.70	38.33	15.94	18.21
13	2008	3985.20	9.25	10.28	7.22	29.73	29.67	17.32	17.24
14	2009	5494.45	7.71	8.87	9.16	31.17	35.38	16.39	18.11
15	2010	5543.00	7.67	8.84	9.26	31.21	35.55	16.36	18.14
16	2011	4977.25	8.16	9.29	9.26	30.78	33.53	16.68	17.95
17	2012	4853.43	8.28	9.40	9.26	30.67	33.07	16.76	17.90
18	2013	5716.40	7.54	8.71	9.26	31.32	36.14	16.27	18.20
19	2014	4579.75	8.55	9.65	9.26	30.41	32.04	16.93	17.80
20	2015	3746.53	9.57	10.57	9.26	29.39	28.66	17.48	17.48
	Avg.	5228.32	8.04	9.17	8.32	30.84	34.27	16.57	17.87

TABLE 3:
DESCRIPTIVE STATISTICS OF AREAL RECHARGE FROM FORMULAE.

Empirical Equations	Chaturvedi	UPRI	Bhattacharjee	Krishna Rao	Sehgal	Kumar & Sethapathi
N Valid	20	20	20	20	20	20
Missing	0	0	0	0	0	0

Mean	8.045	9.173	8.329	30.84	34.27	16.57
Median	7.86	9.015	8.43	31.04	34.74	16.495
Std. Deviation	0.865	0.800	0.963	0.798	3.422	0.543
Variance	0.749	0.640	0.928	0.637	11.713	0.295
Maximum	9.73	10.71	9.63	31.97	40.08	17.56
Minimum	6.75	7.95	6.68	29.22	28.18	15.69
Sum	160.9	183.47	166.58	616.88	685.87	331.53

TABLE 4:
INTER CORRELATION MATRIX OF ANNUAL AREAL RECHARGE

	Chaturvedi	UPRI	Bhattacharjee	Krishna Rao	Sehgal	Kumar & Sethapathi
Chaturvedi	**1.000**	0.999	0.028	-0.999	-0.996	0.997
UPRI	0.999	**1.000**	0.035	-0.998	-0.997	0.998
Bhattach-arjee	0.028	0.035	**1.000**	-0.006	-0.072	0.060
Krishna Rao	-0.999	-0.998	-0.006	**1.000**	0.991	-0.993
Sehgal	-0.996	-0.997	-0.072	0.991	**1.000**	-0.999
Kumar & Sethapathi	0.997	0.998	0.060	-0.993	-0.999	**1.000**

C. The Correlation Analysis

Inter Correlation Matrix of Annual rainfall Recharge shows Chaturvedi formulae is more positively correlated with UPRI formulae and Kumar and Sethapathi formulae and very less positively correlated with Bhattacharjee formulae. Chaturvedi formula is more negatively correlated with Krishna Rao and Sehgal formuale. It indicates Chaturvedi, UPRI and Kumar and Sethapathi formulas are nearly same. Inter Correlation Matrix of Annual rainfall Recharge is shown in Table 4.

IV. CONCLUSION

The present study demonstrates empirical models based groundwater recharge estimation and application of statistical techniques for comparative analysis. According to Sehgal formulae mean highest groundwater recharge of 34.27% observed and ased on Chaturvedi formulae minimum groundwater recharge of 8.04% is observed in the period of 1996 to 2015. The Inter Correlation Matrix of Annual groundwater recharge indicates Chaturvedi, UPRI and Kumar and Sethapathi formulas are nearly same. These approaches are helpful without availability of the hydrogeological data.

ACKNOWLEDGEMENTS

The authors are thankful to chairman and Coordinator UGC SAP, Department of Marine Geology, Mangalore University for extending laboratory facilities.

REFERENCES

[1]. Adhikary S. K., Chaki T., Rahman M. M. and Gupta A D (2013) Estimation of groundwater recharge into a shallow unconfined aquifer in Bangladesh, Journal of Engineering Science 04 (1): 11-12

[2]. Ebrahimi H., Ghazavi R., Karimi H. (2016) Estimation of groundwater recharge from the rainfall and irrigation in an Arid environment using inverse modeling approach and RS. Water Resource Management 30:6, pp1939-1951.

[3]. Oke, M. O. Martins O., Idowu O. A. and Aiyelokun, O. (2015) Comparative analysis of groundwater recharge estimation value obtained using empirical methods in Ogun and Oshun river basins. Ife Journal of Science, 17(1) p53-56

[4]. Gontia N and Patil P. Y. (2012) Assessment of groundwater recharge through rainfall and water harvesting structures in Jamka Microwatershed using Remote sensing and GIS J Indian Soc. Remote Sens, 40(4):639-648

[5]. Jukik D. and Jukik V. D. (2004) A frequency domain approach to groundwater recharge Estimation in Karst , Journal of Hydrology , 289(1-4): 95-110

[6]. Karthick B. and Ramachandra T. V. (2007) Spatial variation of physico-chemical and hydrological parameters with land-use in Venkatapura Catchment, Karnataka, 9(4): 1001-1005.

[7]. Kumar, C. P. and Sethapathi, P. V. (2002) Assessment of natural Ground water recharge in upper Ganga Canal command area. Journal of Applied Hydrology, 15(4):13-20.

[8]. Scalon B. R., Hearly, R. W. and Cook, P. G. (2002) Choosing appropriate techniques for quantifying groundwater recharge . Hydrogeology Journal 10(1): 18-39.