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Assessment of ground water requirements for the irrigation operation in Samastipur district, Bihar

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Abstract
Ground Water remains the lifeline of socio-economic development in the Ganga Alluvial Plain (GAP) since the down of civilization in the Indian subcontinent. Assessment of ground water resources yields knowledge necessary for their informed management and governance. Over exploitation of ground water resource threaten the future of irrigated agriculture. Keeping the importance of the above points a study was conducted for assessment of volume of ground water needed for the irrigated crops (rice, wheat, sugarcane, maize) for all the blocks of Samastipur district (Bihar). The total ground water volume that required for irrigation was estimated to be 800523.08 ha-m in which the contribution of *Kharif* and *Rabi* were 42.86% and 57.14% respectively. The maximum ground water requirement for the district was in the 44644 ha-m in the month of June while the minimum was 74.03 ha-m in the month of August.

Keywords: Ground water, water requirements**,** evapotranspiration, irrigated agriculture

Introduction
Globally, area equipped for irrigation is currently about 301 million ha of which 38% are equipped for irrigation with ground water. The countries with the largest extent of areas equipped for irrigation with ground water, in absolute terms, are India (39 million ha), China (19 million ha) and the USA (17 million ha). Ground water has made significant contributions to the growth of India's Economy and has been an important catalyst for its socio-economic development. Its importance as a precious natural resource in the Indian context can be gauged from the fact that more than 85% of India's rural domestic water requirements, 50% of its urban water requirements and more than 50% of its irrigation requirements are being met from ground water resources. The increasing dependence on ground water as a reliable source of water has resulted in its large-scale and often indiscriminate development in various parts of the country, without due regard to the recharging capacities of aquifers and other environmental factors. Bihar is undergoing fast economic development with its impact on life style, natural resources and environment. But economic growth has persisting inadequacies. One such challenging area is agriculture, which has the key role in poverty alleviation in Bihar, where 90% population is rural. Though the state is bestowed with water and land, the state needs to substantially increase the cropping intensity and also the irrigation intensity. Assured availability of water for drinking, agriculture and industries are the key factors to determine the future economic scenario. During the last six decades, the remarkable feature in irrigation development is the conspicuous growth in the use of ground water. However, in Bihar at present, the ground water meets the irrigation to only about 65% of the gross irrigated area. It has affected the agricultural production for want of irrigations. To enhance the irrigation potential ground water can safely be developed at least to the level of 60-70% as ground water irrigation is under the direct control of the farmers and is amenable to precision agriculture and higher irrigation efficiency. The sustainable utilization of ground water resource demands a quantitative assessment. So the study had been carried out to estimate the volume of ground water for irrigation purpose. Irrigation in Samastipur (Bihar) is provided by tube well, wells, tanks, ponds, rivers *i.e.* by surface and ground water. However rainwater is still a major source of irrigation in most of the part of Samastipur district. Though the part of district falls in the tail end of the Gandak canal, ground water provides main source of irrigation. Keeping the importance of the above points a study was conducted for assessment of volume of ground water needed for the irrigated crops (rice, wheat, sugarcane, maize) for all the blocks of Samastipur district (Bihar).

Materials and Methods

Description of the Study Area

All the blocks of Samastipur district had been selected. Its latitude is 25.98ºN longitude is 85.67º E and about 52 m above mean sea level. The soil type is sandy loam and major crops are rice, wheat, maize and sugarcane. Annual rainfall is 1142 mm. Depth of ground water level generally varies from 7.2 to 11.10 mbgl in pre-monsoon while in post monsoon it varies from 3.2 to 6.4 mbgl.

Irrigation Water Requirements

The irrigation requirement for cropped season can be estimated from water balance equation

$$I_n = ET_m - ER + W_n + W_c + W_s \quad (1)$$

Where, I_n (Net irrigation requirement, mm) is calculated by using ET_m (crop evapotranspiration), W_n (water requirement for seed bed preparation), W_c (upward movement of water in to the root zone, mm) and W_s (carryover soil moisture, mm). Under normal conditions, W_c and W_s are negligible so equation-(1) reduces to;

$$I_n = ET_m - ER \quad (2)$$

Stewart *et al.* (1974) proposed a linear relationship of the form:

$$\left(1 - \frac{Y_a}{Y_m}\right) = K_y \left(1 - \frac{ET_a}{ET_m}\right) \quad (3)$$

Where, Y_m is maximum possible crop yield per hectare at ET_m, Y_a is actual crop yield per hectare at ET_a , ET_a is actual evapotranspiration per crop season; mm and K_y is crop yield response factor.

$$IR = ET_a - ER + W_n \quad (4)$$

Combining equation (3) and (4)

$$IR = \left[1 - \frac{1}{K_y}\left(1 - \frac{Y_a}{Y_m}\right)\right] ET_m - ER + W_n \quad (5)$$

The water requirement for seed bed preparation and other special need can be expressed as

$$W_n = \sum_{i=1}^{3} W_i \quad (6)$$

Where, W_1 is amount water required for nursery raising for crop (mm), W_2 is water requirement for seed bed preparation (mm), W_3 is deep percolation loss in rice field (mm). Thus the amount water drawn from the water source (IR_s) had been expressed in terms of conveyance Efficiency (η_c) and water application efficiency (η_a).

$$IR_s = \frac{IR}{\eta a \times \eta c} \quad (7)$$

$$IR_s = \frac{1}{\eta a \times \eta c}\left[1 - \frac{1}{K_y}\left(1 - \frac{Y_a}{Y_m}\right)\right] ET_m - ER + \sum_{i=1}^{3} W_i \quad (8)$$

Let 'A' be the irrigated area of the crop.

$$Q = \frac{10A}{\eta a \times \eta c}\left[1 - \frac{1}{K_y}\left(1 - \frac{Y_a}{Y_m}\right)\right] ET_m - ER + \sum_{i=1}^{3} W_i \quad (9)$$

Where, A is the irrigated area (ha) and Q is the total amount of water required (m^3). Another factor had been introduced in equation (9) to account for soil type by assuming that effect of soil type is same on ET_m and ER. Thus equation (9) becomes.

$$Q = \frac{10A}{\eta a \times \eta c}\left[\left\{\left\{1 - \frac{1}{K_y}\left(1 - \frac{Y_a}{Y_m}\right)\right\} ET_m\right\} S + \sum_{i=1}^{3} W_i\right] \quad \textbf{(10)}$$

Crop water requirement

The monthly reference evapotranspiration was obtained by using Papadakis (1965) method.

The reference evapotranspiration (ETo) will be estimated by using the following equation:-

$$\mathbf{ET_o} = 5.625 \{e_{amax} - e_{amin\text{-}2}\} \quad \textbf{(11)}$$

$$ET_m = K_c \times ET_o \quad \textbf{(12)}$$

Where, ET_o is reference evapotranspiration (mm), ET_m istotal crop evapotranspiration, e_{amax} is saturated vapour pressure in millibar at monthly maximum air temperature (ºC), $e_{amin\text{-}2}$ is saturated vapour pressure in millibar at monthly minimum air temperature minus 2 ºc and K_c is crop co-efficient.

Effective rainfall (ER)

$$ER = f(D)\,[1.25P^{0.824} - 2.98] \times 10^{0.0000955ETm} \quad (13)$$

Where, ER is Monthly effective rainfall (mm), D is Depth of water depletion in root zone prior to precipitation (mm), P is Actual monthly rainfall (mm).

And f (D) = 1.0 for D ≤ 75mm = $\{0.53 + 0.0116D - 8.94 \times 10^{-5} D^2 + 2.32 \times 10^{-7} D^3$ for D > 75mm

In this study the value of f (D) was considered 1.

Results and discussions

Crop water requirement

Based upon the area under different crops, month wise and block wise crop water requirement were computed. The crop water requirement was maximum in the month of June *i.e.* 44644 ha-m while it was minimum in the month of August *i.e.* 74.03 ha-m. The total crop water requirement is minimum in Bidyapati block *i.e.* 7726.2 ha-m and maximum in Kalyanpur block *i.e.* 20222.3 ha-m (Table-1).

Effective rainfall

The value of mean rainfall (Fig.-1) and ET_m were used to calculate the effective rainfall value for each crop using USDA- SCS method (equation 13). The monthly effective rainfall for all the selected crop was maximum in the month of August *i.e.* 887.08 mm while it was zero in the months of April, November and December (Table-2).

Irrigation water requirement

The value of crop evapotranspiration, effective rainfall, crop yield, response factor, maximum, actual crop yields, application efficiency, conveyance efficiency and water required for seed bed preparation and other special need were use to find ground water requirements. The total amount of pumpage for Samastipur district is 800523.8 ha-m with the minimum of 74.3 ha-m (0.009% of total) in the month of

August to maximum 185772.03 ha-m in June (23% of the total). Block wise annual ground water volume varies from 21832.3 ha-m (*i.e.* minimum) in Mohanpur to 676617.7 ha-m (*i.e.* maximum) in Kalyanpur block (Table -3). The variation is due to variation in cropping pattern, effective rainfall and area to be irrigated.

Table 1: Crop evapotranspiration of selected crops from irrigated area. (ha-m)

Blocks	Jan.	Feb.	March	April	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Total
Samastipur	931.70	943.07	1052.56	1003.50	24.82	3071.6	1448.74	3.879	706.03	1374.60	1259.40	897.40	12717.30
Pusa	642.40	658.06	732.84	688.60	10.81	1598.1	799.45	2.010	497.09	820.70	876.70	611.30	7938.20
Kalyanpur	1546.20	1543.98	1819.86	1790.90	168.39	3745.2	2112.63	7.351	1290.80	2296.60	2376.40	1524.00	20222.30
Warisnagar	992.30	1004.40	1119.01	1066.10	23.88	2389.9	1155.92	3.117	537.71	1283.00	1270.80	955.30	11801.50
Khanpur	955.40	957.66	1208.56	1207.70	197.89	2391.6	1385.66	4.130	675.49	1410.90	1395.50	951.40	12741.80
Tajpur	774.30	782.84	855.89	812.00	0.36	1859.2	932.85	2.414	416.34	998.30	979.40	744.10	9158.00
Morwa	849.00	849.53	925.81	886.50	0.00	2189.1	1064.51	3.071	652.77	1143.20	1184.10	822.40	10569.90
Patori	790.50	787.58	856.25	823.80	0.00	2003.3	1109.66	3.396	620.12	1132.20	1128.80	768.80	10024.40
Mohanpur	516.30	516.49	562.79	539.00	0.00	1276.7	806.44	1.981	457.10	734.50	702.20	500.20	6613.80
Sarairanjan	1080.70	1088.34	1190.23	1131.60	0.00	2821.1	1273.50	2.997	865.66	1388.30	1373.30	1040.50	13256.30
Dalsinghsarai	757.20	757.05	824.63	790.40	0.00	1896.4	889.20	1.965	572.96	954.40	954.00	734.10	9132.20
Bidyapati	664.20	667.64	729.38	694.90	0.00	1569.4	811.14	1.755	350.46	839.10	757.50	640.70	7726.20
Ujiarpur	1476.10	1558.38	1814.84	1667.20	83.711	3198.9	1602.47	4.507	894.58	1825.60	1938.90	1368.80	17434.00
Mohidinagar	831.40	843.11	925.52	873.30	0.000	1991.4	1034.80	2.768	664.10	1092.00	1130.20	795.20	10183.70
Rosra	740.80	744.47	1116.67	1160.30	363.76	2089.80	1431.30	4.467	772.12	1287.20	1320.90	764.00	11795.80
Shivaginagar	896.20	901.31	1000.44	959.9	21.422	1985.9	1042.51	3.011	553.61	1169.20	1202.00	868.20	10603.80
Bithan	629.50	639.41	1005.51	1046.5	363.24	1855.8	1302.46	4.048	730.14	1126.60	1186.90	650.50	10540.50
Hasanpur	936.90	957.73	2041.02	2233.3	1174.36	3324.9	2747.65	9.676	1454.96	2220.50	2344.60	1045.60	20491.10
Bibhutipur	1319.40	1309.12	1475.50	1445.0	68.96	3283.9	1648.41	4.744	805.52	1822.70	1714.10	1298.50	16195.90
Sindhiya	812.50	814.30	892.57	857.0	8.20	1900.9	1004.95	2.752	472.83	1078.50	1053.20	788.30	9686.00
Total	18143	18324	22149.0	21677	2509.8	44644	25761.2	74.03	13990.2	25998.20	26148.20	17749.20	2388232.70

Table 2: Monthly effective rainfall of selected crops.

Months	Crops				Total
	Maize	Rice	Sugarcane	Wheat	
January	0.00	0.00	0.00	4.90	4.90
February	0.00	0.00	18.85	19.37	38.22
March	0.00	0.00	5.60	5.61	11.21
April	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	33.70	35.07	68.77
June	49.38	49.70	47.60	35.07	180.70
July	148.68	478.10	145.70	0.00	771.10
August	151.34	549.20	141.70	0.00	887.04
September	63.92	66.15	63.80	0.00	195.22
October	43.40	43.26	42.66	43.78	129.40
November	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00

Table 3: Block wise and month wise volume of Ground water required for selected crops (ha-m)

Blocks	Jan.	Feb.	March	April	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Total
Samastipur	3726.92	3772.3	4210.2	4014.0	99.290	12286.4	1448.7	15.52	2824.1	1374.6	5037.5	3589.5	42399.2
Pusa	2569.73	2632.2	2931.3	2754.6	43.240	6392.4	799.4	8.04	1988.4	820.7	3507.0	2445.1	26892.2
Kalyanpur	6184.60	6175.9	7279.5	7163.8	673.547	14980.9	2112.6	29.40	5163.2	2296.6	9505.4	6096.1	67661.7
Warisnagar	3969.333	4017.6	4476.0	4264.4	95.506	9559.7	1155.9	12.47	2150.8	1283.0	5083.4	3821.4	39889.4
Khanpur	3821.6	3830.6	4834.2	4830.7	791.543	9566.3	1385.7	16.52	2702.0	1410.9	5582.0	3805.7	42577.7
Tajpur	3097.29	3131.4	3423.6	3247.9	1.449	7436.7	932.9	9.66	1665.4	998.3	3917.7	2976.3	30838.4
Morwa	3396.04	3398.1	3703.2	3545.9	0.000	8756.3	1064.5	12.28	2611.1	1143.2	4736.2	3289.5	35656.4
Patori	3162.08	3150.3	3425.0	3295.3	0.000	8013.2	1109.7	13.58	2480.5	1132.2	4515.0	3075.2	33372.0
Mohanpur	2065.22	2066.0	2251.2	2156.1	0.000	5106.7	806.4	7.92	1828.4	734.5	2809.0	2000.9	21832.3
Sarairanjan	4322.91	4353.4	4760.9	4526.6	0.000	11284.5	1273.5	11.99	3462.6	1388.3	5493.0	4162.1	45039.8
Dalshinghsarai	3029.0	3028.2	3298.5	3161.4	0.00	7585.6	889.20	7.86	2291.8	954.4	3815.9	2936.3	30998.1
Bidyapati	2656.9	2670.5	2917.5	2779.7	0.00	6277.5	811.14	7.02	1401.8	839.1	3029.8	2562.7	25953.8
Ujiarpur	5904.6	6233.5	7259.3	6668.9	334.84	12795.5	1602.47	18.03	3578.3	1825.6	7755.5	5475.0	59451.7
Mohidinagar	3325.5	3372.4	3702.1	3493.1	0.00	7965.7	1034.80	11.07	2656.4	1092.0	4520.8	3180.7	34354.6
Rosra	2963.1	2977.9	4466.7	4641.4	1455.07	8359.1	1431.30	17.87	3088.5	1287.2	5283.6	3056.0	39027.6
Shivaginagar	3585.0	3605.2	4001.8	3839.7	85.69	7943.7	1042.51	12.04	2214.5	1169.2	4807.9	3472.9	35780.1
Bithan	2518.0	2557.6	4022.0	4186.1	1452.99	7423.1	1302.46	16.19	2920.6	1126.6	4747.4	2601.8	34874.9
Hasanpur	3747.4	3830.9	8164.1	8933.2	4697.47	13299.6	2747.65	38.70	5819.8	2220.5	9378.2	4182.4	67060.0
Bibhutipur	5277.7	5236.5	5902.0	5779.9	275.84	13135.5	1648.41	18.98	3222.1	1822.7	6856.2	5194.1	54370.0
Sindhiya	3250.0	3257.2	3570.3	3427.9	32.81	7603.7	1004.95	11.01	1891.3	1078.5	4212.7	3153.1	32493.5
Total	362865.2	73297	88589.91	86710.6	10049.5	185772.03	25761.6	74.39	55961.2	25998.2	104594.2	71076.8	800523.8

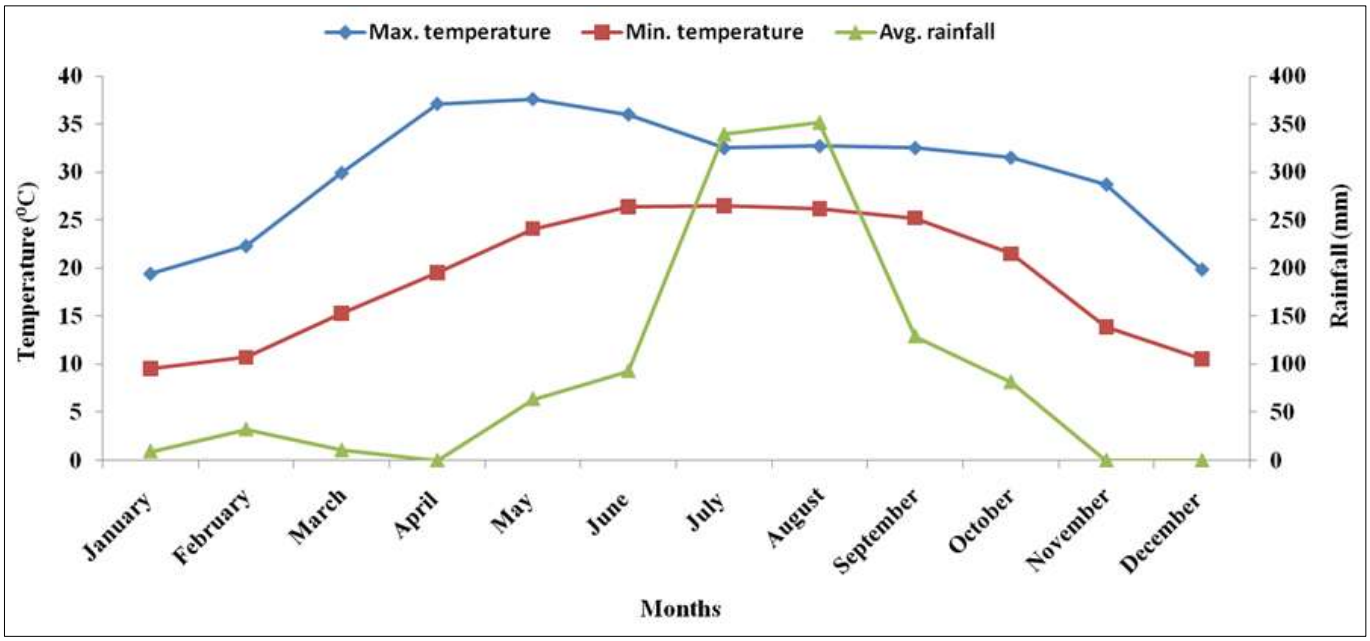

Fig 1: Optimum temperature and average rainfall

Conclusions

In this study, information on rainfall, climatic parameter cropping system crop yield water table depth below ground water surface, area cultivated under different crops were obtained from different department and used to calculate the volume of ground water required for irrigation operation of all the blocks of Samastipur district. The total volume of ground water required for irrigation operation in Samastipur district was 800523.80 ha-m. Ground water volume were maximum (185772.03 ha-m) in the month of June and minimum (74.39 ha-m) in the month of August. Minimum crop water requirement was in the Bidyapati block *i.e.* 7726.2 ha-m and maximum crop water requirement was in Kalyanpur block *i.e.* 20222.3 ha-m. Minimum ground water could be pumped from the Mohanpur block *i.e.* 20222.3 ha-m and maximum water could be pumped from Kalyanpur block *i.e.* 676617.7 ha-m. The total ground water volume that required for irrigation was estimated to be 800523. 08 ha-m in which the contribution of *Kharif* and *Rabi* were 42.86% and 57.14% respectively.

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