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Ground Water Resources Scenario, Its Mining and Crop Planning In Chhattisgarh State of India

R. B. Singandhupe[1]* & R. R. Sethi [2]
[1]ICAR- Central Institute for Cotton Research, Nagpur 440010, Maharashtra India
[2]ICAR-Indian Institute of Water Management, Bhubaneswar -751023 Odisha, India

***Abstract**: The groundwater resources of Chhattisgarh are quite high but its exploitation is only 20.43%, which is very low as compared to other states of India. Within districts, spatial variation on ground water use is there and the coefficient of variation is as high as 106.2 %. In agriculture sector groundwater use is considerably low and needs adequate ground water structures for exploitation. In all districts, annual rainfall is very high but its distribution is erratic as 87-91% of annual rainfall is received during rainy season. The computed rainfall recharged study by various methods reveals that 14.35 to 23.4 % of annual rainfall is recharged and contributed to groundwater. This recharged rainwater of 3.69 million ha-m (computed based on geographical area of each district) can irrigate 2.26 million ha area considering annual ETo of 1.646 m. This state is cereal-dominated crops and consume maximum share of water with less water productivity. Hence pulses and oilseeds crops may be introduced on large scale. During kharif season total ETo demand of all crops was 2.078 million ha-m and during rabi/summer season 0.425 million ha-m. This demand has been estimated based on ET crops and area covered by each crop. So to harvest potential crop yield during both the season, recharged annual rainwater is not sufficient to cope up the demand of crops and hence abstraction of ground water through dug well, shallow tube well and deep tube well and in-situ rain water harvest technology is highly essential to improve crop yield economic return of the farmers.*

***Key words**: Reference evapotranspiration, Groundwater recharge, Crop planning.*

1. INTRODUCTION

In India groundwater has been used for irrigation, domestic and industries since time immemorial. Groundwater is an important source of irrigation and caters more than 45% of the total irrigation in India. Groundwater resources in India is 433.02 billion cubic meter (bcm), however only 58 % is utilized in agriculture, domestic and industrial sector. In agriculture sector 49.1 % of the total ground water resources are utilized but distribution of utilization varies within block of the same district (Anonymous 2003-04). The long term observations (1981-2000) on ground water table fluctuations in India by Central Ground Water Board, New Delhi through countrywide network of 15000 stations have shown declining water table depth by 4 meter(20 cm/day) in approximately 220 blocks of 15 states. The number of dark area (85-100 % exploitation) and over exploited area (ground water exploitation > 100%) is more in the state of Punjab, Haryana, Uttar Pradesh , Rajsthan, Gujarat and Tamil Nadu. On an average, the ground water development of Punjab is 145 %, Haryana 125 % and Delhi 170%. In western states of India the ground water development ranges from 45 % to 125 %. In southern states the development ranges from 27 % to 85 %. But in eastern region of India, the ground water exploitation is quite low and it ranges from 0.05 % to 42 % (CGWB 2004). The large variations on ground water utilization in eastern region of India is primarily due to more rainfall during main crop season (rainy season) which is quite high than crop water demand and the crop does not requires any irrigation except during long dry spell. But in other regions, the rainfall is lower than crop water demand except in coastal belt of western and southern states where rainfall is quite high. The reference evapotranspiration of nineteen-agro ecological region of India varies from 800-1900 mm. The annual rainfall ranged as low as less than 150 mm in cold arid climate of Himalaya ranges to as high as 1600- 2000 mm in hot per humid region of Andaman and Nicobar Island (Sehgal *et. al.,* 1992).

The Chhattisgarh state of India has been carved from Madhya Pradesh in November 2000 and has very good potential of natural resources for its overall development. Groundwater is one of the important components of irrigation sources for growing crops throughout the year and improve livelihood of the poor farmers who are migrating to neighbor states for their survival. The groundwater resources in state of Chhattisgarh is quite sufficient, however the development is very much limited. If these resources are used during rabi and summer season then farmer may earn good return from their farm. The total ground water resources of states are 14.83 billion cubic meter and annual draft for irrigation, domestic and industries are 2.80 bcm out of which annual draft in irrigation sector is 2.31 bcm. Rest of the ground water resources (12.03 bcm) is untapped due to several constraints. One of the major constraints is rural electrification at farm site and number of developed ground water structure (shallow tube wells, bore well and open well). As per minor irrigation census report of Government of India 2000-01, the ground water structure viz., the dug well in this state is 2.05lakh, shallow tube wells 0.77 lakh and deep tube wells 0.0052 lakh in numbers. The number of electrified villages in this state is 91.66 % out of 18790 villages but electrical networking at farm level is not adequate and hence the ground water use in this state is very low and most of the developed structure remains defunct due to lack of power supply. The electrical consumption in agriculture sector is only 13.01 % out of total 8050.58 Giga Watt-hour (Anonymous 20006). Such type of state scenario lead to very poor irrigation intensity as only 20.3 % of the total area of principal crop is under irrigation.

Rainfall is the principal source of recharge to the groundwater body. Besides rainfall, canals, streams, ponds, springs etc also plays an important role in improving groundwater level. The annual groundwater recharge is the sum total of monsoon recharge and non-monsoon recharge. Geographical area, infiltration index and specific yields are the governing parameters to determine the availability of groundwater in an aquifer (Karanth, 1990). Chhattisgarh fall under subtropical climate characterized by extreme summer hot and moderate winter ecosystem in eleven and twelve agro ecological region of India and receives an average annual rainfall of about 1400 mm in 73 rainy days (ranging from 5 years to 70 years). Out of this, about 87 to 91 % is received during June-September and rest amount during both winter and summer seasons. The number of rainy days comes to 60 to 90 in different districts and coefficient of variation is 18 to 37.8 %. Flood and drought is also a common phenomenon in this region and groundwater use can reduces such aberrant events. The severe drought with rainfall deficiency of -37.2% in 1979, -35.2 % in 1941 over normal rainfall was noticed. With respect to floods, it was severe and largest flood interval of 33 years was recorded during 1961 to 1994, there was no flood during consecutive two years in any occasions.

Keeping this in view, present study was carried out to assess the availability of groundwater for irrigation use so that cropped area could be increased specially during dry periods without any adverse effect on groundwater depletion. In this paper the district-wise cropped area for the year 2003-04 and ET requirement of different crops has been computed and assessment has been made for future planning.

2.MATERIAL AND METHODS

This state has been carved out of India s' one of the largest state i.e Madhya Pradesh on November, 2000. It is extended from 80 ^{0} 15'N to 84^{0} 24' N latitude and from 17^{0} 47' to 24^{0} 6' E longitude in Central part of India(Photo Image 1). To make available water resources of the state for irrigation to different crop in effective ways, the assessment of block-wise groundwater resources potential has been carried out up to 31.3.2004 by the Central Ground Water Board North Central Chhattisgarh Region, Raipur (Anonymous 2006) as per the Groundwater Estimation Committee Norm 1997, Ministry of Water Resources, Govt. of India. Based on groundwater development, the statistical measures like standard deviation, coefficient of variation were estimated to assess the water extract variability within districts.

2.1 Estimation of crop water requirements

The district- wise monthly evaporative demand was calculated as per the globally accepted method of FAO 56 - Penman Monteith (Allen et al, 1998). All the aerodynamic and radiation terms and the additional physical factors that is surface resistance (70 s m^{-1}, crop height 0.12 m, and albedo 0.23) was considered for calculating monthly ETo rate. The following Penman Monteith equation was used for computing ETo.

Where,

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma\ (1 + 0.34 U_2)}$$

ET_0 = reference evapotranspiration, mm/day
Δ = slope of vapour pressure curve (kPa /^{0} C)
R_n = net radiation (MJ/m^2/day)
G = soil heat flux density (MJ/m^2/day)
γ = psychrometric constant (0.0671 kPa /^{0} C)
T = mean daily temperature at 2 m height
U_2 = wind speed at 2 m height (m/s)
e_s = saturation vapour pressure (kPa)
e_a = actual vapour pressure(kPa)
e_s-e_a = saturation vapour pressure deficit (kPa).

The monthly reference ETo was calculated by using software of World Water and Climate Atlas of International Water Management Institute, Sri Lanka. Then considering the major crop-growing season, reference ETo was categorized as June-October, November to March and Aril- May to assess crop ET demand. This assessment scenario gives us an idea about total water requirement of crops (excluding the water required in application loss, conveyance loss, special needs) to be extracted from ground water. After considering date of sowing / planting and harvest, the crop coefficient value was taken from FAO 56 Irrigation and Drainage paper and actual crop ET was computed. Then total ET crop demand was computed by multiplying with area (in ha) covered by each crop.

2.2 Estimation of groundwater recharge

Groundwater recharge is a key component in a hydrologic system. Major factors that affect the ground water recharge are climatic, hydrological and geomorphologic like topography, soil and vegetation. Common methods for estimating ground water recharge are empirical formulae (rainfall analysis), water budget, water table fluctuation, and soil moisture balance technique. These methods produce estimates over various time and space scales and encompass a wide range of complexity and expense. Different methods were followed on estimation of groundwater recharge (Simmers 1988,1997; Lerner et. al. 1990; and Scanlon et. al. 2002). But it is extremely difficult to assess the accuracy of any method. For this reason, it is highly beneficial to apply multiple methods of estimation and hope for some consistency in results-even though consistency, by itself, should not be taken as an indication of accuracy (Healy and Cook, 2002). Based on the studies undertaken by different scientists and organizations regarding correlation of ground water level fluctuation and rainfall, some empirical relationships have been developed for computation of natural recharge to ground water from rainfall. Different approach to estimate natural groundwater recharge in India was documented by (Kumar, 1977).

In the present study, annual rainfall data of 15 years (1993 to 2004) was collected. As per Chaturvedi, 1973, recharge was calculated (when rainfall exceeds 40cm) as,

$R = 1.35(P-14)^{0.5}$----------------------------(1)

Where, R is net recharge due to precipitation during the year in inches and P is annual precipitation.

As per Amritsar formula, $R = 2.5(P-0.6)^{0.5}$------ (2)

Where, recharge (R) & precipitation (P) both measured in inches.

As per Krishna Rao (1970) ground water recharge in limited climatologically homogeneous areas can be defined as

$R = K (P-X)$--- ---------(3)

Relation used for different parts of country for areas with P above 2000 mm is

$R= 0.35(P-600)$ -- ------------------------------(4)

Where, R & P are expressed in millimeters.

2.3 General Crop scenario of Chhattisgarh

Paddy is dominated crop of this state. Out of 89.60-lakh ha gross cropped area, 44.5 lakh ha (50 % area) is in paddy, 22% in pulses, 9% in oilseeds, 7 % in vegetables, 5% other cereals and rest area in sugarcane, fibre crops, spices. In case of paddy crop, 3.14 lakh ha area is in rabi /summer season. Since this crop is being grown under semi-aquatic condition with canal water, shallow tube well and deep tube well water, requires highest amount of irrigation water for its growth. So based on exiting cropping pattern, as and the areas occupied by each crop, suggestion is made to improve cropping pattern by high value crops with groundwater use and improve overall income of the farmers.

3. RESULTS AND DISCUSSION

3.1 District-wise Ground Water Development

Chattisgarh is mainly dominating by semi consolidated aquifer (60-65% area) followed by 20-25% consolidated aquifer and 3-5% unconsolidated formations. (CGWB, 2006). Out of 146 blocks, 16 blocks (5.5%) have reached ground water development more than 70%. Rests 106 blocks have ground water development within 30% (Table 1). Among other districts of Chattisgarh, lowest ground water development has occurred in Datewara (2.36%). Raipur district has also poor ground water development (21.4%). Durg district has maximum ground water development of 53.99% followed by Dhamtari (36.75 %). The block -wise ground water development in state of Chhattisgarh reveals substantial variations ranging from 28.86 % in Dhamatari district to 106. 23 % in Surguja district. Durg district has good potential of growing crops throughout the year. Similarly the industries, which are located in Durg city, also use extensive groundwater. In Baster region (Datewara, Kanker, Jagadalpur district) due to low discharge rate (< 3 lps) and dug well problem in lean period also, the ground water utilization is very low (Table 2). Considering the importance of ground water for future use in irrigation sector, maximum amount of ground water has been allotted (Table 1) for these districts, as the cropped area in these districts is lower than remaining districts.

3.2 Ground water Structures and irrigation potential created

The irrigation potential created under open wells, shallow tube wells and deep tube wells up to 2000-01 is 5, 21,617 ha but actual irrigation potential utilized is only 45.1%. Rest area remained un-irrigated though good amount of facility was created in different sections of ground water structures. More irrigation facility was created in open well section, as actual irrigated area through open well was quite high than shallow tube wells and deep tube wells. Out of total irrigated area of 2,35, 204 ha, kharif irrigated area was 1,31,171 ha which was 36.8 % more than rabi irrigated area(Anonymous,2000-01). Hence there is tremendous scope to cover more area under irrigation during kharif season itself as good amount of annual rainfall (87-91%) is received during kharif itself. With respect to distribution of area irrigated under three sources of ground water structures, total dug well irrigated area is 55, 037 ha, shallow tube well irrigated area is 1,67,579 ha and deep tube well irrigated area is 12,589 ha. From this statistical data it is inferred that shallow tube well is quite effective for ground water extraction and the farmers who are having 2-10 ha area for irrigation can afford this type of groundwater structures. But the electrical networking in rural area is very important though, out of 76, 862 shallow tube well which are available, 75, 997 shallow tube wells are already working on electrical pump and rest 865 shallow tube wells are functioning with diesel operated pump. The electrical consumption in agriculture sector is only 12.79 % of the total consumption of 5300 million kwh .It further needs to improve electric consumption by enhancing more number of open dug wells, shallow tube wells and deep tube wells in this state.

Total recharge to groundwater includes several components like seepage from canals, return flow from surface water irrigation, return flow from ground water irrigation, seepage from tanks and ponds etc. Among other factors rainfall is the major source of recharge to the aquifer. In Chhattisgarh, recharge from rainfall is in the order of 1.3 million ha-m whereas that from other sources is 0.16 million ha-m. Comparisons of recharge from rainfall and recharge from sources other than rainfall (estimated by CGWB, Raipur) showed that in most of the districts, the later accounts for less than 20% of the total recharge. However, in the districts like Bilaspur, Dhamtari, Durg and Janjgir-Champa, recharge from sources other than rainfall is as high as 40% of the total annual recharge. This is due to the fact that these districts practice intensive irrigation from surface water as well as groundwater resources. Canal network in the above districts is also comparatively large. Due to the above reasons seepage from canal and return flow from irrigation becomes substantial in the above districts. Of the various sources other than rainfall, return flow from groundwater irrigation accounts for 56%, return flow from surface water irrigation accounts for 32%, recharge from tanks and ponds accounts for 10% and seepage from canals accounts for 2%.

3.3 Estimation of groundwater recharge by empirical methods

Based on the recharge coefficient values, empirical formulas have been derived for different climatic conditions of India (Kumar, 1994). These empirical methods have been used to estimate the recharge from annual rainfall of Chattisgarh (table-3). Based on these methods, the average annual recharge to the aquifer varied from 12.45 cm to 34.18 cm. The percentage rainfall contributed to ground water recharge was ranged from 14.35% in Dantewada to 23.40% in Raipur out of the annual rainfall received in different districts. If proper crop and cropping pattern are followed during rabi season then the recharged rain water could be utilized effectively as most of pulses and oilseed crops requires three to four supplemental irrigations to harvest good crop yield except in Datewada, farmers can irrigate twice to their field crops with water resistant crops. Considering the annual ETo demand of 1515.8mm to 1789.9 mm in different districts, the total recharged rain water ranged from 0.106 million ha-m to 0.516 million ha-m with total amount of 3.690 million ha- m. With this total recharged rain water and annual ETo demand the district-wise area to be irrigated ranged from 0.060 million ha to 0.340 million ha with total area of 2.260 million ha. To bring such huge area under irrigation, the state government has to implement appropriate rainwater harvest technology and develop ground water structures considering location specific problems.

3.4 Water requirement of crops

As per Penman Monteith equation (FAO- 56 Irrigation and Drainage paper), reference ET was estimated. Crop evapotranspiration rate was derived by considering the crop coefficient (kc) value of different crops.

3.4.1 Kharif Season

In all district of Chhattisgarh, crop water requirement was maximum in case of rice crop which is dominated in this state followed by pigeanpea . Remaining kharif crops required less amount of water (Table 4). The total consumption of water for all kharif season crops was 2.078 million ha-m . Out of this huge amount of water consumption, maximum share was diverted towards rice (1.31 million ha-m) followed by pigeaonpea (0.076 million ha-m). In rice the average crop yield for the year 2003-04 was 1654 kg/ha, which ranged between 1233-2914 kg/ha in different districts. The average yield of pigeanpea was 1210 kg/ha with range of 950-1490 kg/.ha. The water productivity (kg yield / ET crop) in rice was 0.316 kg/m^3 and in pigeanpea 0.213 kg/m3 ET. So it is highly essential to make suitable crop like groundnut which gives more return though WP is less (0.207kg/m^3 ET) as the market rate is high. This crop may be taken on large area wherever it is feasible. Pigeanpea has also covered large area but this crop being a long duration, needs more water in later crop growth period. If good amount of rainfall is received in later crop growth period (up to October, when the crop is in early flowering to pod development stages) and is recharged in to soil profile then the recharged rainwater can save the crop from moisture stress. Remaining long duration kharif crop can also be irrigated with recharged rain water and also with harvested rainwater in small farm pond , good crop yield can be obtained by providing supplemental irrigation if long dry spell occurs. Further it is suggested that since total area under cereal crop is 3.79 million ha and under oilseed 0.309 million ha and pulse crops 0.46 million ha, large area can be diverted under oilseeds and pulses as these crops are more remunerative than cereals.

3.4.2 Rabi Season

Total water requirement of different rabi crops was 0.425 million ha-m. During rabi season, wheat and chickpea are dominated crops and consumed maximum share of water (0.69 and 1.24 million ha.m, respectively) followed by summer paddy .In case of summer paddy the water productivity was very high (0.401 kg/m^3 ET). Still this crop should not be advocated in this season as crop water demand is quite high and requires more water as compared to other cereal crops like maize which is quite good with respect to yield (2619 kg/ha). The water productivity of maize is very high (0.569 kg/m^3 ET). Hence rice cropped area may be reduced and area of pulses and oilseed crops may be increased as both crops are also equally important and water productivity is comparatively higher than paddy crop. The total cereal crop area was 0.112 million ha and pulse and oilseed crop area was 0.721 and 0.138 million ha, respectively.

3.5 Water Quality

About 331 ground water samples were analyzed by CGWB, Raipur in 2004. In general the groundwater is alkaline to near neutral in nature. The electrical conductivity is 56 micro-siemen /cm to 2650 microsiemen/cm. In some places like Durg, Raipur and Dantewada districts the EC were high. But in most of the places EC were within 1000 microsiemen/cm. Slightly higher concentration of iron was recorded in Dantewada district. Calcium varied from 4 to 340 mg/l with average of 50.61 mg/l. Magnesium was in the range of 2.4 to 80.32 mg/l.

Sodium Adsorption Ratio (SAR)= $\frac{Na}{\sqrt{(Ca+Mg)/2}}$ in ground water sample varied from 0.12 to 4.6 mg/l with concentration of sodium in the range of 3 to 241 mg/l. With respect to soluble iron, 93.4% samples had iron concentration within permissible limit (up to 0.3mg/l), 2.8% samples within 0.3 to 1mg/l and 3.8% samples were beyond l mg/l (CGWB 2006). Overall the available groundwater is not harmful in agriculture if the farmers want to use for growing field crops.

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3.6 Rainfall and ETo Scenario

The annual reference ETo and the long-term annual rainfall data revealed that in each district, the deficit of water over the rainfall is 356.5 mm. This annual deficit water can be fulfilled from the groundwater and three crops can be grown in a year with short duration rice varieties during rainy season (June-September), followed by rabi vegetables, oilseed and pulse crops during October to February and then short duration pulse crop in March to May. If three crops are not possible , then cultivation of two crops is quite possible in most of the districts. As far as district wise annual crop water demand and rainfall is concerned, the annual water deficit against the rainfall ranges from 94.8mm in Jaspur to 678.9 mm in Durg district. When water demand and supply scenario of each season is visualized, the rainfall (not given here) is more than double over the ET demand as 87-91% of the annual rainfall in different places is received during rainy season and very little amount i.e. 9-13% is received during rest of the year. This excess rainwater can be effectively recharged in to groundwater or stored in small tank and used during winter and summer seasons for crop production. In state of Orissa (adjoining state of Chhattisgarh), Srivastava et al., (2004) have developed runoff-recycling pond (cap. 1468m^3, water area 900m^2) to store rainwater and use during non-monsoon period for humid plateau region of eastern India. The catchments area was 3 ha and command area was 0.95 ha. They reported that on an average of three years (1998-2001), 2574m^3 water was stored and simultaneously used for kharif and rabi crops (rice, mustard, groundnut). Thus water yield/ storage capacity ratio was quite satisfactory (1.75). On embankment of pond, plantation crop like papaya and banana were grown and in pond fish were reared to maximize net return from the developed systems. On small watershed basis the state government can make in-situ rainwater harvesting structures on large scale to harness such precious natural resources and improve social economic status of the farmers. Sahu et al., (2003) developed small farmers reservoir (SFR) technology for Chhattisgarh to mitigate negative aspect of large scale reservoir in which there is uncertainty of water supply to the tail reach farmers, problems of water logging and salinity, long gestation period in construction of the system and high investment per unit of irrigation potential developed. They have reported that due to development of SFR, and application of supplemental irrigation ranged from one-four irrigations during winter season. There was 14.3 to 87.1% increase in yield of various crops grown with harvested rainwater over rainfed crop. Similar results were reported by Rathore et al., (1996) in which 750m^3 capacity (0.09 ha area) farm pond water was made with micro catchment area of 0.66 ha and command area of 0.33 ha. They took rice, soybean, peanut and pigeanpea during rainy season and chickpea and mustard during rabi season. With this farm pond harvested rainwater, the crop yield was improved considerably. The benefit cost ratio was maximum (2.81) under soybean-chickpea cropping pattern. Several workers (Rathore and Pal, 1994; Pal et al., 1993) worked on conservation of excess rainfall and changes on moisture status after harvest of rainy season crops for growing rabi crops in developed farm pond which can help for growing rabi crops with supplemental irrigations. They found very good response with respect to crop performance.

CONCLUSION

There is substantial variation on groundwater use within block due to several socio-economic as well as geological constraints.

In all district of Chhattisgarh, the evaporative demand (ETo) is greater than water supply through rain. Under such excess water supply condition, conservation of rainwater through various water recharge techniques is necessary. When season wise crop evaporative demand and availability of rainwater as supply is concerned, in most of the districts, the availability of water during wet season (June to October) through rainwater is quite high than the crop evaporative demand.

This excess water can be recharged in to the groundwater by various techniques wherever the groundwater recharge technique is feasible. This recharged water can be reutilized for crop growth during dry season that is rabi and summer and the cropping intensity and irrigated area can be increased as there is substantial deficit of water exists in these seasons.

In existing rice based cropping system, high value and more remunerative crops can be introduced, and then the income of the farmers can be further enhanced.

The irrigation through canal network is limited due to limited number of major, medium and minor irrigation projects. Further development of new irrigation projects also needs a lot of investments and more time to complete the project work. Under such condition, it is essential to make an assessment of water resources available from all sources to make efficient utilization of available water in crop production.

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Table 1 Statistical analysis of ground water development (%) of Chhattisgarh

District Name	No of Blocks	Ground water development (mean of blocks)	Minimum	Maximum	Standard deviation	CV %
Raipur (Labhandi)	15	21.4	9.71	36.85	8.63	40.89
Mahasamund	5	23.5	18.5	35.56	6.78	28.86
Dhamtari	4	40.83	25.64	79.46	26.13	64.06
Durg	12	65.41	36.11	95.3	23.52	35.95
Rajnandgaon	9	30.41	16.69	61.79	11.51	37.76
Kawardha	4	34.49	19.68	63.34	19.33	56.05
Bilaspur	9	34.19	14.41	70.59	20.27	68.07
Janjgir	9	32.2	13.75	68.93	22.32	69.3
Korba	5	13.65	6.97	29.39	8.81	64.56
Raigarh	9	25.18	8.29	64.96	21.50	85.39
Surguja	19	20.05	9.39	72.01	21.29	106.23
Jashpur	8	18.63	8.3	37.83	9.91	53.19
Koriya	5	16.85	10.77	37.49	10.63	63.09
Baster	14	6.42	1.75	16.1	4.17	65.0
Dantewara	11	2.36	1.24	8.03	1.98	83.78
Kanker	7	9.22	3.92	25.48	9.35	101.38

Table 2 - Ground water resources status

District	Available ground water resources (ha-m)	Ground water draft for irrigation use (ha-m) in 31.03.2004	Balance ground water for future irrigation excluding allocation for industries, domestic use for 2025	Ground water development (%)
Bastar(Jagdalpur)	181706	8665	168818	6.42
Bilaspur	66505	18128	40716	34.19
Dantewada	175503	2490	170748	2.35
Dhamtari	37182	13540	21218	40.83
Durg	77658	44319	24213	65.40
Jangirchampa	46925	12061	30470	32.20
Jashpur	87401	14592	70579	18.63
Kanker	90987	6871	81799	9.22
Kawardha	26310	7741	16793	34.49
Korba	46554	3992	38974	13.65
Koriya	31220	3909	25412	16.84
Mahasamund	78070	16415	59311	23.50
Raigarh	63919	13165	46529	15.18
Raipur	138949	22329	106443	21.10
Rajnandgaon	65138	16851	44074	30.41
Suruguja	154455	26326	120827	20.05
Total /mean	1368482	231394	1066924	20.43

Table- 3 Estimation of natural recharge based on annual rainfall of Chhattisgarh

District 1	Mean rainfall cm(1994-2003)	Recharge, cm (Chaturvedi's formula)	Recharge, cm (Amritsar formula)	Recharge, cm (Krishna Rao formula)	Average recharge, cm	Mean recharge as % of rainfall	Total geographical area (M.ha)	Total recharge water through rainfall (M-ha-m)	Expected area to be irrigated as per annual ETo demand (M ha)
Raipur	98.29	16.53	38.78	13.70	23.00	23.40	1.345	0.309	0.182
Mahasamund	107.89	17.68	40.43	16.76	24.96	23.13	0.496	0.124	0.072
Dhamtari	111.32	17.43	40.74	19.42	25.86	23.23	0.408	0.106	0.060
Durg	112.84	18.49	41.81	18.49	26.27	23.28	0.870	0.229	0.128
Rajnandgaon	110.19	18.33	41.18	17.57	25.69	23.32	0.802	0.206	0.115
Kawardha	113.50	18.54	41.98	18.72	26.41	23.27	0.435	0.115	0.076
Bilaspur	112.80	18.37	41.71	18.48	26.19	23.22	0.857	0.224	0.131
Janjgir	115.64	18.92	42.34	19.47	26.91	23.27	0.715	0.192	0.113
Korba	150.68	22.47	48.33	31.74	34.18	22.68	0.447	0.153	0.100
Raigarh	125.31	19.96	44.12	22.86	28.98	23.13	0.653	0.189	0.124
Surguja	143.44	21.66	47.24	29.21	32.70	22.80	1.603	0.524	0.340
Jashpur	141.61	21.68	46.99	28.56	32.41	22.89	0.646	0.209	0.138
Koriya	137.22	21.30	46.28	27.03	31.53	22.98	0.598	0.188	0.120
Baster	131.95	20.59	45.26	25.18	30.34	23.00	1.702	0.516	0.323
Dantewara	86.76	13.43	12.45	11.47	12.45	14.35	1.561	0.194	0.117
Kanker	143.91	21.74	47.14	29.37	32.75	22.76	0.643	0.211	0.121

Rainfall and recharge was based on the data (1994-2003)

Table- 4 (a) Seasonal evapotranspiration and total ET requirement of different kharif season crops

District	Paddy		Sorghum		Maize		Millet		Peanut	
	ET crop ,mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)	ET crop ,mm	Total ET demand (ha-m)	ETcrop , mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)
Bilaspur	521	147351	554	66	554	3325	489	1954	534	4810
Durg	526	195030	559	190	559	2473	492	3841	539	1779
Kabirdham	508	39874	540	97	540	2084	476	11897	521	505
Dhamtari	515	65405	547	32	547	257	547	186	526	21
Kankar	508	74680	508	483	539	4413	539	4003	519	10
Jagdalpur	591	149761	591	591	591	16488	591	14543	591	1234
Dantewada	607	89160	607	576	607	972	607	17008	607	36
Surguja	516	150907	546	782	547	22583	486	8480	529	6506
Korea	500	33165	531	579	531	5977	470	2223	513	180
Jashpur	488	75127	517	31	517	5568	459	2505	499	4536
Korba	476	48234	505	151	505	4191	447	492	488	731
Raigarh	517	113190	546	33	546	918	487	209	528	4331
Jangirchamp	518	123950	550	No crop	550	473	487	No crop	531	790.63
Mahasamund	516	115375	547	49	510	398	427	38	528	5283
Raipur	559	269469	552	83	552	2462	487	1266	433	951
Total	524	1305834	547	249	546	72582	499	68645	526	31704

Table 4 (b) Seasonal evapotranspiration and total ET requirement of different kharif season crops

District	Sesamum		Soybean		Pigeaonpea		Moong		Black gram		Horse gram		Total ET of kharif season (M-ha-m)
	ETcrop ,mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)	ET crop ,mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)	
Bilaspur	489	1466	534	2138	597	6332	330	893	409	2541	554	1330	0.172
Durg	492	3349	539	13857	604	1335	411	1523	411	4544	559	1689	0.242
Kabirdham	476	914	520	2083	578	6672	400	100	403	2604	540	70	0.067
Dhamtari	483	484	526	No crop	591	951	524	93	524	855	546	66	0.068
Kankar	477	1150	519	26	582	1886	517	1669	517	3900	539	4563	0.097
Jagdalpur	591	703	591	591	591	2116	591	154	591	1407	591	9695	0.197
Dantewada	607	2281	607	152	607	5502	607	243	607	3573	607	4301	0.124
Surguja	485	3328	529	16	589	5351	413	318	413	8477	547	6695	0.213
Korea	469	1645	513	92	571	5183	397	63	397	2778	531	2045	0.054
Jashpur	459	495	499	20	555	5034	389	323	389	1274	517	764	0.096
Korba	447	1552	488	88	543	4928	378	374	378	2960	505	2196	0.066
Raigarh	489	2201	528	No crop	528	4789	414	118	414	1081	546	2813	0.130
Janjgirchampa	487	1548	530	90	531	4812	401	192	410	1208	551	16	0.133
Mahasamund	485	887	527	748	528	4787	407	186	407	5735	547	38	0.134
Raipur	487	3189	433	No crop	533	4832	409	613	409	2514	555	165	0.286
State Total	495	25192	526	19901	568	76526	439	6862	445	45451	549	36446	2.078

Table 5 (a): Seasonal evapotranspiration and total ET requirement of different rabi season crops

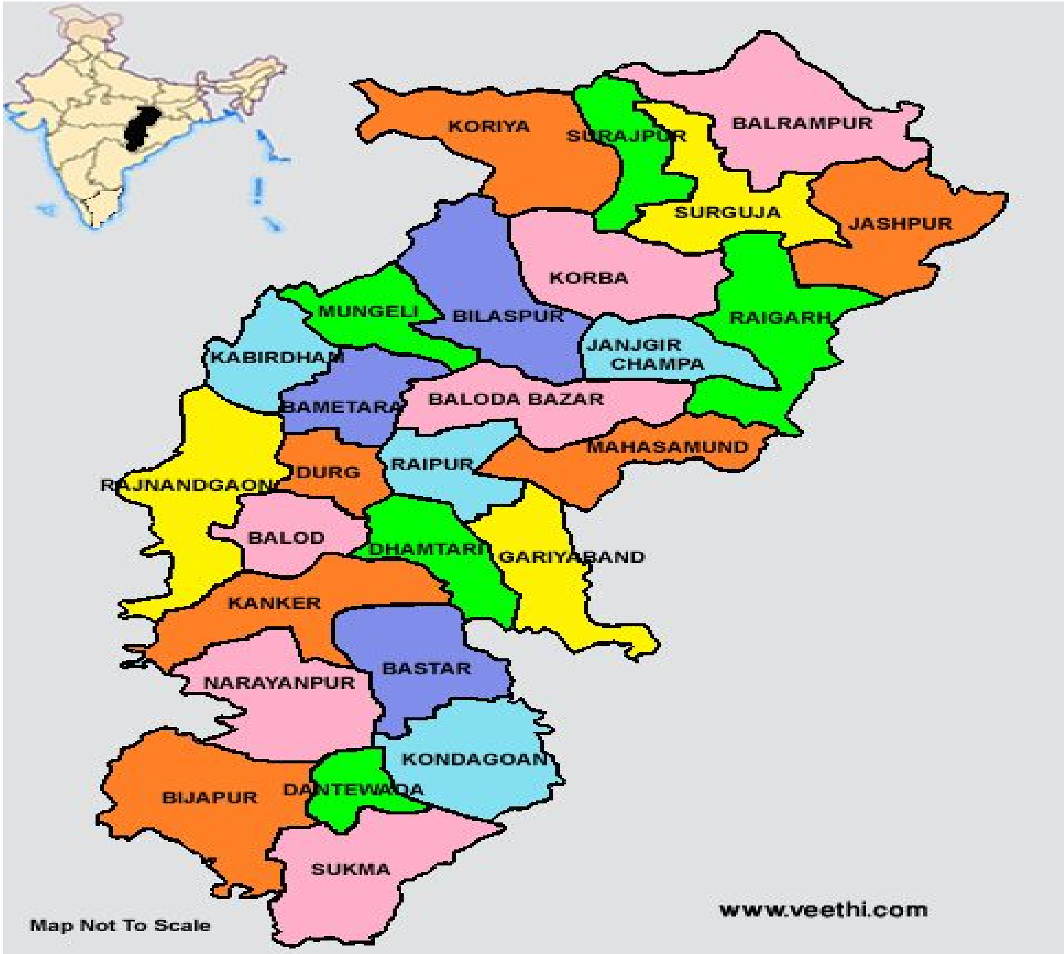
District	Wheat		Maize		Summer paddy		Chickpea		Pea	
	ETcrop ,mm	Total ET demand (ha-m)	ETcrop ,mm	ET crop (ha-m)	ET crop ,mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)
Bilaspur	511	11020	466	23	692	1730	438	26622	449	1250
Durg	553	14901	503	179	736	1347	434	41948	487	1187
Kabirdham	456	2715	452	No. crop	540	No crop	436	29023	436	196
Dhamtari	559	3070	510	92	735	18569	493	9206	493	2261
Kankar	555	994	502	2261	731	2193	488	1221	489	1803
Bastar	594	1283	594	1283	705	705	594	891	806	677
Dantewada	549	104	499	409	713	585	485	233	485	58
Surguja	421	13448	381	313	581	468	368	3978	368	188
Korea	454	4765	411	8	506	No crop	397	849	397	635
Jashpur	436	1099	395	36	593	65	386	889	382	458
Korba	450	922	408	8	609	1084	394	327	394	197
Raigarh	418	1518	378	71	578	2374	364	638	364	1184
Janjgirchampa	510	4547	463	42	689	2143	446	465	447	679
Mahasamund	529	1395	480	19	708	7514	463	487	464	663
Raipur	518	7307	459	22	684	6591	443	7453	443	2474
StateTotal	501	69088	460	4766	653	45368	415	124230	460	13910

Table5 (b) **: Seasonal evapotranspiration and total ET requirement of different rabi season crops**

District	Horse gram		Lathyrus		Lentil		Total crop ET of rabi season (milliomn ha-m)
	ETcrop ,mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)	ETcrop ,mm	Total ET demand (ha-m)	
Bilaspur		No crop		No crop	392	627	0.0413
Durg	350	4132	350	47841	426	4022	0.1156
Kabirdham		No crop	310	8227	381	557	0.0480
Dhamtari	355	20026	355	10658	432	1301	0.0652
Kankar	351	1299	351	1151	428	129	0.0111
Bastar	416	220	416	383	594	59	0.0055
Dantewada	351	6073	351	3	439	13	0.0075
Surguja		No crop	256	310	329	926	0.0196
Korea		No crop	280	280	357	214	0.0068
Jashpur	269	81	269	242	393	209	0.0031
Korba		No crop	280	1666	355	81	0.0043
Raigarh	253	848	253	1770	326	114	0.0085
Janjgirchampa		No crop	317	14239	402	15	0.0022
Mahasamund	329	319	329	3901	418	17	0.0143
Raipur	314	816	314	26382	399	1573	0.0526
Mean /Total	335	33814	317	117053	460	9857	0.4253

Table-6 Water supply and demand scenario of Chhattisgarh State

District	ETo (mm)				Normal annual rainfall (mm)
	June-October	November-March	April -May	Total ETo (mm)	
Raipur (Labhandi)	660.2	552.6	484.5	1697.3	1164.9
Mahasamund	652.5	577.0	487.2	1716.6	1339.3
Dhamtari	653.3	610.3	490.6	1754.2	1204.6
Durg	671.1	603.1	507.7	1782.0	1103.1
Rajnandgaon	675.8	606.6	507.5	1789.9	1200.5
Kawardha	612.8	476.8	426.2	1515.8	1213.4
Bilaspur	663.0	560.4	491.9	1715.3	1152.7
Janjgirchampa	655.5	557.0	486.9	1699.4	1268.4
Korba	600.8	491.6	429.2	1521.6	1283.1
Raigarh	645.4	458.5	426.1	1530.0	1348.7
Surguja	647.7	462.1	432.6	1542.3	1382.7
Jashpur	612.8	476.8	426.2	1515.8	1421.0
Koriya	632.9	496.4	446.6	1575.9	1305.9
Baster	582.7	590.9	423.1	1596.7	1348.4
Dantewara	606.6	599.2	448.9	1654.7	1381.5
Kanker	643.6	605.4	487.2	1736.1	1521.2
Mean	638.5	545.3	462.6	1646.5	1290.0



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