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Analysis of Groundwater Dynamics and Potential in Central India Using Water Balance Approach

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Abstract:

Groundwater dynamics of Allahabad district of central India was analyzed and groundwater potential was estimated using water balance approach during the monsoon and non-monsoon season. Ground water balance equation proposed by ***Chandra and Sexena (1975)*** *was adopted for the present study. Different input and output parameters of the equation such as recharge from rainfall, recharge due to canal seepage, recharge from tanks, and recharge from field irrigation, evapotranspiration losses, groundwater discharge from tube-wells, sub-surface inflow-outflow, and groundwater storage change were estimated. Software was also developed in* ***C-Language*** *to estimate these different inflow and outflow parameters. For estimation of subsurface inflow-outflow of groundwater, water table contour map was developed for each block of Allahabad. The necessary data were required for analysis and estimation was collected from the Regional office of Central Ground Water Board, Allahabad and Irrigation Department of Allahabad.*

The results of the study reveals that various inflow parameters i.e. recharge from rainfall, recharge from canal seepage, recharge form tanks, and recharge from field irrigation, during monsoon season were estimated 185.9 Mm³, 156.3 Mm³, 7.4 Mm³, and 378.8 Mm³ *respectively. During non-monsoon period these inflow parameters were estimated 53.1 Mm^3, 182.8 Mm^3, 10.7 Mm^3 and 183.9 Mm^3 respectively. Groundwater outflow parameters i.e. evapotranspiration losses, tube well discharge and groundwater storage during monsoon season were estimated 1189.5 Mm^3, 17.6 Mm^3 and 31.4 Mm^3 respectively. During non-monsoon season these outflow parameters were estimated 574.9 Mm^3, 44 Mm^3 and 12.1 Mm^3. Results of the study clearly reveals that Allahabad district has a declining groundwater level trend in Koraon, Manda, Meja, Phulpur and Pratappur blocks are at critical stage and there is an urgent need of artificial ground water recharge techniques at appropriate locations and proper management techniques to check the declining trend of groundwater level.*

Key words: ground water, potential, water balance, Allahabad

I. Introduction

Today's various government and non-government organization are attempting in developing innovative approaches for proper management of depleted groundwater, quantitatively and qualitatively as well to prevent over-exploitation. In such context, it becomes necessary to know the exact groundwater trend. Various methods, models and structures have been developed for excess use of excess rainfall by water harvesting so that the groundwater could be conserved up to some limit and to divert the excess rainwater from ground surface to the groundwater strata to recharge the level of groundwater and to improve the quality of subsurface water. Groundwater balance equation is extensively used to assess the groundwater. Evaluation of groundwater recharge from ground water balance method essentially involves the quantitative estimation of two components- inflow to the groundwater and outflow from the groundwater. In order to evolve proper management strategies and development of groundwater recharge of an area, it is essential to quantify all the component of recharge to and discharge from the groundwater reservoir to derive the groundwater balance. The handling of various data and calculation of these data for estimating each and every component of inflow and outflow from groundwater is become very complex some times. In this context computer aided techniques can be very much helpful and can provide easy handling and calculation of various data related to assessing the groundwater recharge. C programming language was used in this study for estimation of inflow and outflow component of groundwater. This study is aimed to estimate groundwater draft, change in groundwater storage and water table fluctuation and to develop the software for estimation of inflow and outflow parameter of water balance equation in different blocks of a district. Allahabad district is taken as a study area. It is situated at east of U.P. state. It covers an area of 5246 sq. km and comprises 20 blocks i.e. Bahadurpur, Baheria, Chaka, Dhanupur, Handia, Holagarh, Jasra, Karchhana, Kundhiyara, Kaurihar, Koraon, Manda, Mau-Aima, Meja, Phoolpur, Pratappur, Saidabad, Soron, Shankargarh, Urwa. The Ganga River passes through Allahabad. The most important tributaries are Yamuna and Tons. Course of Ganga is longest i.e. 125 km than Yamuna i.e. 80 km and flows in the east. The average rainfall in Allahabad is 895.15 mm. Depth of water level in phreatic zone varies from 3-15 m b.g.l. during monsoon and non-monsoon season. It varies from 2.42- 10.75 m b.g.l. in Trans Ganga area and 2.00- 10.00 m in Trans Yamuna area.

II. Material and Method

The area of the district Allahabad lies approximately between latitudes 24° 49' 25″ to 25°04'30″ North and longitudes 81°33'05″ to 82°21'00″ East covering an area of 5332 square km. The district area represents alluvial, as well as hard rock. It can be divided into three natural subdivisions i.e. Active Flood Plain, Older Alluvial Plain and Rock Surface.

2.1 Groundwater Balance Equation

Inflow to the system - outflow from the system = change in storage of the system (over a period of (time)

$R_i + R_c + R_r + R_t + I_g = Et + T_p + O_g + \Delta S$ ....(1)

Where,
R_i = recharge from rainfall; R_c = recharge from canal seepage; R_r = recharge from field irrigation; R_t = recharge from pond storage; I_g = inflow from other blocks; Et = evapo-transpiration; T_p = ground water discharge from tubewell; O_g = outflow to other blocks; and ΔS = change in ground water storage.

Influent and effluent seepage from rivers was omitted from the main equation as its effect is negligible in Allahabad area

2.2 Study Period

The periods for study depend from the time of maximum water table to the time of minimum water table elevation. Thus the study periods are taken as monsoon period for the duration June to October and non-monsoon period for the duration of November to May (Kumar C.P.2004).

2.3 Data Collection

The required data for carrying out the ground water balance study was enumerated from different sources as described below.

- **Climatological data**

The rainfall data, mean temperature, relative humidity, wind speed, and maximum sun shine hours used in this study was collected from the meteorological station of School of Forestry, Sam Higginbottom Institute of Agriculture, Technology and Sciences. The daily rainfall data of last five years (2006-2010) was collected and analyzed for the study.

- **Lithological and Ground Water data**

The specific yield, monsoon and non-monsoon ground water level data, transmissivity of aquifers, Canal Water Supply in Major and Minor Distributaries, and Pond storage in various blocks were needed to estimate the groundwater recharge from Allahabad Regional office of State Ground Water Board, U.P.

2.4 Estimation of inflow component of groundwater balance equation

- **Recharge from Rainfall (R_i)**

Recharge from rainfall was calculated from the following equation (Chaturvedi, 1986)

$$R = 1.35(P - 15)^{0.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.2)$$

For the analysis, monthly rainfall depth of each month of last five year (2010-20105) was considered.

Recharge from rainfall in different blocks = Rechargeable area A × precipitation R ……..(3.3)

- **Recharge due to Canal Seepage (R_c)**

Average length (meters), average wetted perimeters (meters) of the main, branch, distributaries and minor were considered with average no. of running days of canals in different blocks of Allahabad. Seepage losses per million square meter of wetted area in unlined channels were taken as 3 m^3/sec. (Kumar C.P., 2004). The following formula was adopted for computing the recharge from canal (Rc)

R_c= k × Area (length × wetted perimeter of the canal) × No. of running days ……………(3.4)

Where k = 3 × 60 × 60 × 24 / 100000 = 0.2592 m^3/day/million square of wetted area

- **Recharge from Ponds (R_t)**

It was assumed that overall 50 cm/year (Kumar C.P.) for the estimation of recharge from pond water seeps down from the ponds. Following equation was used to estimate the seepage from ponds

Recharge (R_t) (m^3) = $k_1 \times k_2 \times$ (no. of days of availability of water in the Tank) $\times$ water spread area (m^2) ....(3.5)

Where, k_1 is the seepage from pond (m/year) (1.37×10^{-3} m/year) and k_2 is the modified factor on availability of water in the ponds (0.7) as per the recommendations of State Ground Water Board, Uttar Pradesh.

- **Recharge from Field Irrigation (R_r)**

Ground Water Estimation Committee (2009) has recommended the following norms for return seepage from irrigation fields:

Table 1. Percentage of Return Recharges

Source of Irrigation	Type of Crop	Percentage (%) of return recharge Water table below ground level <10 m	10-25 m	>25 m
Ground water	Non-Paddy	25	15	5
Surface water	Non-Paddy	30	20	10
Ground water	Paddy	45	35	20
Surface water	Paddy	50	40	25

Recharge from field irrigation = 10 × Area under crop (ha) (Paddy or Non-Paddy) × factor according to the water level of the block (from Table 1) × Crop water requirement (mm) ....(3.6)

Area under paddy and non-paddy was determined for each block with source of irrigation i.e. ground or surface water irrigation source. Considering the depth of ground water level in that block, the corresponding factor was determined from Table 1. Total average water required by paddy crop for its whole season was estimated to be almost 65 cm and water required by non-paddy crop was almost 30 cm. Recharge during paddy crop was considered under monsoon season and non-paddy crop was considered for non-monsoon season.

2.5 Estimation of outflow component of groundwater balance equation

- **Crop Water Requirement :** it was estimated using Penman-Monteith Equation (FAO Publication No. 56)

$$ET_o = \frac{0.408\Delta(Rn - G) + \frac{\gamma 900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1+0.84u_2)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.7)$$

Where,

ET_o is reference evapotranspiration [mm day^{-1}]; R_n is net radiation at the crop surface [MJ m^{-2} day^{-1}]; G is soil heat flux density [MJ m^{-2} day^{-1}]; T is air temperature at 2 m height [°C], u_2 is wind speed at 2 m height [m s^{-1}]; e_s is saturation vapour pressure [kPa]; e_a is actual vapour pressure [kPa]; (e_s-e_a) is saturation vapour pressure deficit [kPa]; Δ is slope vapour pressure curve [kPa $°C^{-1}$] and γ is psychometric constant [kPa $°C^{-1}$].

Crop water requirement = K_i. ET_{0i}. D_i + K_m.ET_{0m}. D_m + K_l.ET_{0l}. D_l ……………………(3.8)

Where,

K_i is crop coefficient for initial and development periods; ET_{0i} is reference evapotranspiration of corresponding month of initial development periods; D_i is no. of days in initial development periods; K_m is crop coefficient for mid periods; ET_{0m} is reference evapotranspiration of corresponding month of mid periods; D_m is no. of days in mid periods; K_l is crop coefficient for late periods; ET_{0l} is reference evapotranspiration of corresponding month of late periods and D_l is no. of days in late periods.

Further all the crops were classified blocks wise according to monsoon and non-monsoon season and crop water requirement for the same were estimated.

2.6 Ground Water Discharge from Tubewells

Discharge from ground water (T_p) in monsoon and non-monsoon season in different blocks was calculated as

T_{w1} = No. of annual average running Days × Average no. of running hours × discharge from well (m^3/hr). ……………………………….(3.9)

$T_{p1} = T_{w1} \times n$ ……………………………………………………(*3.10)*

Where T_{w1} is discharge of a well in a particular block during the monsoon and non-monsoon periods ; T_{p1} is total groundwater discharge from the block and n are No. of wells in the block

2.7 Groundwater Inflow and Outflow (I_g & O_g)

For the estimation of sub-surface inflow/outflow of ground water, contour maps of the phreatic surface were prepared based on the phreatic level data for monsoon and non-monsoon season. Water level depth of each block was marked in the center of each block on the map then the contour maps were prepared for monsoon and non-monsoon

The flow into the block or out of the block is governed mainly by the hydraulic gradient and the transmissivity of the aquifer. The length of the section, across which ground water inflow/outflow occurs, was determined from contour maps. The inflow or outflow was determined by the following relationship

$Q = \Sigma\ T\ i\ \Delta L$ ………………………………………………….(3.11)

Where i is hydraulic gradient; T is transmissivity and L is total length of the contour line; the gradient was determined by taking the slope of the water table normal to water table contour as in following Equation

2.8. Change in Ground Water Storage (ΔS)

The change in storage was computed from the following equation

$$\Delta S = \Sigma\, h\, A\, S_y \quad \text{...} (3.12)$$

Where h is change in water level at start and end of monsoon and non-monsoon season (m); A is rechargeable area of each blocks the well (ha); and Sy is the specific yield.

The change in water level for start and end of monsoon and non-monsoon season of each block were multiplied with rechargeable area and specific yield of corresponding blocks. Thus groundwater fluctuation for monsoon and non-monsoon season was calculated.

2.9 Groundwater Recharge

The entire inflow component (i.e. recharge from rainfall, canal seepage, field irrigation, and tanks) and outflow component (i.e. crop water requirement, draft from tubewell, inflow and out flow of water from blocks and groundwater fluctuation) were estimated for each block separately and total groundwater recharge was estimated

2.10 Computer Models of Ground Water Recharge Components

Computer software was developed in C language for estimating different inflow and outflow of water balance equation. Each component of the equation was programmed and then combined to calculate the desire results.

III. Result and Discussion

3.1 Inflow Component

- **Recharge from Rainfall (R_i)**

The recharge was estimated using the software for all 20 blocks of Allahabad. Result shows that maximum recharge due to the monsoon and non-monsoon rainfall was estimated for Koraon block i.e. 24.17 Mm^3 and 6.91 Mm^3 respectively. The minimum recharge due to monsoon rain was estimated for Soraon block i.e. 5.16 Mm^3 and 1.47 Mm^3.

- **Recharge due to Canal Seepage (R_c)**

Recharge from Canal Seepage was computed through software for each block with the corresponding canal falling in respective block i.e. main, branch, distributary and minor. Result shows that maximum recharge from canal seepage during monsoon and non-monsoon period was estimated for Holagarh block i.e. 18.13 Mm^3 and 23.21 Mm^3 respectively. Minimum recharge from canal seepage during monsoon and non-monsoon period was estimated for Bahadurpur block i.e. 0.41 Mm^3 and 0.38 m^3 respectively

- **Recharge from Tank Storage (R_t)**

The maximum recharge during monsoon and non-monsoon season season was computed for Jasra block i.e. 1.41 Mm^3 and 2.06 Mm^3 respectively. The minimum recharge due to canal seepage in the monsoon and non-monsoon period was estimated for Kaurihar block i.e. 0.02 Mm^3 and 0.02 Mm^3 respectively. Jasra block was having the highest water spread area for ponds and thus recharge was observed maximum. Kaurihar block was having the small water spread area for ponds, so the recharge was low. This was also calculated through the software.

- **Recharge from Field Irrigation (R_r)**

Basic data was fed into the software as input to calculate the recharge for all 20 blocks of Allahabad. Maximum recharge from the field irrigation during monsoon season was estimated 39.75 Mm^3 for Koraon block. The minimum recharge from the field irrigation during monsoon season was estimated 6.07 Mm^3 for Chaka block. The maximum recharge from the field irrigation during non-monsoon season was estimated 15.67

Mm^3 for Baheria block. The minimum recharge from the field irrigation during non-monsoon season was 3.01 m^3estimated for Chaka block followed by Meja block (4.55 Mm^3). Koraon block is having the highest agricultural land so the seepage from the irrigation water is higher and secondly the percentage of recharge from surface irrigation is higher than that of ground water irrigation, thus the seepage from irrigation was observed higher in Koraon block and lowest in Meja block.

3.2 Outflow Component

- **Crop Water Requirement**

Crop water requirement estimated by software during the monsoon season was maximum for Koraon block i.e. 181.33 Mm^3 as highest area covered under paddy and wheat was observed in Koraon block (30554.62 ha) and minimum crop water requirement during monsoon season was estimated for Chaka block i.e. 15.62 Mm^3. Crop water requirement estimated during the non-monsoon season was also maximum for Koraon block i.e. 77.86 Mm^3 followed by Meja block (36.52 Mm^3) and minimum crop water requirement during monsoon season was estimated for Chaka block i.e. 11.72 Mm^3 followed by Urwa block (19.25 Mm^3).

- **Groundwater Draft from Tubewells (T_p)**

The maximum groundwater discharge during monsoon season was estimated for Baheria block i.e. 1.41 Mm^3. The minimum groundwater draft during monsoon season was estimated for Chaka block i.e. 0.35 Mm^3. The maximum groundwater discharge during non-monsoon season was estimated for Kaurihar block i.e. 3.31 Mm^3. The minimum groundwater draft during monsoon season was estimated for Shankargarh block i.e. 0.90 m^3. Baheria and Kaurihar blocks higher groundwater discharge were observed because the number of all tubewells in these blocks was higher and lower for Shankargarh and Chaka blocks. The total groundwater discharge State Tubewells, Geostatic Tubewells, Private Tubewells, and Boring Pump Sets during monsoon and non-monsoon season was estimated 17.59 Mm^3 and 44.01 Mm^3 respectively. Results shows tubewells discharge during non-monsoon season was higher than that of monsoon season.

- **Groundwater Inflow and Outflow (Ig & Og)**

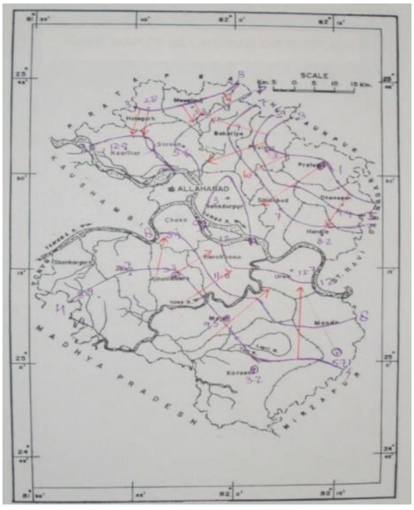
To estimate the Subsurface inflow and outflow water level contour lines were sketched on the maps through the interpolation. Water level contour maps are shown in Fig. 1 and 2. Maximum water was in-flowed to Baheria block i.e. 0.49 Mm^3 followed by Bahadurpur block (0.042 Mm3) and out-flowed from Phulpur block i.e. 0.45 Mm^3 followed by Soraon block (0.35 Mm^3) during monsoon season. During non-monsoon season maximum water was also in-flowed to Baheria block i.e. 0.75 Mm^3 followed by Bahadurpur block (0.64 Mm^3) and out-flowed from Phulpur block i.e. 0.423480 Mm^3 followed by Soraon block (0.39 Mm^3) in non-monsoon season. The soil type of Meja, Urwa, Koraon and Manda blocks aquifer was observed of fine sand and thus transmissivity was quite lower than that of other blocks which gave very low water inflow and outflow result.

Table 2 . Inflow/ Outflow from/to Blocks during Monsoon and non monsoon Season (Mm^3)

	Monsoon season			Non monsoon season		
Blocks	**Inflow (Mm^3)**	**Outflow (Mm^3)**	**Resultant Inflow/ Outflow (Mm^3)**	**Inflow (Mm^3)**	**Outflow (Mm^3)**	**Resultant Inflow/ Outflow (Mm^3)**
Bahadurpur	0.43	0.00	0.43	0.64	0.00	0.64
Baheria	0.49	0.00	0.49	0.75	0.00	0.75
Chaka	0.01	0.00	0.01	0.15	0.00	0.15
Dhanupur	0.13	0.15	-0.02	0.10	0.17	-0.07
Handia	0.15	0.00	0.15	0.17	0.00	0.17
Holagarh	0.00	0.13	-0.13	0.00	0.24	-0.24
Jasra	0.00	0.00	0.00	0.00	0.00	0.00
Karchhana	0.30	0.00	0.30	0.23	0.00	0.23
Kundhiyara	0.00	0.31	-0.31	0.00	0.37	-0.37
Kaurihar	0.41	0.00	0.41	0.62	0.00	0.62

Koraon	0.00	0.00	0.00	0.00	0.00	0.00
Manda	0.00	0.00	0.00	0.00	0.00	0.00
Mau-Aima	0.00	0.20	-0.20	0.00	0.44	-0.44
Meja	0.00	0.00	0.00	0.00	0.00	0.00
Phoolpur	0.00	0.45	-0.45	0.00	0.42	-0.42
Pratappur	0.00	0.21	-0.21	0.00	0.10	-0.10
Saidabad	0.08	0.24	-0.16	0.00	0.37	-0.37
Soraon	0.05	0.35	-0.30	0.18	0.39	-0.21
Shankargarh	0.00	0.00	0.00	0.00	0.00	0.00
Urwa	0.00	0.00	0.00	0.01	0.00	0.01

The groundwater contour lines during monsoon and non monsoon season are drawn and ground water movement was analyzed using ground water contour lines.



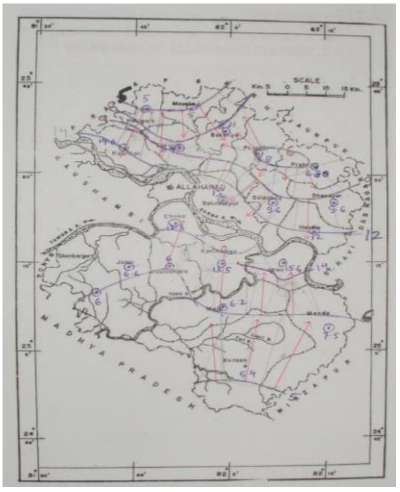


Fig 1. Groundwater Contour Map during monsoon season

Fig 2. Groundwater Contour Map during Non-Monsoon season

3.3 Change in Ground Water Storage (ΔS)

The groundwater had a declining trend in Bahadurpur and Manda blocks i.e. 1.59 Mm^3 and 1.63 Mm^3 during monsoon season whereas the maximum groundwater water was replenished in Chaka block i.e. 54.19 Mm^3 followed by Dhanupur block (41.16 Mm^3). During non-monsoon season the highest groundwater declining was observed for Kaurihar block i.e. 18.16 Mm^3 followed by Jasra block (15.96 Mm^3) and maximum groundwater was replenished in Pratappur block i.e. 50.64 Mm^3 followed by Koraon block (45.46 Mm^3). Soil type is main factor for groundwater declining and replenishment. The low specific gravity corresponds to lower contribution to the groundwater and secondly groundwater is being exploited in theses area than that of replenishment.

3.4 Total Ground Water Recharge

Total inflow, total outflow, and groundwater recharge (m^3 and cm/year) in different blocks of Allahabad during monsoon and non-monsoon periods. The tabular data shows that in all the blocks over exploited of water is being practiced. The maximum water was exploited from Koraon block i.e.177581691.7 m^3 and 242862906 m^3 during monsoon and non-monsoon season and there is need to take proper precautions. In monsoon season the discharge of water from the groundwater resources was lower than non-monsoon season. Study also reveals that Koraon, Manda, Meja and Phulpur blocks of Allahabad are at critical situation as the water is being over-exploited from these blocks and need to check the water use.

Table 3. Ground water Recharge during Monsoon and Non Monsoon Season (Mm^3)

Blocks	Ground water Recharge during Monsoon season(Mm^3)			Ground water Recharge during Non Monsoon season(Mm^3)		
	Input to the Blocks	Output from the Blocks	Total Recharge	Input to the Blocks	Output from the Blocks	Total Recharge
Bahadurpur	9.22	65.73	-56.51	20.42	53.34	-32.92
Baheria	34.68	122.21	-87.54	51.77	113.65	-61.87
Chaka	6.41	35.62	-29.21	13.74	73.63	-59.89
Dhanupur	13.63	88.76	-75.13	23.27	137.31	-114.04
Handia	14.05	104.82	-90.77	25.33	103.58	-78.25
Holagarh	37.91	25.75	12.16	53.78	68.21	-14.44
Jasra	26.86	32.13	-5.27	48.43	85.78	-37.35
Karchhana	25.10	88.42	-63.32	40.89	81.54	-40.66

Kundhiyara	38.15	82.81	-44.66	48.55	72.12	-23.57
Kaurihar	19.99	116.70	-96.71	40.36	97.75	-57.39
Koraon	23.49	266.35	-242.86	65.62	243.20	-177.58
Manda	14.86	243.72	-228.86	24.73	127.06	-102.33
Mau-Aima	20.70	70.80	-50.10	34.03	88.53	-54.50
Meja	17.53	257.46	-239.93	33.18	171.49	-138.31
Phoolpur	25.06	165.25	-140.19	36.84	127.18	-90.34
Pratappur	20.73	143.09	-122.36	29.86	114.75	-84.89
Saidabad	20.27	91.43	-71.17	30.70	93.77	-63.07
Soraon	25.24	84.24	-59.00	42.30	78.92	-36.63
Shankargarh	19.97	58.73	-38.76	38.84	46.75	-7.91
Urwa	16.84	85.68	-68.84	26.07	85.82	-59.74

Negative sign represents the discharge from the aquifer system

IV. Conclusion

It was concluded that in Allahabad district the rate of discharge of groundwater in different blocks of Allahabad during monsoon periods ranging from 2.41 to 65.83 cm/year where as during non-monsoon period it is from 1.19 to 112.33 cm/year. In 19 blocks the declining trend of groundwater was observed and in only one block i.e. Holagarh the recharge of groundwater during non-monsoon periods was recorded. The highest significant decline rate in ground water was found in Manda and Meja blocks i.e. 112.33 cm/year and 70.57 cm/year. only in Holagarh block the groundwater water replenishment was observed which is at the rate of 8.19 cm/year during monsoon season. During non-monsoon season the highest groundwater declining rate was observed for Dhanupur block i.e. 65.83 cm/year. Dhanupur, Manda, Handia, Meja, Phulpur and Pratappur blocks were found over exploited. It is further concluded that the developed software may effectively be used to estimate the various inflow and outflow component and help to manage the proper ground water balance helping to effective management of groundwater resources.

Table 4. Effective annual Rise / decline in ground water level of Allahabad district

Blocks	Area Under Recharge (ha)	Effective Rise / Decline in ground water level (cm/year)	
		Monsoon	Non-Monsoon
Bahadurpur	26468	-21.35	-12.44
Baheria	24875	-35.19	-24.87
Chaka	15359	-19.02	-38.99
Dhanupur	17322	-43.37	-65.83
Handia	16067	-56.49	-48.7
Holagarh	14846	8.19	-9.73
Jasra	26958	-1.95	-13.85
Karchhana	23281	-27.2	-17.46
Kundhiyara	20046	-22.28	-11.76
Kaurihar	42035	-23.01	-13.65
Koraon	63142	-38.46	-28.12
Manda	20373	-112.33	-50.23
Mau-Aima	15060	-33.26	-36.19
Meja	34001	-70.57	-40.68
Phoolpur	22529	-62.23	-40.1
Pratappur	21101	-57.99	-40.23
Saidabad	19142	-37.18	-32.95
Soraon	13485	-43.75	-27.16
Shankargarh	32828	-11.81	-2.41
Urwa	16890	-40.76	-35.37

Negative sign represents the decline in ground water level

REFERENCES

Allen, Richard G., Pereira, Luis S., Raes, D. and Smith, M. (1990). FAO Irrigation and Drainage Paper 56: Crop Evapotranspiration.

Arya, A., Ansari, M.M., Tribhuwan and Sinha, R.S., (2006). Groundwater governance in Uttar Pradesh – issues, initiatives and actions, in Romani, S., et al., eds., Groundwater Governance: Capital Pub. Co., New Delhi, p. 1-9.

CGWB (2009). Ground Water Resource Estimation Methodology.

CGWB (2009). Report of the Group for Suggesting New and Alternate Methods of Ground Water Resources Assessment.

Chandra, Satish and Saksena, R. S. (1975). Water Balance Study for Estimation of Groundwater Resources, Journal of Irrigation and Power, India, pp. 443-449.

Doorenbos, J. and Pruitt, W. O. (1977). Guidelines for Predicting Crop Water Requirements, FAO, Irrigation, and Drainage Paper 24.

Finch, J. W. (1998). Estimating direct groundwater recharge using a simple water balance model – sensitivity to land surface parameters. Journal of Hydrology 211: 112–125.

Ground Water Estimation Committee, Ministry of Irrigation, Government of India, (1984). A Report on Ground Water Estimation Methodology New Delhi, March 1984, pp: 39.

Karanth, K. R., (1987). Groundwater Assessment, Development and Management, Tata McGraw-Hill Publishing Company Limited, New Delhi, pp. 576-657.

Kumar, C. P. and Seethapathi, P. V. (1988). Effect of Additional Surface Irrigation Supply on Groundwater Regime in Upper Ganga Canal Command Area, Part I - Groundwater Balance, National Institute of Hydrology, Case Study Report No. CS-10.

Kumar, C. P. (1993). Estimation of Ground Water Recharge due to Rainfall by Modeling of Soil Moisture Movement, National Institute of Hydrology, Technical Report No. TR-142, 66p.

Kumar, C. P., and Seethapathi, P. V. (2002). Assessment of Natural Groundwater Recharge in Upper Ganga Canal Command Area, Journal of Applied Hydrology, Association of Hydrologists of India, Vol. 15, No. 4, pp. 13-20.

Kumar, C.P., (2003). Estimation of Ground Water Recharge Using Soil Moisture Balance approach. Journal of Soil and Water Conservation. Soil Conservation Society of India, 2 (1-2): 53-58.

Pandey, H.K. (2009). Ground Water Brochure of Allahabad District, U.P.

Todd, D.K., (1980). Groundwater Hydrology, 2nd Edition, John Wiley and Sons, New York.

Sakthivadivel, R. (2007). The Groundwater Recharge Movement in India. CAB International 2007. The Agricultural Groundwater Revolution: Opportunities and Threats to Development 195-209.

Sharma, D. N., and Patel, J.N., (2008). Development of Software Module for Groundwater Recharge, World Applied Sciences Journal 3 (6): 963-968.

Sree Devi, P.O. (2003). Assessment of Ground Water Resources of Pageru River Basin, Cuddapah District, Andhra Pradesh. Indian J. Agric. Res., 37 (4); 245 · 252.

Wahid, S.M. (2005). Assessment of Groundwater Potential for Irrigation in Bangladesh. Integrated Watershed Management: Studies and Experiences from Asia p515-528.

Xu, C. Y., and Chen, D. (2005). Comparison of seven models for estimation of evapotranspiration and groundwater recharge using lysimeter measurement data in Germany. Hydrological Process. 19, 3717–3734 (2005)