Original Research Article

Estimation of Ground Water Recharge in the Command Area of Krishna Central Delta

Abstract

Groundwater recharge is the most important component in all the water balance studiesand in ground water development projects as a part of sustainable groundwater management. Norms set by the Groundwater Resource Estimation Committee, GEC-2015 was used for the estimation of recharge. The study was conducted for the Bandar canal command area constituting the Krishna Central Delta in Andhra Pradesh. Following the norms of GEC-2015, the recharge was estimated for the past decade from 2012-13 to 2021-22 and it was found that recharge rate ranged from 438135.8 ha-m in the year 2015-16 to 1677730 ha-m in the year 2013-14.While computing the gross recharge, recharge attributed by rainfall, canal seepage, irrigation return flow and from the ponds/tanks are considered.Recharge estimated sheds information on replenishment and improved management of coastal aquifers where seawater intrusion is a major problem.

Keywords: Recharge, GEC-2015, Canal Seepage, Rainfall

1. Introduction

In India, groundwater is a primary source of freshwater and used mainly for agriculture and irrigation purposes. Approximately 80% of the population is dependent on groundwater for household and agricultural purposes in India. Recharge to groundwater is the most important component in all the water balance studies. Groundwater resource assessment is of major importance with the increased trend in groundwater draft for various purposes. Recharge can be contributed from various sources and considering all the sources it has to be estimated. Variation in recharge is found to be of more significant in all the hydrologic studies. Ground water reservoir gets recharged from various sources such as rainfall, return flow form the irrigation, seepage from the canal, tanks, inflow from the river etc.

There are many methods in use for estimation of recharge. In the absence of site-specific values, the norms and guidelines developed by the Central Groundwater Board (CGWB) (GEC 1997) of India, based on measurements with similar hydrogeologic units can be used (Kumar and Srinivas 2012). Ground water resource estimation committee (GEC 1997), has given certain recommendations for calculating the recharge, which are further revised in 2015 (GEC-2015) (referred as MoWR, RD&GR, 2017). Sitender and Rajeshwari (2015) attempted to quantify the gap between the availability and draft of Ground water as well as to evaluate the stage of ground water development following the GEC 1997 methodology for Gurgaon District, Haryana. Thomas et al. (2009) estimated the groundwater recharge based on the Groundwater Estimation Committee (GEC) norms for afractured basaltic aquifer in Central India. Krishna Central Delta, the command area of Bandar canal constitutes the coastal area in which sea water intrusion is of major concern. Excess usage of ground water and inadequacy in rainfall resulted in sea water interface. Study of aquifer recharge aids in development of improved management strategies. Hence, it is selected to estimate the recharge for command area of Krishna Central Delta (KCD) for an decade as per the GEC norms.

2. Material and Methods

2.1 Study area: Krishna Central Delta (KCD) which is the part of Krishna Eastern Delta is considered for the estimation of recharge. KCD is the command area under Bandar canal, which is from the left bank of Prakasam Barrage on Krishna river at Vijayawada, Andhra Pradesh, India.Krishna Central Delta covers the command area of Bandar Direct and Krishna Eastern Bank Canals (major canals under Bandar canal) totally constituting ayacut in about eighteen mandals of which two mandals fall under Krishna district and the others in NTR district of Andhra Pradesh, India. The geographical location details are shown in the Fig. 1. The mandals possessing the aayacut under KCD are: Avanigadda, Challapalli, Ghantasala, Guduru, Kankipadu, Koduru, Machilipatnam, Mopidevi, Movva, Nagayalanka, Pamarru, Pamidimukkala, Pedana, Penamaluru, Thotlavalluru, Vijayawada (R), Vijayawada (U) and Vuyyuru.The total area of aayacut mandals under KCD is 2692 sq km.

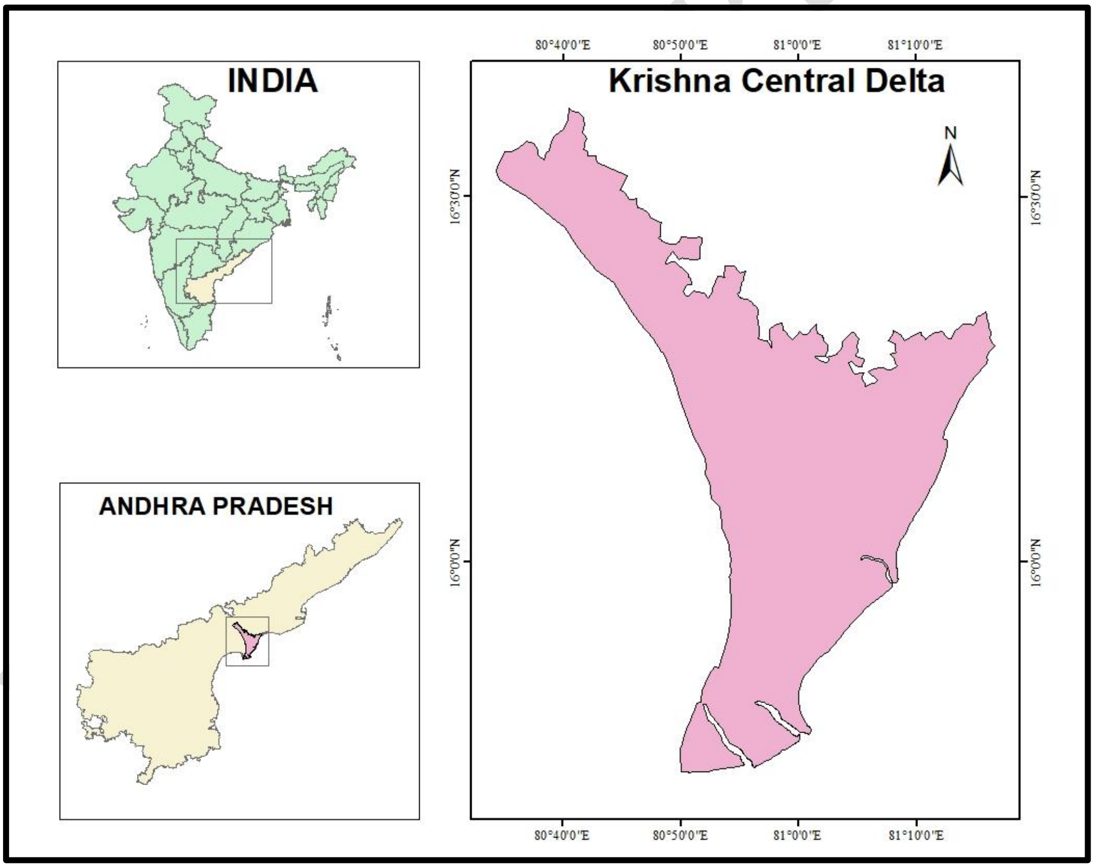

Fig. 1: Location details of Krishna Central Delta

The approach utilized for recharge estimation in this study closely adheres to the methodology suggested by the Ground Water Resource Estimation Committee-1997, widely recognized as GWREC-97 (CGWB, 1997). This methodology has been endorsed by the Government of India as the recommended approach for estimating ground water resources in all states and Union Territories. An attempt has been made to assess the ground water recharge of Krishna Central Delta based on this methodology for the command area ofBandar canal. Utilizing the norms of GEC-2015 the recharge potential in KCD has been considered as the composite of the following components.

i. Recharge from rainfall
ii. Recharge from canal seepage
iii. Recharge from ponds, tanks
iv. Recharge due to return flow from irrigation

The recharge estimation has been carried out for a decade that is from 2012-13 to 2021-2022, for which the required data such as rainfall and canal particulars were collected from the respective departments.

2.2Recharge from Rainfall:

Rainfall contributes major part to Recharge and is the most reliable source for replenishment of ground water resources. Recharge attributed due to rainfall has been computed following the GEC recommendations. The study has been considered for the Kharif and Rabi seasons. The normal annual rainfall for the area of interest has been computed for the period of 1993-2022 utilizing the rainfall data collected from the Directorate of Economics and Statistics Department, Vijayawada and is found to be as 956.88 mm.10% of normal annual rainfall is considered as minimum rainfall threshold. To compute the recharge from the rainfall, the minimum rainfall threshold is deducted from the rainfall of that monsoon season and the balance rainfall is considered for estimation of recharge. For the non monsoon season also the same calculation is followed and if the normal rainfall during the non monsoon season is less than 10% of normal annual rainfall, then the recharge is considered as zero.As the Krishna central delta comprises of coastal alluvium, the rainfall infiltration factor is considered to be 16% of rainfallas per the recommended norms of GEC-2015.

2.3Recharge from canal seepage

Canals continue to be major conveyance systems for delivering water for irrigation in the alluvial plains of India. But the seepage loss from irrigation canals constitutes a substantial percentage of the usable water (Swamee et al., 2000). The study area is mainly the command area of Bandar Canal network. Seepage from this dense canal network adds on a significant amount to the ground water reservoir. Canal seepage depends on the various factors such as canal bed material and its characteristics, slope, flow depth etc.Hydraulic particulars of Bandar Direct and Krishna Eastern Bank canals were obtained from the earlier research studies conducted in the Krishna Central Delta from the Water Resources department. The Hydraulic particulars of all the sections in the two major canals was considered for the calculation of total wetted area of the entire canal network in KCD.Daily Canal release data was collected from Krishna Central Division, Water Resources Department, Vijayawada. From the canal release data, the number of canal running days are calculated for recharge calculation. For the unlined canals in normal soils with some clay content along with sand, recommended canal seepage factor of 17.5 ham/day/million square meters of wetted area is considered as per the norms of the GEC and is used for the estimation of recharge attributed to the ground water reservoir from canal seepage. The seepage attributed to the ground water recharge from the canal seepage is calculated by multiplying the wetted area of canals with seepage factor and the number of canal running days.

2.4Recharge from ponds, tanks

Water spread area of ponds and tanks was interpreted from the Landsat 8 satellite data as there is no availability of dynamic data on tanks. Average of area obtained from the satellite images for the months of May, 2013 and June, 2022are considered depending on the availability of cloud free imagery. Recharge from the tanks is the product of the average water spread area and the seepage factor. Considering the GEC-2015 norms, recharge from tanks may be assumed as the 44 to 60 cm per year over the total water spread area of tanks. Hence the average of 52cm/year is considered. For the seasonal estimation of recharge, 75% of recharge from tanks is considered to be in the monsoon period and the 25% is consideredto be in the non-monsoon period (Gaur, 2001)

2.5Recharge from irrigation return flow:

The portion of irrigation water that infiltrates and contributes to the groundwater table is classified as return flow. The replenishment of groundwater resulting from irrigation water application, whether sourced from surface water or groundwater, plays a substantial role in the overall recharge of the groundwater system. The extent of recharge through field irrigation is contingent on factors such as soil type, crop variety and irrigation methods. This process is site-specific, exhibiting variations from one geographical area to another. From the canal release data collected from Water Resources Department, Vijayawada, monthly canal release in ha-mm was calculated and 60% of release isconsidered to be used for irrigation in command area (Malik and Rajeshwari, 2015). For applied ground water in KCD, mandal wise ground water draft from command area, the Krishna district published reports of CGWB were considered. Then the total amount of surface and ground water irrigation applied is calculated and is multiplied with the recharge factor 0.4, (which is average of recharge factors for paddy and non-paddy under both surface and ground water irrigations) as per the norms of GEC-2015.

3. Results and Discussion

3.1 Recharge from rainfall: The normal annual rainfall of KCD was calculated as 956.88mm. As per the recommendations, 10% of normal annual rainfall i.e., 95.6mm is considered to be the minimum rainfall threshold. While estimating the seasonal recharge, the minimum rainfall threshold is subtracted from the average rainfall of that season and is then multiplied with the 16% rainfall infiltration factor and the final estimates of seasonal recharge are tabulated in Table1. It was found that in the rabi season for the years 2018-19 and 2021-22, the rainfall is less than the minimum threshold and hence the rainfall attributing to recharge is considered as zero for those periods. As the monsoon season receives higher amount of rainfall correspondingly a higher recharge from rainfall is found in Kharif season during the entire study period. Highest amount of recharge that is 170.48 mm is found in the Kharif season of 2012-13 and least 3.55 mm is found in 2013-14 Rabi season.

Table 1: Estimation of Recharge from Rainfall in KCD

Year	Season	Average seasonal rainfall, mm	Seasonal rainfall considering minimum threshold, mm	Rainfall infiltration factor (%)	Recharge from rainfall, mm	Recharge from rainfall, ha-m
2012-13	Kharif	1161.189	1065.509	16	170.48	38788.97
	Rabi	276.3944	180.7144	16	28.91	6577.83
2013-14	Kharif	1158.75	1063.07	16	170.09	38700.24
	Rabi	117.8944	22.21444	16	3.55	807.72
2014-15	Kharif	569.4444	473.7644	16	75.80	17246.62
	Rabi	319.3833	223.7033	16	35.79	8143.23
2015-16	Kharif	648.1278	552.4478	16	88.39	20111.2
	Rabi	408.2667	312.5867	16	50.01	11378.68
2016-17	Kharif	459.7667	364.0867	16	58.25	13253.51
	Rabi	200.0722	104.3922	16	16.70	3799.72
2017-18	Kharif	542.8167	447.1367	16	71.54	16277.35
	Rabi	182.4222	86.74222	16	13.88	3158.08
2018-19	Kharif	548.6667	452.9867	16	72.48	16491.23
	Rabi	52.73889	0	16	0	0
2019-20	Kharif	750.3556	654.6756	16	104.75	23833.56
	Rabi	153.9222	58.24222	16	9.32	2120.56
2020-21	Kharif	1037.261	941.5811	16	150.65	34277.09
	Rabi	179.6889	84.00889	16	13.44	3057.98
2021-22	Kharif	898.55	802.87	16	128.46	29228.25
	Rabi	18.45	0	16	0	0

3.2 Recharge from canal seepage:

From the hydraulic particulars data of all canal sections under Bandar Direct and Krishna Eastern Bank, the total wetter area is found to be as 158.09 million m^2. Utilizing the canal release data collected from the Water resource Department, the total number canal release days in Kharif and Rabi seasons is arrived. In Kharif, for the study period the maximum number of canal running days is 184 and minimum is 92 and for Rabi the maximum number of canal running days is 130 and minimum is in the year 2015-16 with 32 days of canal run. By multiplying the respective canal running days with the wetted area and the seepage factor, the recharge from canal seepage in ha-mm is calculated and is given in Table 2 and Table 3 for Kharif and Rabi seasons respectively.

Table2: Estimation of recharge from canal seepage during the Kharif season

Year	Wetted Area (10^6 m^2)	Canal Running Days Kharif (day)	Seepage Factor (ha-m d^{-1} per 10^6 m^2)	Recharge from the canal seepage (ha-m)
2012-13	158.09	171	17.5	473084.33
2013-14	158.09	151	17.5	417752.83
2014-15	158.09	184	17.5	509049.80
2015-16	158.09	92	17.5	254524.90

2016-17	158.09	169	17.5	467551.18
2017-18	158.09	184	17.5	509049.80
2018-19	158.09	174	17.5	481384.05
2019-20	158.09	172	17.5	475850.90
2020-21	158.09	170	17.5	470317.75
2021-22	158.09	174	17.5	481384.05

Table 3: Estimation of recharge from canal seepage during the Rabi season

Year	**Wetted Area (10^6 m^2)**	**Canal Running Days Rabi (day)**	**Seepage Factor (ha-m d^{-1} per 10^6 m^2)**	**Recharge from the Canal Seepage (ha-m)**
2012-13	158.09	38	17.5	105129.85
2013-14	158.09	113	17.5	312622.98
2014-15	158.09	128	17.5	354121.60
2015-16	158.09	32	17.5	88530.40
2016-17	158.09	56	17.5	154928.20
2017-18	158.09	69	17.5	190893.68
2018-19	158.09	70	17.5	193660.25
2019-20	158.09	121	17.5	334755.58
2020-21	158.09	130	17.5	359654.75
2021-22	158.09	99	17.5	273890.93

It was found that during the Kharif season, an average amount of 453994.96 ha-m is recharged from canal seepage and in Rabi season it is 236818.82 ha-m.The study area investigations concluded that there exists sub surface flow between the KEB canal and the alongside Krishna river and hence the local people also calls this KEB canal as the "Karuvu (Drought)" canal. Due to this a significant percentage of canal release is lost due to seepage.

3.3 Recharge from ponds, tanks

Wetted area calculated for the month of May,2013 using Landsat8 satellite imagery was found to be as 502.92 ha and for the month of June, 2022 it was found to be as 1522.17 ha using the Normalized Difference Water Index index in Arcmap software. For the calculation of recharge from tanks, average wetted area for the months of May and June is considered to be as 891 ha.As per the GEC norms, the recharge factor of 0.52 m/year is considered and the recharge from tanks was calculated for the entire study period and is tabulated below in Table 4. For the entire Krishna Central Delta it was found that the recharge from tanks is 526.52 ha-m/year. Of which, recharge of 394.89 ha-m is considered for monsoon period and 131.63 ha-m is considered to be recharged to aquifers in the non-monsoon period from the tanks/ponds.

Table 4: Estimation of recharge from ponds/tanks in KCD

Year	Average water spread area (ha)	Recharge factor (m/year)	Recharge from tanks (ha-m/year)
2012-13	1012.55	0.52	526.52
2013-14	1012.55	0.52	526.52
2014-15	1012.55	0.52	526.52
2015-16	1012.55	0.52	526.52
2016-17	1012.55	0.52	526.52
2017-18	1012.55	0.52	526.52
2018-19	1012.55	0.52	526.52
2019-20	1012.55	0.52	526.52
2020-21	1012.55	0.52	526.52
2020-22	1012.55	0.52	526.52

3.4 Recharge from irrigation return flow:

The amount of irrigation water that gets recharged to aquifer is calculated by multiplying the total amount applied surface and ground water irrigation with the considered recharge factor. The recharge calculation for the entire study period in KCD from the irrigation return flow is tabulated and shown in Table 5. It is seen that a crucial amount of irrigation water is turned as return flow. The return flow is found to range from 63127.31 ha-m in 2015-16 to 907382.58 ha-m in 2013-14. The amount of return flow in Kharif is comparatively higher than Rabi and is found to range from 47345.48 ha-m in 2015-16 to 680536.93 ha-m in 2013-14. In Rabi, return flow from irrigation ranges from 15781.83 ha-m in 2015-16 to 226845.64 ha-m in 2013-14.

Table 5: Estimation of recharge from applied irrigation waterin KCD

Year	Applied surface water, (ha-m)	Ground water draft for command area, (ha-m)	Total amount of applied irrigation water, (ha-m)	Recharge factor	Recharge from return flow in (ha-m)	Recharge for kharif, (ha-m)	Recharge for Rabi, (ha-m)
2012-13	833550.9	19037	852587.9	0.4	341035.15	255776.36	85258.79
2013-14	2249419	19037	2268456	0.4	907382.58	680536.93	226845.64
2014-15	1643573	19037	1662610	0.4	665043.81	498782.86	166260.95
2015-16	138781.3	19037	157818.3	0.4	63127.31	47345.48	15781.83
2016-17	1330140	19037	1349177	0.4	539670.82	404753.12	134917.71
2017-18	1519157	19037	1538194	0.4	615277.65	461458.24	153819.41
2018-19	1624446	19037	1643483	0.4	657393.23	493044.92	164348.31
2019-20	1992070	19037	2011107	0.4	804442.96	603332.22	201110.74
2020-21	1772676	19037	1791713	0.4	716685.14	537513.86	179171.29
2021-22	1757306	19037	1776343	0.4	710537.05	532902.79	177634.26

Table 6: Estimation of gross recharge from all the sources in KCD

Year	Season	Recharge from rainfall (ha-m)	**Recharge from canal seepage (ha-m)**	**Recharge from ponds, (ha-m)**	**Recharge from return flow, (ha-m)**	**Gross Recharge, (ha-m)**
2012_13	Kharif	38788.97	473084.3	394.89	255776.4	768044.6
	Rabi	6577.834	105129.9	131.63	85258.79	197098.1
2013_14	Kharif	38700.24	417752.8	394.89	680536.9	1137385
	Rabi	807.7244	312623	131.63	226845.6	540408
2014_15	Kharif	17246.62	509049.8	394.89	498782.9	1025474
	Rabi	8143.227	354121.6	131.63	166261	528657.4
2015_16	Kharif	20111.2	254524.9	394.89	47345.48	322376.5
	Rabi	11378.68	88530.4	131.63	15781.83	115822.5
2016_17	Kharif	13253.51	467551.2	394.89	404753.1	885952.7
	Rabi	3799.718	154928.2	131.63	134917.7	293777.3
2017_18	Kharif	16277.35	509049.8	394.89	461458.2	987180.3
	Rabi	3158.089	190893.7	131.63	153819.4	348002.8
2018_19	Kharif	16491.23	481384.1	394.89	493044.9	991315.1
	Rabi	0	193660.3	131.63	164348.3	358140.2
2019_20	Kharif	23833.56	475850.9	394.89	603332.2	1103412
	Rabi	2120.561	334755.6	131.63	201110.7	538118.5
2020_21	Kharif	34277.09	470317.8	394.89	537513.9	1042504
	Rabi	3057.976	359654.8	131.63	179171.3	542015.6
2021_22	Kharif	29228.25	481384.1	394.89	532902.8	1043910
	Rabi	0	273890.9	131.63	177634.3	451656.8

The seasonal gross recharge is estimated for Krishna central Delta and is found to range from 115822.5 ha-m in the year 2015-16 during the rabi season and 1137385 ha-m in the year 2013-14 during the Kharif season. When seen on annual basis the gross recharge is found to range from 438199 ha-m in the year 2015-16 to 1677793 ha-m in the year 2013-14. Seepage from canal is the major contributing source of recharge in Bandar canal command area and is followed by return flow from the irrigated fields. A similar result was also found in understanding the recharge process in the Dhaka City, Bangladesh by Hossain*et al*., 2017. Facilitating the replenishment of groundwater and securing the long-term viability of canal irrigation necessitate meticulous management of the canal command area. Effective management involves employing various strategies, such as water conservation, improved irrigation practices, and the adoption of sustainable agricultural techniques.

4. Conclusion

Recharge estimation in Krishna Central Delta for the period of 2012-13 to 2021-22 has been taken up as per the GEC norms. The gross recharge has been estimated as the sum of recharge from all the different sources and is ranging from 438135.8 ha-m to 1677730 ha-m. Recharge to the ground water reservoir is highly variable and is dependent on various factors. In the canal command area, it was found that seepage from the canal is the highest contributing source among all the other sources. Repeated studies using different estimation methodologies can be carried out for best comparison. Based on the recharge to aquifer, its usage can be managed without deteriorating the water resources. The Ground water resources estimation is helpful for better management planning.

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