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# Estimation of Groundwater Recharge of Yadalavagu Sub–Basin Using Rainfall Infiltration Factor Method, and GIS, Prakasam District, Andhra Pradesh, India

KEYWORDS: GEC'97, Groundwater recharge, Rainfall infiltration factor method, GIS, command area, non-command area

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**ABSTRACT** *Results of the present study describe the groundwater recharge of Yadalavagu sub-basin using rainfall infiltration factor method, Prakasam district, Andhra Pradesh. It includes the groundwater recharge in a Yadalavagu basin through rainfall, other sources like canals, irrigation water applied by surface water irrigation, irrigation water applied by groundwater irrigation, tanks and ponds, water conservation structure in both monsoon and post monsoon seasons. Average rainfall of the basin based on the rain gauge stations established in the sub-basin is 612.7 mm based on the received rainfall data from 2004-2014.Based on the Groundwater Estimation Committee (GEC) 97, cumulative rainfall recharge including monsoon and non monsoon seasons; and command and non-command in Yadalavagu sub-basin in a hydrological year is 362.92 ha.m. Groundwater recharge from the rainfall in monsoon is 188.75 ha.m. Non-monsoon Ground water recharge from other sources is 174.18 ha.m. Groundwater recharge from all other sources is 18.22 ha.m. Groundwater recharges from the rainfall in monsoon is 9.22 ha.m and non-monsoon ground water recharge is 9.02 ha.m. Groundwater draft from all other sources is 697.84 ha.m; combined with monsoon recharge about 116.31 ha.m and non-monsoon is 581.53 ha.m.*

**Introduction**

Groundwater recharge depends on the amount of rainfall received in the vicinity of groundwater basin. Amount of groundwater recharge particularly depends on the area of the basin, soil type, soil, geology, weather, climate, and land-cover charectestics of the basin. The present study made an understanding of the groundwater recharge of Yadalavagu sub basin which is tributary of the Gundlakamma River flowing Markapur and Tarlupadu mandals.

**Location**: The geographical area of study area is 14,326 hectares falls between $15^0$ 47' 01.25" to $15^0$ 35' 47.27" north latitude and $79^0$ 14' 42.57" to $79^0$ 21' 48.92" east longitudes, covering toposheet nos: 57M/5 and 57M/6. The temperature ranges between $10^0$C in the month of January and $35^0$C in the May. Location of the Yadalavagu is shown sub-basin shown in figure 1.


**Figure1: Location map of the Yadalavagu sub-basin**

**Material and Methods:**

Groundwater Estimation Committee (GEC) 97 methodologies are used for estimation of recharge in both monsoon (June-September), non-monsoon (October-May) seasons. To calculate natural rainfall recharge, rain fall infiltration factor method has been used; whereas recharge from all other sources such as canals, tanks, ponds, water conservation structures, return flow by surface water irrigation and groundwater irrigation has been calculated by using procedure described in the GEC' 97 methodology. Return flow factor is also considered from the GEC'97 methodology. Average rainfall of the basin for deriving groundwater recharge has been taken from the six rain gauge stations established in the basin from 2004-14. Groundwater recharge is estimated in two assessment units namely command and non-command areas. Groundwater recharge in hilly area is not considered because no recharge has been taken place where slope is more than 20%. GIS is used for delineation of the sub-basin; calculate the area for each geological unit spread in the sub-basin; identify the surface water bodies; and location map of the sub-basin.

**Results and Discussions**

**Mean, Annual and Seasonal rainfall:**

South-west monsoon which commence in early June, is the predominant monsoon in the Yadalavagu sub-basin. Mean annual rainfall of the Yadalavagu sub basin is 612.7 mm. Mean south west monsoon rainfall is 319.2 mm; whereas non-monsoon rainfall including north east and summer is 293.5 mm.(Umamaheswara Rao B, P. Snakara pitchaih, 2015)

**Geology:** Geological Survey of India (GIS) clearly described that Yadalavagu geology belongs to cumbhum formations of Nallamallai group of Cuddapah super group of middle proterozoic period. Three types of rocks are found in the sub-basin. Cumbhum quartzite is the oldest formation overlain by cumbhum dolomite followed by cumbhum shale as youngest formation. Of the 14,326 hectares of Yadalavagu sub-basin, cumbhum dolomite occupies 96 hectares; cumbhum quartzite spread in 563 hectares; and

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remaining 13,667 hectares area of the sub-basin covered by cumbhum shale.

**Groundwater draft:** Groundwater draft is defined as lifting water through different sources like dug wells, bore wells and dug-cum-bore wells for use of domestic, industrial and agriculture purposes from underground. Groundwater draft has been calculated in the command and non-command area of the sub-basin. Unit groundwater draft from unit well in average pumping hours in a day has been calculated by following formula.

Unit groundwater draft = Average discharge of all types of wells X Average pumping hours per day per unit well

Estimated groundwater draft per well is 55.4 cubic meters per day from a unit bore well in non-command area where there is no other bore wells such as dug wells and dug cum bore wells; average bore well discharge per hour is about 13,846 liters, which is leads to withdrawn about 55,384 liters per day per bore well with four hours average pumping in a day; whereas draft in command area groundwater draft is zero from all sources. Ground water draft from all wells in each season for irrigation has been calculated by the following formula.

Gross groundwater draft in monsoon season = Draft per well during monsoon X No. of wells functioning

Gross groundwater draft in non-monsoon season = Draft per well during non- monsoon X No. of wells functioning

*Whereas, Draft per well during monsoon = Unit draft per well X No. of wells functioning*

*Draft per well during Non-monsoon = Unit draft per well X No. of wells functioning*

Annual gross groundwater draft from irrigation requirements is 667.9 ha.m. Out of this 111.3 ha.m were withdrawn in the monsoon and 556.6 ha.m in non-monsoon season. In monsoon season thirty days where as in non-monsoon bore well functional days are 150. Groundwater draft in monsoon season is 0.17 cubic meters, as well as non-monsoon season 0.83 cubic meters of water is drawn for irrigation from 670 wells in each season.

Annual gross groundwater draft for domestic needs is 19.94 ha.m. Out of this 3.32 ha.m were withdrawn in the monsoon and 16.62 cubic meters in non-monsoon season. Functional days in monsoon are 122 days and non-monsoon is 243 days.

Annual gross groundwater draft for industrial purpose is 9.97 ha.m. Out of this 1.67 ha.m were withdrawn in the monsoon and 8.31 cubic meters in non-monsoon season. Functional days in monsoon are 122 days and non-monsoon is 243 days.

**Table 1: Annual groundwater draft in from all uses in hectare meters**

| Sl.No. | Groundwater use | Monsoon | Non-Monsoon | Annual |
|---|---|---|---|---|
| 1 | Irrigation | 111.32 | 556.61 | 667.93 |
| 2 | Domestic | 3.32 | 16.62 | 19.94 |
| 3 | Industrial | 1.66 | 8.31 | 9.97 |
| Total | | 116.31 | 581.53 | 697.84 |

Table 1 describing annual groundwater draft in Yadalavagu sub-basin is 697.84 ha.m. Of this major portion 667.93 ha.m are utilized for irrigation purpose where as 19.94 ha.m are consuming for domestic purpose and remaining 9.97 ha.m of groundwater are exploited for slate industry in the Yadalavagu hydrological unit. However, 96 percentage of the groundwater is using for irrigation supply remaining 4 percent sharing both domestic and industrial sector.

**Groundwater Recharge:** Groundwater recharge have been happened from recharge from other sources and recharge from rainfall. Possible other sources in the sub basin are canals, irrigation water applied by surface water irrigation, irrigation water applied by groundwater irrigation, tanks and ponds, water conservation structures. Rain fall recharge is estimated by using rainfall infiltration factor method. GEC 97 methodologies are described the methodologies for estimation of the recharge from other sources (CGWB, 2009). Table 2 describes the gross groundwater recharge in the Yadalavagu sub-basin. The following formulas are used for the groundwater recharge.

i. *Groundwater recharge from Rainfall in ha.m = Area of estimated unit in hectares X Average rain fall in meters X Infiltration factor of respective geological formation*

Groundwater recharge from canal in ha.m = Canal seepage factor in hectare meter per day per million square meters of wetted area X Wetted area X No. of days the canal segment is in operation.

Whereas

Wetted area in million square meter = (Wetted perimeter in square meters X Canal length in meters)/$10^6$

Wetted perimeter in square meters = [(2 X 0.6 X design depth of flow in meters)/Sin of side slope in degrees] + Base width in meter.

ii. *Ground water recharge from surface water irrigation = Irrigation water applied by surface water irrigation in hectare meter X Return flow factor*

Whereas

Irrigation water applied by surface water irrigation in hectare meter = design discharge in hectare meter per day X Number of days water is released from the outlet X 0.6

iii. *Groundwater recharge from groundwater irrigation = Irrigation water applied by groundwater irrigation in hectare meter X Return flow factor*

Whereas

Irrigation water applied by groundwater irrigation in hectare meter is derived from the groundwater draft from the all wells.

iv. *Groundwater recharge from tanks and ponds in ha.m = (1.44 X Average water spread area in hectare X No. of days water available)/1000*

v. *Groundwater recharge from water conservation structures in ha.m = (0.25 X Gross storage in ha.m*

Whereas

Gross storage in ha.m = Storage capacity in ha.m X Num-

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**Table 2: Annual gross groundwater recharge from all sources in hectare meters**

| Source | Command area | | Total | Non-Command area | | Total | Net Recharge |
|---|---|---|---|---|---|---|---|
| | Monsoon | Non-Monsoon | | Monsoon | Non-Monsoon | | |
| Rainfall -I | 9.77 | 8.99 | 18.76 | 169.78 | 156.16 | 325.94 | 344.70 |
| Other sources - II | | | | | | | |
| Canal | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Surface water irrigation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Groundwater irrigation | 0.00 | 0.00 | 0.00 | 2.10 | 1.92 | 4.02 | 4.02 |
| Tanks and ponds | 0.00 | 0.00 | 0.00 | 2.10 | 2.10 | 4.20 | 4.20 |
| Water conservation structures | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 10.00 | 10.00 |
| Total-Other sources -II | 0.00 | 0.00 | 0.00 | 9.20 | 9.02 | 18.22 | 18.22 |
| Total - (I+ II) | 9.77 | 8.99 | 18.76 | 178.98 | 165.19 | 344.16 | 362.92 |

Table 2 shows that annual gross groundwater recharge for estimated year (2013-14) is 362.92 ha.m in Yadalavagu sub-basin including command and non-command areas (Ngounou Ngatcha Benjamin et al, 2007). Of this, 18.22 ha.m has been recharged through other sources such as canal, surface water irrigation, groundwater irrigation, tanks and ponds, water conservation structures whereas 344.70 ha.m recharged through rainfall. During estimated year about 9.77 ha.m were recharged from rainfall in monsoon in command area, as there is no other recharge source in command area, so that it has shown as zero from other sources. In non-command area, out of 344.16 ha.m of recharged as groundwater; 178.98 ha.m in monsoon season and 165.19 hectares in non-monsoon season.

Regarding non-command area rain fall recharge occurred about 344.16 ha.m; out of this 178.98 and 165.19 ha.m were monsoon and non-monsoon seasons respectively. Recharge from rainfall in non-command area was 325.94 ha.m where as other sources contributed about 18.22 ha.m. In non-command area, out of 178.98 ha.m 169.78 hectares happened from rainfall and 9.20 hectares occurred from other sources. Similarly, out of 165.19 ha.m of groundwater, 156.16 ha.m recharged from rainfall and 9.02 ha.m formed from other sources (W. R. Osterkamp et al,1995).

Cumulative groundwater recharge from all other sources in the Yadalavagu sub-basin was reached about 18.22 ha.m which was contributed from non-command area as there is no groundwater recharge from other sources in command area in the Yadalavagu hydrological unit. Of this major amount of groundwater about 10.00 ha.m contributed by water conservation structures; 4.02 ha.m available from groundwater irrigation; 4.20 ha.m recharged by tanks and ponds. In non-command area 9.20 and 9.02 hectares were recharged in monsoon and non-monsoon area respectively. 2.10 ha.m, 5.00 ha.m and 2.10 ha.m of groundwater formed as groundwater by groundwater irrigation, water conservation tanks and ponds and respectively in monsoon season. In non-monsoon season out of 9.02 ha.m, recharge from groundwater irrigation contributing 1.92 hectares; 5.00 hectares through water conservation structures and remaining 2.10 ha.m contributing from tanks and ponds (C. Bhuiyan, Ramesh P. et al, 2009).

**Net annual groundwater availability**: It has been computed by deducting the unaccountable discharge from the net groundwater recharge. Unaccountable groundwater recharge derived by multiplication of groundwater recharge with 10 percent of total annual recharge, the results is as shown in table 3 (Adindu Ruth. U et al, 2013).

**Table 3: Net annual groundwater availability for all areas in hectare meters**

| | Command area | | | Non-Command area | | | Net Availability |
|---|---|---|---|---|---|---|---|
| | Monsoon | Non-Monsoon | Total | Monsoon | Non-Monsoon | Total | |
| Net recharge | 9.77 | 8.99 | 18.76 | 169.78 | 156.16 | 325.94 | 344.70 |
| Unaccounted annual discharge | - | - | 1.88 | - | - | 32.59 | 34.47 |
| Net annual groundwater availability | - | - | 16.88 | - | - | 293.35 | 310.23 |

Table 3 depicts that net groundwater recharge of the Yadalavagu sub-basin is 310.23 ha.m, out of this 16.88 ha.m are occurred in command area, remaining 293.35 ha.m recharged in non-command area.

**Stage of groundwater development:** Stage of groundwater recharge has been computed by using formula as expressed in percentage**:**

Stage of groundwater recharge in % = 100 X (Groundwater draft for all uses/Available annual groundwater). Based on this formula stage of groundwater in the Yadalavagu hydrological unit is 225%. Therefore Yadalavagu Sub-basin has been categorized as overexploited.

**Conclusions**

Groundwater is the only source for all needs in Yadalavagu sub-basin. Of the three sectors such as irrigation, domestic and industrial sectors, irrigation sector is stood ahead with 96 % of groundwater utilization. Remaining two sectors are together consuming about 4 %. Net groundwater availability in the basin is 310.23 ha.m; stage of groundwater development is 225% which indicates that there is no possible in groundwater development in the basin. Only 5 % (18.22 ha.m) of the groundwater recharged from the other sources. After this study it is learned that to increase groundwater resources a comprehensive study has to be carried out to implement water conservation measures, artificial recharge and carrying out farm-level strategies like mulching activity, promoting drip, sprinklers, soil conservation activities, farm ponds in individual farmer fields and changing in cropping pattern. Among this land based activities, community empowerment in terms of estimation of available water resources.

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