Assessment of Available water and Crop Water Requirements of Major Crops in Nagarjuna Sagar Right Canal Command Area, Andhra Pradesh, India

ABSTRACT

The mean water releases at head section of 11 years of Nagarjuna Sagar Jawahar right main Canal, Andhra Pradesh, India is found to be 128.13 TMC (3,627.71 MCM). The mean surface water availability was estimated as 2,229 MCM. For the efficient utilization of groundwater, the quality plays a major role in terms of selection of crop variety for sustainable agriculture. The ground water quantity of the command area available was estimated 1385 MCM and the mean annual conjunctive use of command area was 3,614 MCM (128 TMC).

The crop water requirement for paddy, cotton, chilies, millet and pulses were estimated in the command area by using CROPWAT model. The crop water requirement for paddy in NSRC command area of Guntur district for black soils was 848.2 mm. The irrigation water requirement was 638.9 mm and for red soils, crop water requirement for paddy and irrigation water requirements were 848.2 mm and 624.5 mm respectively. Similarly, computed for all the crops and overall crop water demand for both (Guntur and Prakasam) districts of NSRC command area for different soils and different crops per annum was 4,456 MCM without considering cattle and domestic water use. Based on the research, it was concluded that the available water is not sufficient and it is suggested to choose alternative crops for bringing entire area into cultivation.

Key words: surface water, groundwater, cropwat, crops, right canal, Nagarjuna sagar

1. INTRODUCTION

"Irrigation in agriculture plays a major role. Nagarjuna Sagar Project is built across river Krishna at Nandikonda village of Nalgonda District, Andhra Pradesh, India. The Project is having right main canal namely Jawahar canal. The Right main canal (Anonymous, 1999) has Guntur, Zulakallu, Bellarnkonda, Peddanandipadu, Addanki, Eddanapudi, Darsi, Pamidipadu and Ongole branch canals". Tahir et. al. (2014) studied to "define the analysis of rainfall data in order to estimate its contribution towards crop water requirements to overcome crop water deficiency problems". The program estimated the effective rainfall based on the United States Department of Agriculture, Soil Conservation Service (USDS-SCS) formula.Azamathulla [15] developed strategies for optimal cropping pattern for a river basin under semi-arid conditions in India. The strategies are useful for growing less water requiring crops and maximizing water use efficiency and crop productivity over years.

Vikram et. al. (2017) determines "the best-fit distribution of the annual series of rainfall data and study would be useful to the water resource engineers, policy makers and planners for the agricultural development and conservation of natural resources. The irrigation water requirement also includes additional water for leaching of salts and to compensate for non-uniformity of water application". In addition, the uncertainties of canal releases and dissatisfied farmers seeking more quantity water and not supply timely, have tampered with irrigation structures causing further damage. The productivity is reduced due to irregular operation and maintenance of canals. The irrigation water requirement basically represents the difference between the crop water requirement and effective precipitation Allen et. al. (1998). Conjunctive use is the technique which envisages use of Groundwater in conjunction with canal water in the Command Area. This system ensures judicious utilization of Groundwater to ensure safe regime of groundwater table so as to eliminate the water logging conditions and to ensure reliable Irrigation facilities in the tail end areas of the Command Area. In a study study by Thazin [11], the author made an attempt to study the irrigation water requirements of different crops. The CROPWAT 8.0 software for assessing the crop water requirement under Taungdwingyi township.

In a study conducted by Wang *et al*. [16], the authors made efforts to improve the water use efficiency of crops grown under North China Plains. Based on suitable models of yield and irrigation water provided to the crops at regular intervals, the authors provided strategies for improving the water use efficiency of crops and attaining maximum productivity. Babu *et al*. [17] studied on improving the water use efficiency of crops grown under Nagarjuna Sagar Project canal command area. The yield, water use efficiency of different short and long duration crops, rainfall received and canal water released in different years. Chavan *et al*. [18] observed that cropping pattern in Khadambe. It has undergone dramatic changes due to effects of the change and human activities. Cropping pattern is a major factor contributing to yield and food security at local, regional and national scales, and is a critical input variable for many global climate, land surface and crop models. The authors reported on cropping pattern maps for January 2019 at spatial resolution over selected areas of Rahuri.

2. MATERIAL AND METHODS

2.1 Study area

2.1.1. Right Canal Command Area

The command area lies between the latitudes of 15^0 20' to 16^0 41' 24" N and the longitudes of 79^0 18' 44" to 80^0 25' 56" E, encompassing Guntur and Prakasam districts in the state of Andhra Pradesh. The geographical command area consists from block 1 to 22 (GA) as shown in Fig. 1**.**

2.2. Surface water availability

"Canal water releases data i.e., discharge data month wise and branch wise and hydraulic particulars of main and branch canal was collected from Water resources department, Lingamguntla circle and Ongole circle for a period from 2008 to 2018. Daily rainfall data from 1997 to 2018 (22 years) was obtained from the Directorate of Economics and Statistics (DES) and the data was used for calculating annual availability rainfall contribution over the command area". [24]

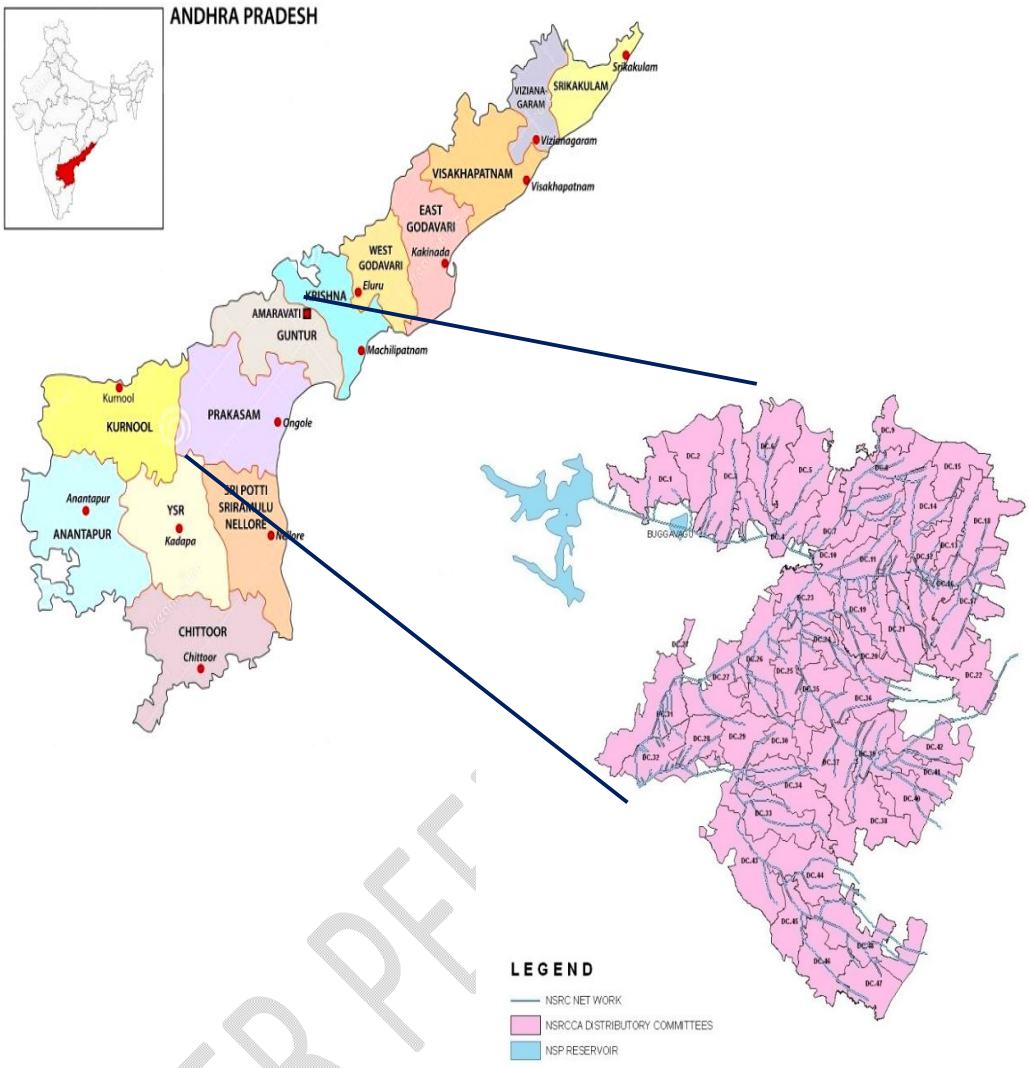


Fig. 1. Location map of study area

2.3. Groundwater availability

Groundwater monitoring was carried-out by 300 observation wells in Nagarjuna Sagar Right Canal command area comprising I to XXII blocks in Guntur. About 188 observation wells and in Prakasam 112 observation wells were established in both districts of Andhra Pradesh by the State Groundwater Department. During the Pre and Post-monsoon periods the monitoring of observation wells with regard to the Groundwater levels was made.

"Water Table Fluctuation (WTF) method is based on the premise that rises in groundwater levels in unconfined aquifers are due to recharge of water arriving at the water table by Thiessen polygon method. It is the most widely used method for estimating recharge" (Healy and Cook, 2002).

Recharge is calculated as

$$R = S_y \frac{dh}{dt} \qquad \text{..... (1)}$$

Where

R recharge, S_y the specific yield, h is water-table height, and 't' is time

Static groundwater reserve = thickness of aquifer below the zone of water level fluctuation down to exploitable limit Avg DTW X areal extent of the aquifer X specific yield of the aquifer

"WTF represent spatially averaged recharge. Determining representative values of S_y is a major difficulty in applying this method. Another difficulty lies in ensuring that the fluctuations in water levels are due to recharge and are not the result of changes in atmospheric pressure, the presence of entrapped air or other phenomena such as pumping". [24]

2.3. Determination of Crop Water Requirement Using Cropwat 8.0

The estimation of crop water requirement for different crops under Nagarjuna Sagar Right Canal Command Area was computed by using CROPWAT 8.0 software.

2.3.1 Data required for CROPWAT 8.0 model

CROPWAT 8.0 is a program that uses Penman-Monteith method for calculating reference crop evapotranspiration. The initial data that are needed for the model in order to get the irrigation crop water requirements are summarized as given below

- Climate data
- Rain data
- Crop data
- Soil data
- Cropping pattern

The mean monthly air temperature and humidity, wind speed, sunshine hours and solar radiation of 18 years from 2000-2018 was collected from Agricultural Research Station, Guntur, Lam. The rainfall contributes to a greater or lesser extent in satisfying crop water requirements, depending on the location. The precipitation data required for CROPWAT 8.0 can be daily, decade or monthly rainfall, commonly available from many climatic stations. Monthly rainfall data was collected from the Chief planning office of Guntur and Praksam districts, which is covered by the Nagarjuna Sagar Right Canal Command Area from 1997-2018.

2.5 Different types of soil data

The soil details which are used in the CROPWAT 8.0 are taken from FAO, Rome, Italy, and Paper No 24 and as shown in Table 1.

Table 1. Different types of soil data

S. No	Soil description	Black clay	Red sandy loam	Red sandy	Red loam
1	Total available soil moisture (FC-WP), mm/m	200	100	100	180
2	Maximum rain infiltration rate, mm/day	30	30	30	30
3	Maximum rooting depth, mm	900	900	900	900
4	Initial soil moisture depletion (as % TAM), %	50	0	0	0
5	Initial available soil moisture, mm/m	100	100	100	180

(Source: FAO Irrigation drainage paper No.24)

In general, there are two groups of soils in the command area, namely black soils and red soils. However, sandy soils also exist all along the coastal area in both the districts. The black soils (Vertisols) are extensively met in the first 11 blocks and also in Block 22 (62%), while the red soils (alfisols) which are very shallow (33%) and shallow sandy barns and gravelly soils (5%) are encountered in the remaining blocks. The block wise distribution of soils is given in the Table 2 (Anonymous, 1999) and Fig.2.

Table 2. Block-wise distribution of soils in the command area

Block	Black cotton soils (%)	Red loamy soils (%)
1 to7	73	27

8&9	47	53
10	84	16
11	65	35
11A,12to14	31	69
15	4	96
16	12	88
17&18	21	79
19	35	65
20&21	9	91
22	60	40
Average	**40.1**	**59.9**

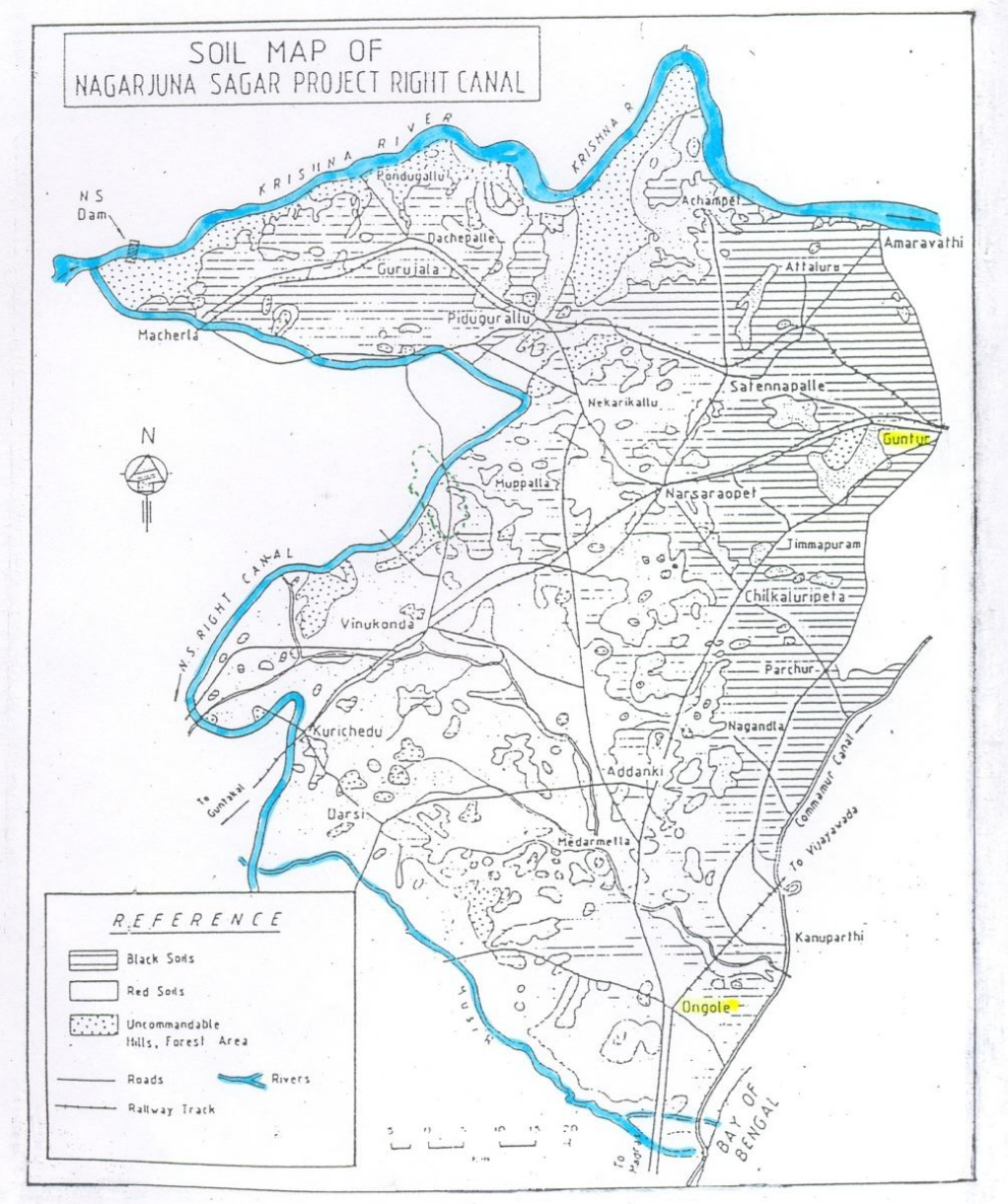


Fig. 2. Soils distributed over the NSRC Command Area

2.6 Crop data

Cropping Pattern

Before inception of the canal system, only rainfed crops like chillies, jowar, bajra, groundnut, cotton were used to be grown during south-west monsoon (kharif) and lands used to be kept fallow during rabi and summer. The crop data was obtained from Chief Planning Officers of respective districts.

The cropping pattern generally followed in the command at present is as follows.

1. Wet lands: Paddy followed by pulses crop.

2. Irrigated dry: Chillies, Minor millets (Sorghum, Bajra) followed by pulses or gingerly during rabi seasons.

3.Rainfed area: Cotton, Chillies, minor millets or pulses

Under Nagarjuna Sagar Right Canal Command Area major crops like paddy, cotton, millet, pulses and chillies are grown and their contemplated area were used for crop water requirement computation for Guntur and Prakasam districts separately.

3. RESULTS AND DISCUSSIONS

The right canal mean off-take wise withdrawals of water releases from the year 2008-09 to 2018-19 was computed and maximum was obtained at Buggavagu O.T. of 104.92 TMC and minimum value was obtained at Pasuvemula Major and Tallapalli Major- I of 0.03 TMC. The mean water releases at head section of 11 years of data was 128.13 TMC (3,627.71 MCM).

Surface Water Availability

Surface water availability of Nagarjuna Sagar Right Canal water releases for last 11 years data from 2008-09 to 2018-19 was tabulated in the Table 3 and Fig. 3. The mean available water was 128.13 TMC (3,628 MCM).

Table 3. Mean water releases data at head regulator of Nagarjuna Sagar Right Canal

Year	Water releases in TMC
2008-09	213.74
2009-10	191.29
2010-11	194.99
2011-12	185.25
2012-13	38.63
2013-14	192.11
2014-15	151.88
2015-16	17.32
2016-17	23.82
2017-18	89.08
2018-19	111.30
Average	**128.13 (3628 MCM)**

"The evaporation losses take place from the exposed water surface area, which would vary with the temperatures, humidity, wind velocity etc. In hot and dry weather months (summer) these losses are maximum but they seldom exceed 1-2% of the total water entering into the canal. The average may vary between 4 mm to 10 mm per day. The conveyance losses now evaluated in the canals selected are inclusive of evaporation losses and no separate studies could be possible. The overall conveyance efficiency of the Nagarjuna Right Bank Canal (including evaporation losses and seepage losses etc.,) was considered as 61.45%, recommended by the CWC, Government of India and then total availability of the surface water is 2,229 MCM". [24]

Groundwater volume data was collected from State Groundwater Department, Guntur by Thiessen polygon method and presented in the Table 4 and Fig.4. From the maximum value was observed as 3062.21 MCM in the year 2008-09 and minimum value occurred 2015-16 as 1825.55 MCM i.e., in the year due to poor rainfall and over drafting of groundwater. Average groundwater volume availability was 2270 MCM (80.16 TMC).

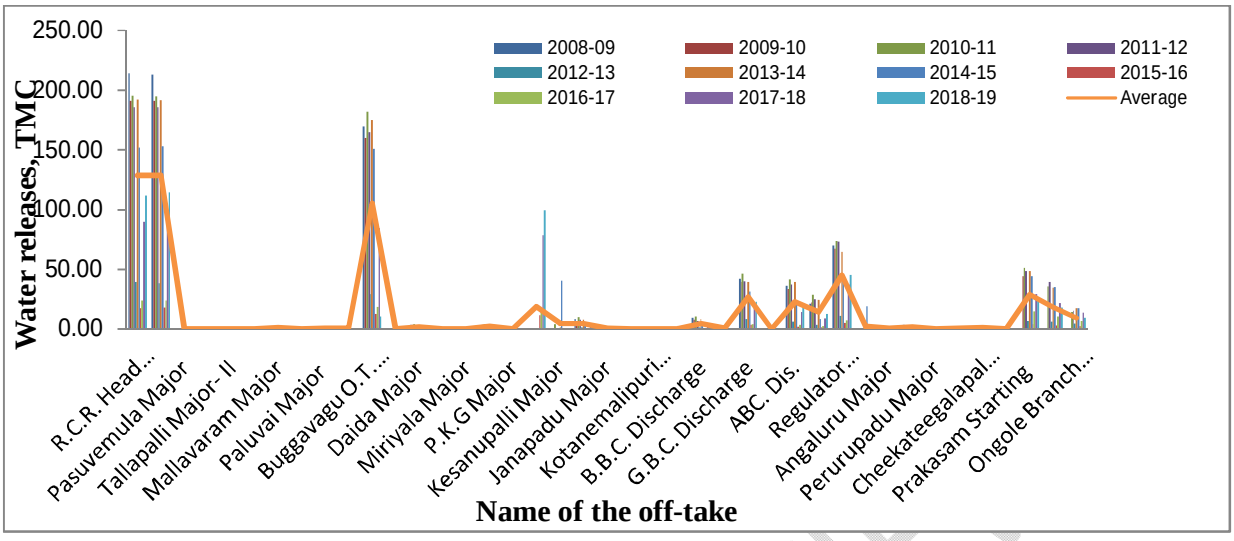


Fig. 3. Off take wise water withdrawals of NSP Right Canal Command area at different levels

Crop water demand

Crop water demand was computed by using CROPWAT software. The weather parameters namely temperature (min and max), humidity, wind speed and sunshine hours were given as input to CROPWAT. Mean metrological data was taken during the years 2008 to 2018. Crop evapotranspiration was computed for different crops in the command area. Cropwat software climate data was shown in the Fig. 5.

Table 4. Annual average available groundwater volume of NSRC command area [24]

Year	Static Available Groundwater resources (ha-m)	Static Available Groundwater resources (MCM)	Static Available Groundwater resources (TMC)
2008-09	306220.56	3062.21	108.14
2009-10	231930.37	2319.30	81.91
2010-11	241896.13	2418.96	85.43
2011-12	231477.38	2314.77	81.75
2012-13	204298.04	2042.98	72.15
2013-14	231477.38	2314.77	81.75
2014-15	211998.85	2119.99	74.87
2015-16	182554.57	1825.55	64.47
2016-17	199768.15	1997.68	70.55
2017-18	231024.39	2310.24	81.59
2018-19	224229.56	2242.30	79.19
Average static groundwater volume	**226988.67**	**2269.89**	**80.16**

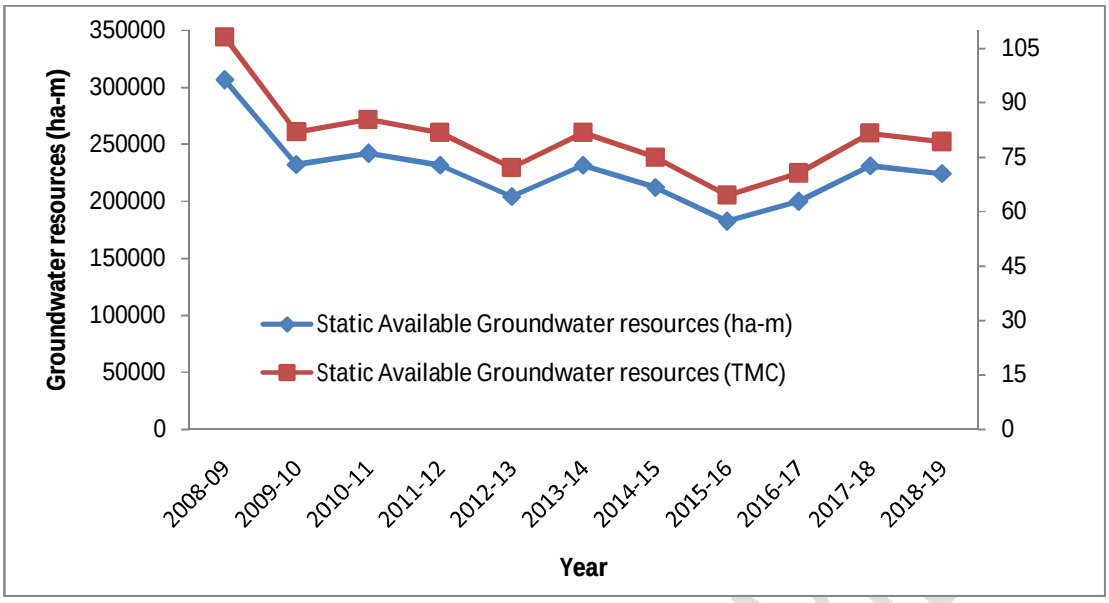


Fig. 4. Available groundwater volume of NSRC command area

Rainfall

The rainfall contributes to a greater or lesser extent in satisfying CWR, depending on the location. The rainfall was not evenly distributed over the entire district.

The rainfall data used for CROPWAT was collected in thirty seven mandals of Guntur district and in twenty three of Prakasam district covered under Nagarjuna Sagar Right Canal Command area for the years 1997 to 2018. The rainfall data of each mandal was used to estimate effective rainfallTahir *et. al.* (2014). From the Table 5&6, it was observed that the 62.39% of total rainfall was received during monsoon months from July to September in Guntur district and it was 422.0 mm. The effective rainfall was 315.7 mm in Prakasam district. The rainfall data was presented in Fig. 6&7.

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\nsprccli.PEM

Country: India Station: NSPRC

Altitude: 33 m. Latitude: 16.34 °N Longitude: 79.18 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	17.5	31.2	91	5	6.6	15.8	2.95
February	17.4	31.8	86	5	7.6	18.6	3.37
March	22.5	35.4	88	8	7.5	20.1	4.12
April	26.0	37.9	83	8	8.2	22.1	4.88
May	27.8	40.9	72	9	7.9	21.7	5.05
June	26.7	38.3	74	9	5.5	17.9	4.19
July	26.1	35.2	79	8	4.4	16.2	3.73
August	24.5	33.4	82	7	4.3	16.0	3.53
September	23.5	33.5	84	5	4.7	16.1	3.46
October	23.3	32.7	88	4	4.9	15.2	3.14
November	23.5	35.5	96	5	6.6	16.0	3.46
December	19.8	34.8	97	4	5.7	14.1	2.98
Average	23.2	35.0	85	6	6.2	17.5	3.74

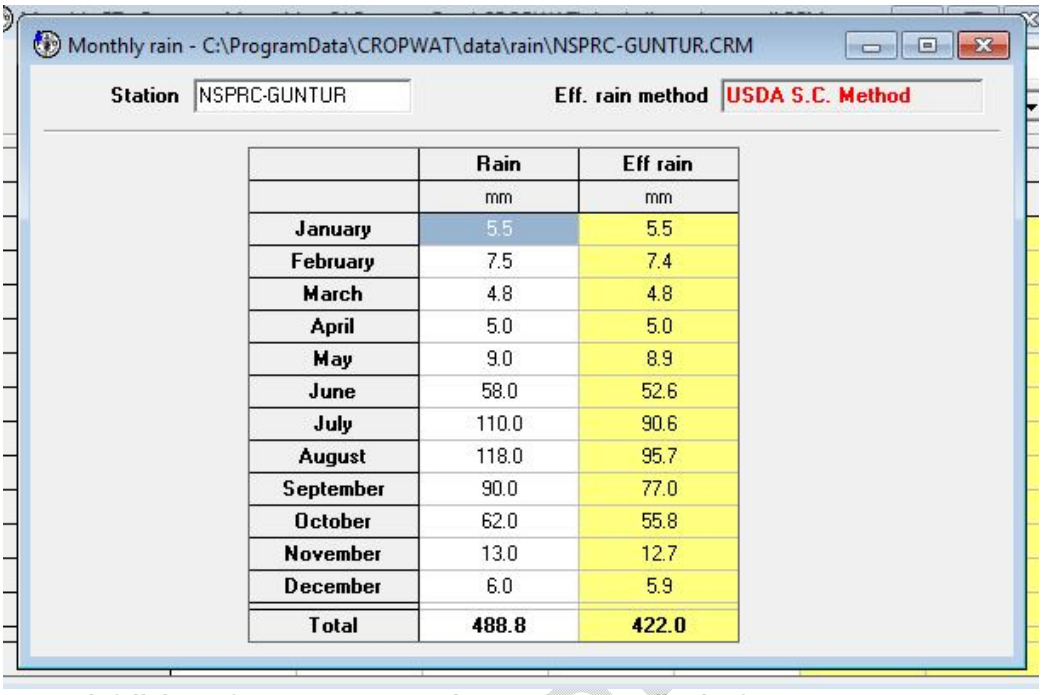
Fig. 5. Mean metrological data of NSPRC Command area from 2008 to 2018

Table 5. Mean monthly rainfall and easy fit software predicted rainfall (at 75% Probability level) data for Guntur district under NSRC Command area

Month	Mean monthly Rainfall, mm	Mean monthly Rainfall, mm
	Computed	Computed rainfall at 75% Probability
January	5.9	5.5
February	8.5	7.5
March	8.4	4.8
April	15.7	5.0
May	20.8	9.0
June	95.2	58.0
July	140.1	110.0
August	154.9	118.0
September	154.8	90.0
October	107.0	62.0
November	44.5	13.0
December	11.5	6.0

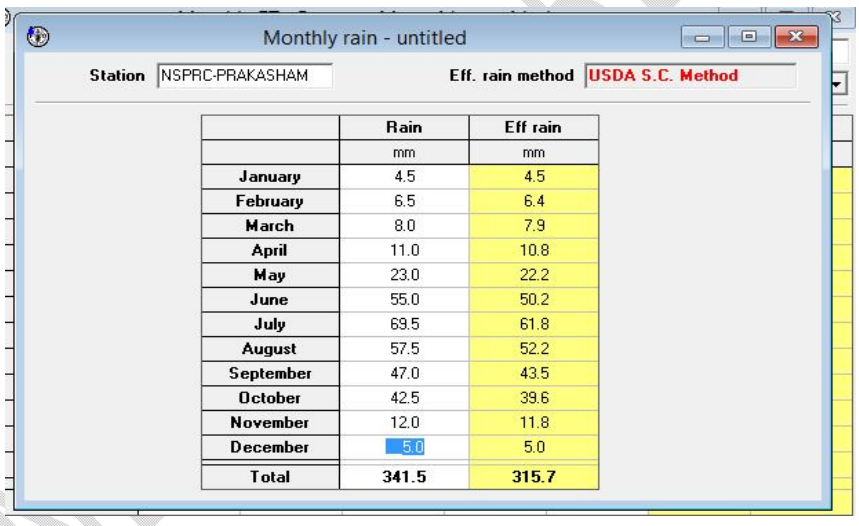
Table 6. Mean monthly rainfall and easy fit software predicted rainfall (at 75% Probability level) data for Prakasam district under NSRC Command area

Month	Mean monthly Rainfall, mm	Mean monthly Rainfall, mm
	Data from Directorate of Economics and Statistics (DES)	Data from Easyfit software excendance of rainfall at 75% Probability
January	61.70	4.5
February	48.87	6.5
March	86.44	8.0
April	81.33	11.0
May	63.62	23.0
June	60.00	55.0
July	75.93	69.5
August	58.33	57.5
September	47.34	47.0
October	55.65	42.5
November	61.97	12.0
December	48.16	5.0



	Rain	Eff rain
	mm	mm
January	5.5	5.5
February	7.5	7.4
March	4.8	4.8
April	5.0	5.0
May	9.0	8.9
June	58.0	52.6
July	110.0	90.6
August	118.0	95.7
September	90.0	77.0
October	62.0	55.8
November	13.0	12.7
December	6.0	5.9
Total	488.8	422.0

Fig. 6. Mean rainfall data of NSPRC Command area of Guntur district from 1997 to 2018



	Rain	Eff rain
	mm	mm
January	4.5	4.5
February	6.5	6.4
March	8.0	7.9
April	11.0	10.8
May	23.0	22.2
June	55.0	50.2
July	69.5	61.8
August	57.5	52.2
September	47.0	43.5
October	42.5	39.6
November	12.0	11.8
December	5.0	5.0
Total	341.5	315.7

Fig. 7. Mean rainfall data of NSPRC Command area of Prakasam district from 1997 to 2018

Crop data

The data on planting date, harvesting date, duration of crop, crop coefficients for different growth stages, duration of different growth stages, rooting depth are provided as input for crop file in CROPWAT(Fig. 8). The data can be used to estimate crop evapotranspiration.

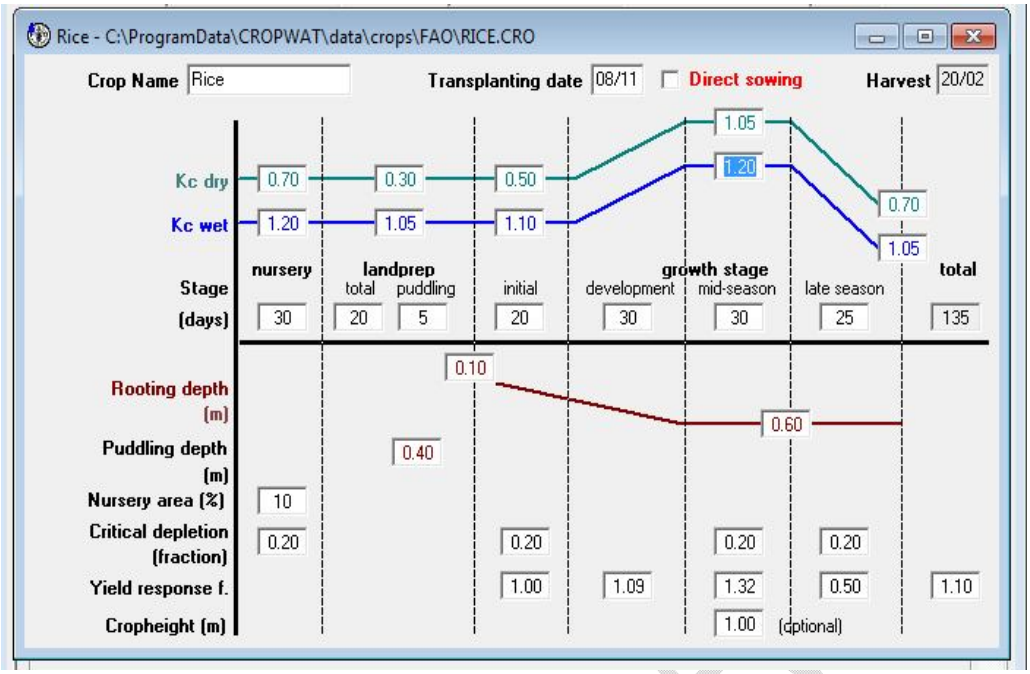


Fig. 8. Crop data for paddy in command area of NSPRC in Guntur District

Soil data

Based on type of soil in the command area, soil characteristics, namely, total available water, maximum rooting depth and initial soil moisture depletion and drainable porosity were given as input to CROPWAT(Fig. 9&10).

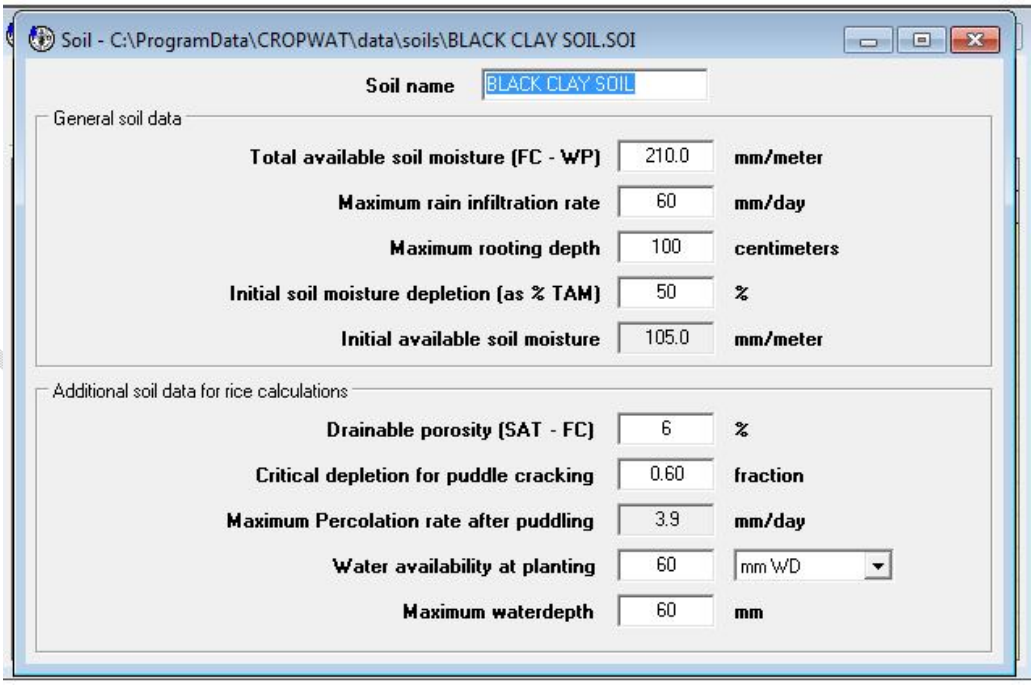


Fig. 9. Soil data of command area of NSRCC in Guntur District

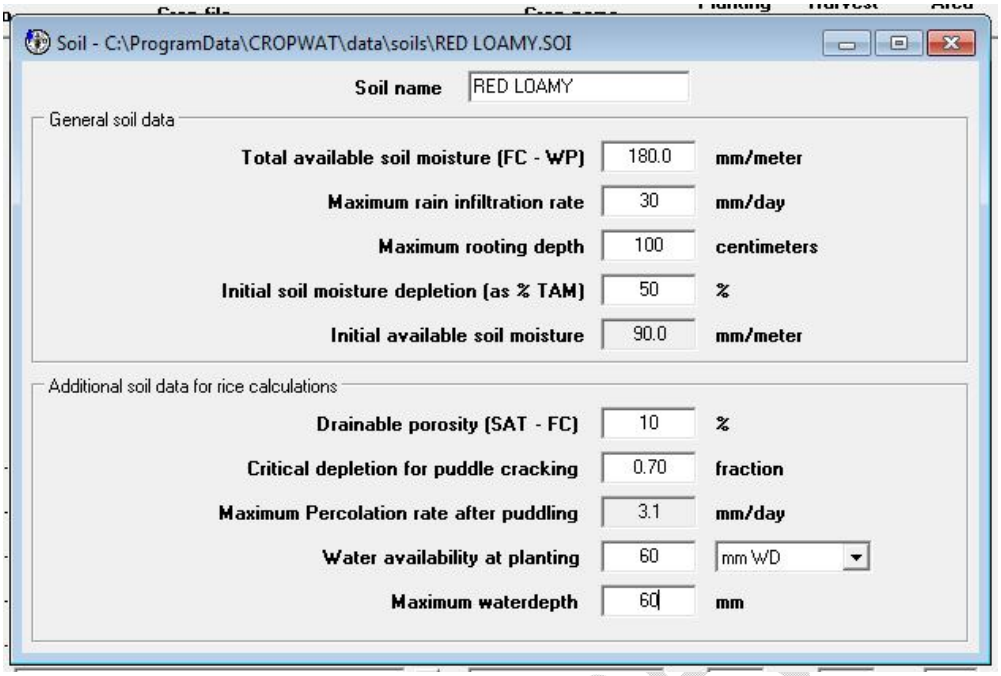


Fig. 10. Soil data of command area of NSRCC in Guntur District

Crop water requirement (CWR)

The data on climate, rainfall, crop, cropping pattern and soil were provided as input to CROPWAT model. The crop water requirements were estimated for all the crops grown in Nagarjuna Sagar Right Canal Command area.

The crop water requirement for paddy in NSRC command area of Guntur District for black soils was 848.2 mm. The irrigation water requirement was 638.9 mm. Similarly, for red soils, crop water requirement for paddy and irrigation water requirements were 848.2 mm and 624.5 mm respectively.

The results obtained from the above study can be used as a guide by farmers for selecting the amount and frequency of irrigation water for the main crop (Saravan and Saravan (2014)).The cumulative crop water requirement for different crops of black cotton in the Guntur district of NSRC command area was obtained as 3,044MCM and red soils was obtained as 3,044MCM. Finally, the black cotton occupied 40.1% and red loamy soils 59.9% as described in the above sections. The crop water demand in the Guntur district of NSRC command area was 3,044 MCM.

The cumulative crop water requirement for different crops of black cotton in the Prakasam district of NSRC command area was obtained as 1,415 MCM and red soils was obtained as 1,410 MCM. Finally, the black cotton occupied 40.1% and red loamy soils 59.9%. Then, the crop water demand in the Prakasam district of NSRC command area was 1,412 MCM.

Overall crop water demand for both districts of NSRC command area for different soils and different crops was 4,456 MCM. Nagarjuna right canal (all together evaporation losses and seepage losses etc.,) as 61.45% recommended by the CWC, Government of India(Anonymous, 2016) and total availability of the surface water is 2,229 MCM. The ground water available is 61% of total volume (i.e., 2270 MCM) of the command area as 1385 MCM. Area under conjunctive use decreased at tail due to decreased canal water supply towards tail while area irrigated by groundwater only increased across head to tail (Usman *et. al,* 2016).

Conjunctive use of water at the command area = surface water volume + groundwater volume

= 2229 + 1385 = 3,614 MCM

But crop water demand alone was 4,456 MCM not considering cattle and domestic use. So, the available water is insufficient and it is suggested to choose other alternative crops for bring entire area into cultivation. Season wise planning is required in both the districts.

4. CONCLUSION

The crop water requirements were estimated for all the crops grown in Nagarjuna Sagar Right Canal Command area. The Overall crop water demand for both districts of NSRC command area for different soils and different crops was 4,456 MCM and not considering cattle and domestic use. Conveyance efficiency of Nagarjuna right canal (all together evaporation losses and seepage losses etc.,) as 61.45% recommended by the CWC, Government of India (Anonymous, 2016) and then total availability of the surface water is 2,229 MCM. The ground available is 61% of total volume (i.e. 2270 MCM) of the command area as 1385 MCM. Conjunctive use water of the command area was 3,614 MCM for annum.Finally, the available water was found not sufficient and it is suggested to choose other alternative crops for bringing entire area into cultivation. It can be concluded that this research will help policy makers and planners of water resources for future planning and to save the water by satisfying crop water requirement. The results obtained from the study can be used as a guide by the farmers for selecting the crops on a regional basis based on the supply and frequency of irrigation water required for the crops.

REFERENCES

1. Allen R, Pereira D, Raes D, Smith M. Crop Evapotranspiration (guidelines for computing crop water requirements). Irrigation and Drainage, FAO, Paper No. 56. 1998;11-203.
2. Al-Zahrani KH,Baig M B. Water in the kingdom of Saudi Arabia: Sustainable management options. The Journal of Animal and Plant Sciences. 2011;21(3): 601- 604.
3. Anonymous. Environment protection training &research institute, Gachibowli, Hyderabad. Report on Integrated social and environmental assessment study for complete rehabilitation and modernization of Nagarjuna Sagar project. 1980;1-273.
4. Anonymous. Study of waterlogging in five canal commands. Nagarjuna sagar right bank canal command area (Andhra Pradesh). 1999; (6):1-93.
5. Anonymous. Performance Overview & Management Improvement Organization Central Water Commission Government of India. report on Summary Report on Water use Efficiency Studies for 35 Irrigation Projects. 2016;45-48.
6. Awan U K, Anwar A, Ahmad W, Hafeez M. A methodology to estimate equity of canal and ground water use at different spatial and temporal scales: A geo informatics approach. Environmental Earth Science. 2016;75: 409-422.
7. Babu RG, Kumar RKN, Venkateswarlu T, Ramulu V. Improving water use efficiency in canal command area –A case study in the Nagarjuna Sagar project. In:5 thAsian Regional Conference, New Delhi, 6-11 December 2009..
8. Carlo F, Renata M, Elisa S. Mixed integer linear programming models for optimal crop selection. Computers and Operations Research. doi: 10.1016/j.cor.2016.12.004. 2016.
9. Chavan KA, Bodake PS, Pande CB, Atre AA, Gorantiwar SD, Raut AD. Identification of cropping pattern in Khadambe bk. using Sentinel 2 Images And Arc GIS Software. International Journal of Current Microbiology and Applied Sciences. 2020;9(9):1139- 1145.
10. Healy RW, Cook P G. Using groundwater levels to estimate recharge. Hydrogeology Journal. 2002;10:91-109.
11. Hossein M, Alireza P. Using easy fit software for goodness of fit test and data generation. International Journal of Mathematical Archive. 2014; 5(1): 118-124.
12. ManasaH G, Anand V S. Implications of Climate Change On Crop Water Requirements in Hukkeri Taluk of Belagavi District. International Journal of Research in Engineering and Technology. 2016; 236 - 241.
13. Mishra C D, Tiwari YK, Nema A K, Gaurav S, Nema RK, Rajesh K. Impact of conjunctive use of water resources on crop production in canal command area- a case study. Indian Journal of Dryland Agricultural Research and Development. 2015; 30(2): 37-43.
14. Nithya K B, Shivpur A V. Study on Water Requirements of Selected Crops Under Tarikere Command Area using CROPWAT. Journal of Irrigation Drainage Systems Engineering. ISSN: 2168 - 9768 IDSE. 2016;1 -4.

15. RajuC R, Yella RK, Satyanarayana T V, Yogitha P. Estimation of crop water requirement using CROPWAT software in Appapuram channel command under Krishna Western Delta. International Journal of Agriculture Sciences. 2016; 8(31):1644-1649.
16. Sanjeev KJ, Dwivedi A K D, Tiwari A. Necessity of Goodness of Fit Tests in Research and Development.International Journal of Computer Science and Technology. 2011; 2(3): 135-141.
17. Sanjeev R, Jaiswal R K, Galakte R V. Estimation of surface and ground water resources in Sagar, Madhya Pradesh, India. Journal of Environmental Research and Development. 2011; 5(3A): 823-829.
18. Saravanan K, Saravanan R. Determination of Water Requirements of Main crops in the Tank Irrigation area using CROPWAT 8.0. International Journal of Interdisciplinary and Multidisciplinary Studies (IJIMS). 2014;1(5): 266-272.
19. Tahir S L, Abdul K, Syed H, Husain S, Shaukat A, Haroon S,Umair, N. Analysis of Rainfall Data to Estimate Rain Contribution Towards Crop Water Requirement Using Cropwat. Model Rjoas. 2014;12: 36-42.
20. Thazin K. Irrigation water requirements of different crops by using CROPWAT 8.0 Software in Taungdwingyi township. Iconic Research and Engineering Journal. 2019;3(4):191-197.
21. Usman M, Abbas A, Saqib Z A. Conjunctive use of water and its management for enhanced productivity of major crops across tertiary canal irrigation system of Indus basin in Pakistan. Pakistan Journal of Agricultural Science. 2016; 53(1): 257-264.
22. Vikram K, Shanu, Jahangeer. Statistical distribution of rainfall in Uttarakhand, India. Journal of Applied Water Sciences. 2017; 7:4765–4776.
23. Wang H, Zhang L, Dawes WR, Liu C. Improving water use efficiency of irrigated crops in the North China Plainmeasurements and modelling. Journal of Agricultural Water Management. 2001;48 (2):151-167.
24. Rao DS, Kumar HH, Devi BS, Edukondalu L, Rao VS. Assessment of Water Resources in Nagarjuna Sagar Right Canal (Jawahar) Command of Andhra Pradesh. Journal homepage: http://www. ijcmas. com.;9(10):2020.