Estimation of Crop Water Requirements, Demands and Supplies in Chintakani Major Distributary Command of Nagarjuna Sagar Project

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Abstract**—** *Considering the promising demand for water in agricultural practices and other applications, efficient use of water has emerged as a critical necessity. This study focuses on the estimation of weekly irrigation water requirements for major crops in the Chintakani major distributary of Nagarjuna Sagar project (NSP) over the period of 2015 to 2018. The methodology employed in this study involved the calculation of reference evapotranspiration using FAO Penmen-Monteith, which is a standard method for estimating evapotranspiration. The results revealed that the average irrigation requirements for Maize and Chillies during the rabi season were 483.12 mm and 898.95 mm respectively. To understand the water dynamics in this region, data pertaining to the weekly canal water during the years 2015-16 to 2017-18 was collected. This data was then used with the estimated demands of crops in the distributary command to assess the adequacy of water supply in meeting the irrigation needs. The analysis of this research revealed that the annual demands of crops during the years 2015-16 to 2017-18 were 1086880, 7956889, 8048374 m*^{3} *respectively. In contrast, the canal water supplies during the same period were 949440, 7891552.46, 6986024.89 m*^{3} *respectively. A key finding of this study was the identification of a severe water deficit during the years 2015-16 and 2017-18. This deficit was attributed to a lower amount of rainfall during these years, based on the agricultural practices and climatic variations of the region. This study underscores the urgent need for strategies aimed at enhancing the efficiency of water use in agriculture, particularly in regions prone to rainfall deficits.*

Keywords**— *Command area, Gross irrigation requirement, FAO Penmen –Monteith, Demands, Supplies, Reference evapotranspiration.***

I. INTRODUCTION

Rainfall in India varies in terms of time and location, leading to floods in some areas due to excessive rain, while some regions face severe drought. The rising demand for water resources in agriculture and other sectors is increasing for its beneficial use of water use efficiency. Traditional irrigation methods like border, furrow, check basin, and flood irrigation, which rely on gravity for water delivery, often result in significant water losses and don’t ensure good water distribution. For optimal crop yield, it is essential to manage groundwater and surface water effectively. The choice of technology is influenced by various factors such as the specific location, soil types, crop species, water availability, cropping pattern, climate, socio-economic conditions, etc. Urban areas and industries often get priority in water allocation, which can intensify the impact of supply shortages on irrigated areas during years of water deficit. The way these temporary and chronic shortages are spread across the command area will determine their overall effect on agricultural production and the livelihoods of farmers within the irrigated command area (Gaur et al., 2008).

Evapotranspiration (ET) plays a crucial role in the water cycle and is vital for interpreting soil surface phenomena in climatology. It is directly related to productivity in ecosystem and agricultural research (Chen et al., 2005). The water requirement of crops varies based on the season, crop stage, management approaches and cultivation area. Calculating these crop needs involves factors like ET and crop coefficients (Gadge et al., 2011). Gaur et al. (2008) conducted an integrated approach to assess how cropping patterns and the spatial equity of canal flow changed with water supply in the left canal command area of Nagarjuna Sagar. They found that water scarcity resulted in 40% land being followed in the left-bank canal command area and suggested that equitable allocations could be achieved by improving the water distribution efficiency of the canal network during normal years and by crop diversification and introduction of alternative water sources during water shortage years.

Venot et al. (2010) examined the strategies of farmers in Nagarjuna Sagar Project during drought periods. They used semi-structures interviews and field observations to collect data from 30 farmers in different zones of the command area and found that farmers adopted various practices such as irrigation scheduling, water harvesting, agroforestry, and market linkages to cope with water scarcity and maintain crop productivity. Kumar and Madhnure (2021) explored the potential of conjunctive use of surface and ground water in left bank canal command area of Nagarjuna Sagar Project, a case study from Khammam district, Telangana state. They found that conjunctive use of surface and groundwater could enhance water availability and reduce conflicts among different users.

Crop water requirements of the major crops grown in Bhimsagar command area as assessed by CROPWAT 8.0 software (Rajput et al., 2018) prepares a rotational water allocation plan for Ratnapura minor located on the right main canal. Rajput et al. (2018) developed a plan that helped in the proper operation of the system for better utilization of water resources and improved crop productivity. Rao and Rajput (2009) proposed a decision support system for can water releases for reducing the gaps between canal supplies and demands for increasing the water use efficiency in canal command areas. Also provided guidelines and suggestions under different situations of water deficit or surplus. Sravya et al. (2019) used the optimization techniques to estimate the crop water requirements, demands and supplies in D-51 distributary command of Sri Ram Sagar project. Conjunctive use planning is a strategy to optimize the use of water resources in different sectors, such as agriculture, industry, and environment.

Lingo software was used to develop an optimization model for conjunctive use planning in the Upper Damodar River basin in India, which is a major river basin with high water demand and low water availability (Jha et al., 2020, Sabale et al., 2022). This algorithm optimizes the water allocation among different sectors such as irrigation, domestic use, and environmental flow for achieving conjunctive use of ground and surface water resources. The concepts, principles, benefits, challenges and strategies of conjunctive use of surface and ground water resources were proposed (Sabale et al., 2023). Afshar et al. (2021) assesses the adaptability of cyclic and non-cyclic approach to conjunctive use of ground and surface water for sustainable management plans under different climate change scenarios. The present study was conducted using the analysis of surface and ground water resources in the Chintakani canal command area of Nagarjuna Sagar project.

II. MATERIALS AND METHODS

The study involves several components. It estimates the reference evapotranspiration (ETo) by using meteorological data, calculates the effective rainfall (ER) from rainfall data, and determines the crop water requirements (CWR) for specific crops in the command area using cropping pattern data. It also assesses the availability of canal water using canal release data. This project focuses on the Chintakani major distributary in the Khammam district (Fig 1&2). The area and length of this distributary is 4493 ha and 8.4 km. There are two primary cropping seasons in this state i.e. Kharif from June to October and Rabi from November to March. The main crops cultivated in the study area are Maize and Chillies (Table 1) (Sravya et al., 2019).

TABLE 1
CULTIVATED COMMAND AREA OF DIFFERENT CROPS GROWN IN THE CHINTAKANI MAJOR DURING 2015-16 TO 2017-18

S. No.	Crop	Command area, ha		
		2015-16	2016-17	2017-18
1	Maize R	700	733	723.62
2	Chillies R	54.26	57.81	50.58

R – Rabi

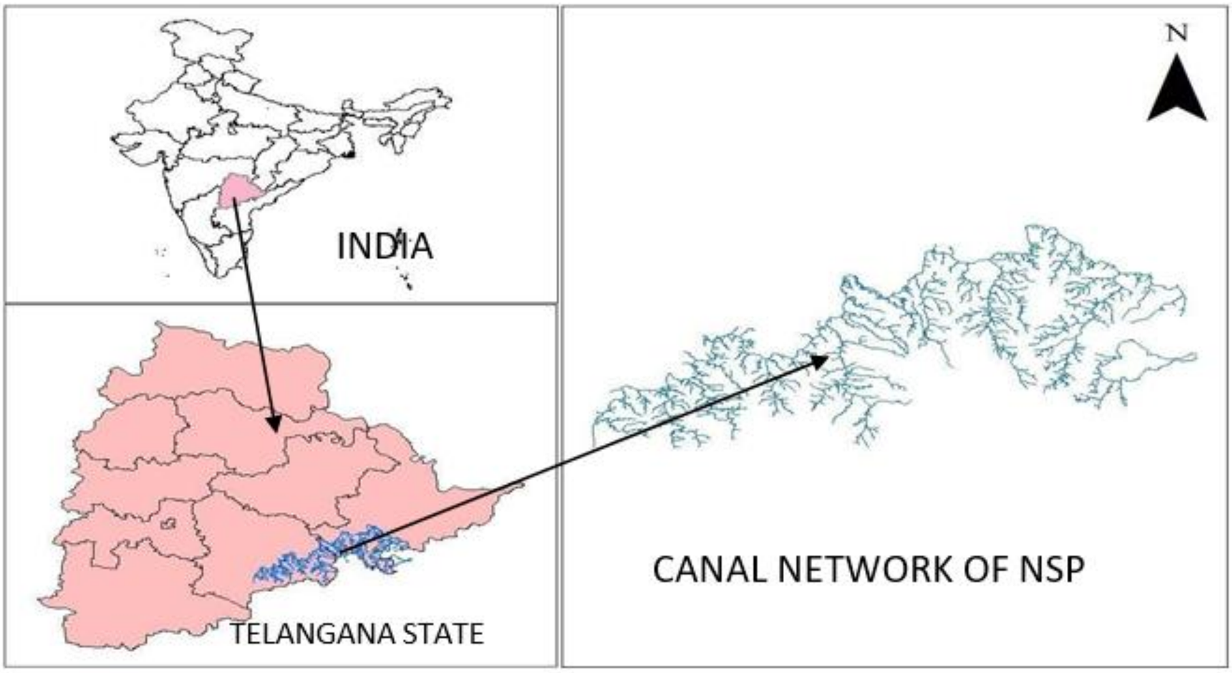

FIGURE 1: Location map of Nagarjuna Sagar Project

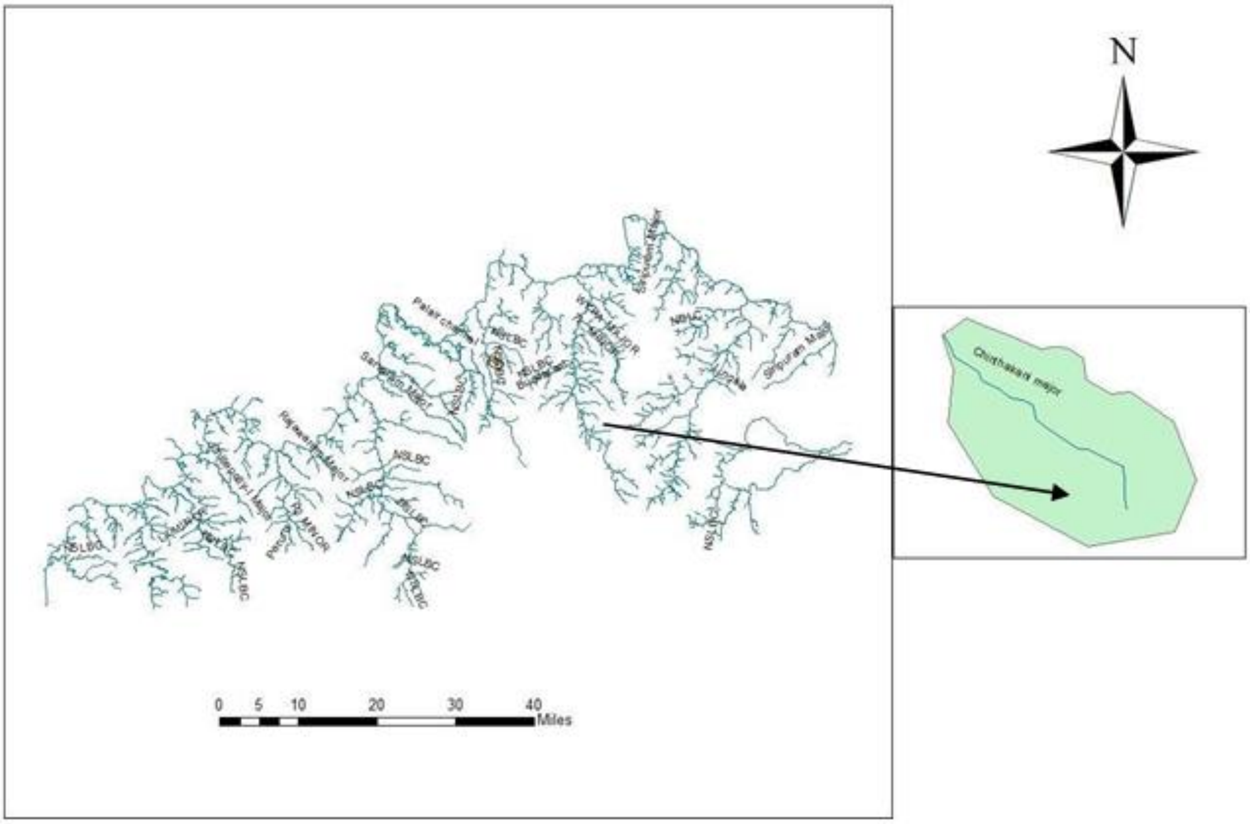

FIGURE 2: Location map of Chintakani major distributary Command area

In this study the values of reference evapotranspiration were calculated by using FAO Penmen-Monteith method. However, penmen-monteith is the only method which is standardized to estimate reference evapotranspiration (ETo). The crop evapotranspiration is estimated by using the following equation given below,

$$ETc = Kc * Eto \quad (1)$$

Where, Kc is crop coefficient, ETc is crop evapotranspiration per day, (mm/day), ETo is reference evapotranspiration per day, (mm/day) (Sravya et al., 2019).

The net irrigation requirement (NIR) of the crop is calculated by using the following equation given below,

$$NIR = WR - ER \tag{2}$$

Where, NIR is net irrigation requirement, (mm), WR is water requirement of crops, ER is effective rainfall, (mm). The weekly NIR of the crops was estimated by adding the daily NIR values of the crops corresponding to the week (Sravya et al., 2019).

The water that is supplied was insufficient to the crops cultivated in the command area termed as gaps. These gaps create imbalances between demands and supplies in the command area. The water regulation in the distributaries was maintained by the field officials. The weekly canal water releases data of the Chintakani major distributary was taken from the Subdivision office, Khammam district of Telangana (Sravya et al., 2019).

$$\text{Canal water releases, } m^3 = \text{release of water, cusec} \times 3600 \times 24 \times 0.0283 \times 10^{-3} \tag{3}$$

III. RESULTS AND DISCUSSION

3.1 Demands and Supplies of Canal water in the Command areas:

The weekly supplies data of canal water of Chintakani major distributary during the years 2015-16 to 2017-18 was collected and is compared to the estimated demands of crops.

TABLE 2
GAPS BETWEEN DEMANDS AND SUPPLIES DURING THE YEAR 2015-16

S.no.	Week	Canal water		Gaps	
		Demands, m^3	Supplies, m^3	Surplus/ Deficit	
				m^3	in %
1	w44	77570	112451.07	34881.07	44.97
2	w45	63030	97046.81	34016.81	53.97
3	w46	106530	158660	52130	48.93
4	w47	91530	54469.45	-37060.55	-40.49
5	w48	80370	35420	-44950	-55.93
6	w6	348370	284978.74	-63391.26	-18.2
7	w10	224130	124774.47	-99355.53	-44.33
8	w15	95350	81640	-13710	-14.38
		1086880	949440	-137439.3	-25.45

These gaps may have occurred due to improper canal water releases by not considering the demands of crops and there also may be changes in crop pattern year to year. The gaps between demands and supplies for three years i.e 2015-16 to 2017-18 of Chintakani major distributary are presented in Table 2 to Table 4.

TABLE 3
GAPS BETWEEN DEMANDS AND SUPPLIES DURING THE YEAR 2016-17

S.no.	Week	Canal water		Gaps	
				Surplus/ Deficit	
		Demands, m^3	Supplies, m^3	m^3	in %
1	w37	381320	170987.24	-210332.76	-55.16
2	w40	123520	6161.7	-117358.3	-95.01
3	w44	144120	274190	130070	90.25
4	w45	158360	295760	137400	86.76
5	w46	148554	26187.24	-122366.76	-82.37
6	w47	172350	340430	168080	97.52
7	w48	133000	77021.28	-55978.72	-42.09
8	w50	372400	582280.88	209880.88	56.36
9	w51	384250	764050	379800	98.84
10	w52	398460	788697.91	390237.91	97.94
11	w2	523310	163285.11	-360024.89	-68.8
12	w3	543450	1012050	468600	86.23
13	w4	551790	33889.36	-517900.64	-93.86
14	w5	541180	338890	-202290	-37.38
15	w6	571300	415914.91	-155385.09	-27.2
16	w7	325760	614620	288860	88.67
17	w8	350710	24646.81	-326063.19	-92.97
18	w9	374180	744020	369840	98.84
19	w10	398230	138638.3	-259591.7	-65.19
20	w11	398220	12323.4	-385896.6	-96.91
21	w12	399920	784070	384150	96.06
22	w13	138780	9242.55	-129537.45	-93.34
23	w14	196070	166365.96	-29704.04	-15.15
24	w15	227655	107829.79	-119825.21	-52.63
		7956889	7891552.46	-65336.54	-20.58

TABLE 4
GAPS BETWEEN DEMANDS AND SUPPLIES DURING THE YEAR 2017-18

S.no.	Week	Canal water		Gaps	
				Surplus/ Deficit	
		Demands, m^3	Supplies, m^3	m^3	in %
1	w45	163060	306540	143480	87.99
2	w46	170000	145480	-24520	-14.42
3	w47	175360	300380	125020	71.29
4	w48	147820	13350.36	-134469.64	-90.97
5	w50	413900	825030	411130	99.33
6	w51	420350	222940	-197410	-46.96
7	w52	435354	140170	-295184	-67.8
8	w2	565100	1041327.71	476227.71	84.27
9	w3	583240	360459.59	-222780.41	-38.2
10	w4	579350	181564.83	-397785.17	-68.66
11	w5	596810	72960	-523850	-87.78
12	w6	650260	487287.96	-162972.04	-25.06
13	w7	370790	350800	-19990	-5.39
14	w8	394250	280357.46	-113892.54	-28.89
15	w9	397310	694218.47	296908.47	74.73
16	w10	411400	72091.92	-339308.08	-82.48
17	w11	410740	377700	-33040	-8.04
18	w12	395690	46726.24	-348963.76	-88.19
19	w13	142760	281670	138910	97.3
20	w14	194840	360450	165610	85
21	w15	206540	411170	204630	99.08
22	w16	223450	13350.36	-210099.64	-94.03
		8048374	6986024.89	-1062349.1	-47.87

The three years supplies and demands of the command area were taken and plotted in different graphs week wise. The demands and supplies vary from week to week and year to year due to some variations. The different curves of water supplies shown in the graphs were continuously fluctuating. In the study area, the supplies given are one week on and one week off by meeting the requirements of different crops in the command area. Three years demands of various crops and supplies of canal water in the Chintakani major distributary were presented from Fig 3 to Fig 5.

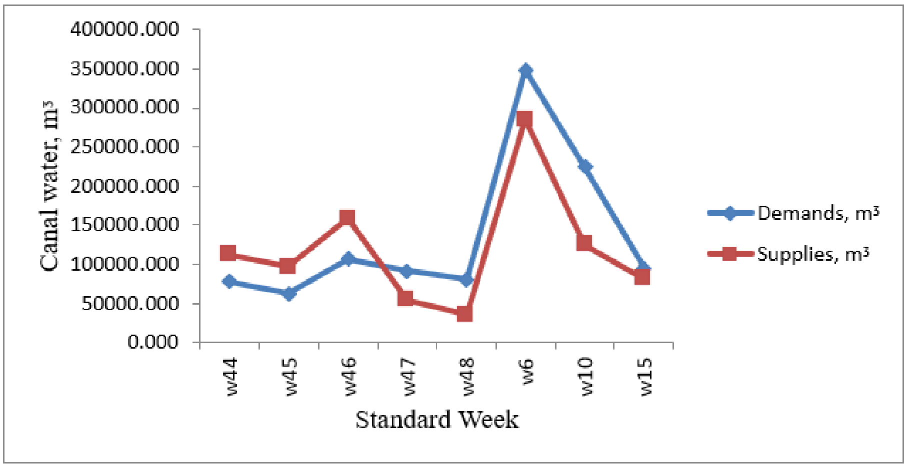

FIGURE 5: Canal water demands and supplies week wise during 2017-18

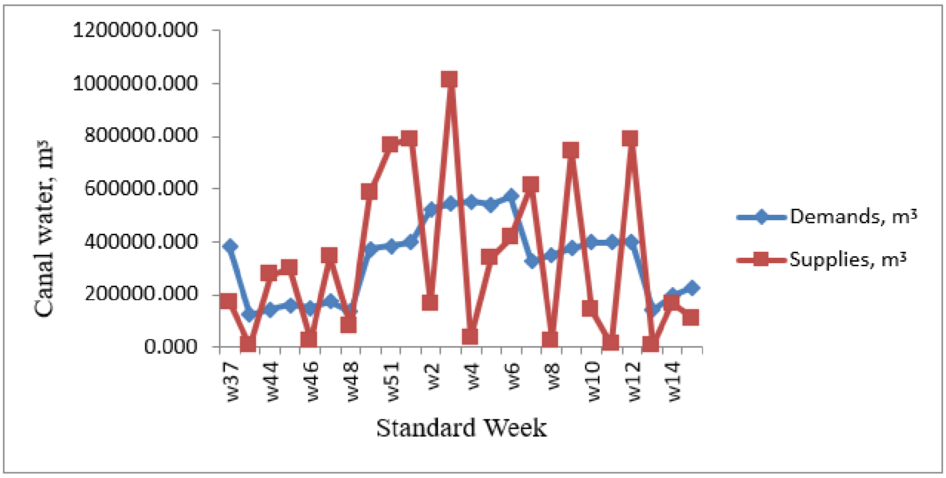

FIGURE 4: Canal water demands and supplies week wise during 2016-17

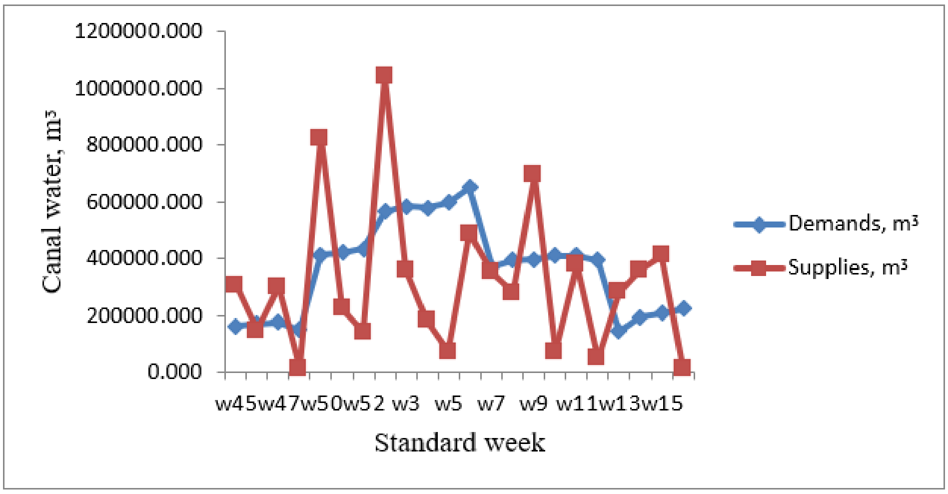

FIGURE 5: Canal water demands and supplies week wise during 2017-18

3.2 Gross irrigation requirements of different crops in the Command area:

The gross irrigation requirements of various crops i.e Maize and Chillies cultivated in the command area were estimated (Table 5 & 6). The average gross irrigation requirements of Maize and Chillies of Rabi season were found 483.12 and 898.95 mm. In this study area, various crops are grown in different seasons, with distinct water requirements. For instance, paddy requires a large amount of water, while sesame needs less. Regardless of these differences, canal water is distributed across the entire command area of the distributary. In some situations, the water supplied may not meet the crop's needs, leading to surpluses or deficits. To address this issue, a combined use of surface and ground water resources is recommended.

To address this issue, a combined use of surface and groundwater resources is recommended. The excess water is directed to the end of the distributary where water shortage is severe. This water, along with available groundwater, is then used for crop cultivation.

TABLE 5
WEEKLY AVERAGE IRRIGATION WATER REQUIREMENT VALUES OF MAIZE (RABI)

S. No	Week	Gross irrigation water requirements, mm			Average
		2015-16	2016-17	2017-18	
1	49	11.25	15.37	20.7	17.54333
2	50	11.46	17.31	23.86	17.23667
3	51	10.29	19.42	22	17.21333
4	52	9.61	18.5	23.53	23.80667
5	1	16.47	19.48	35.47	24.44333
6	2	15.55	27.33	30.45	25.59333
7	3	20.12	26.34	30.32	26.14
8	4	19.49	28	30.93	25.65
9	5	17.28	25.11	34.56	30.11
10	6	21.39	28.13	40.81	11.86
11	7	7.14	15.57	12.87	15.16333
12	8	11.06	17.57	16.86	14.97
13	9	8.06	20	16.85	13.76
14	10	7	20	14.28	15.40333
15	11	8.19	19.5	18.52	14.84667
16	12	9.83	20.5	14.21	12.88
17	13	10.49	13.87	14.28	15.71333
18	14	8.05	19.61	19.48	17.64667
19	15	9.53	22.76	20.65	15.76333
20	16	9.26	15.69	22.34	18.06
21	17	10.01	13.59	30.58	19.17333
22	18	16.86	21.6	19.06	18.44333
23	19	17.92	19.83	17.58	17.45667
24	20	17.57	16.34	18.46	19.26333
25	21	17.92	21.18	18.69	19.21
26	22	17.57	21.6	18.46	483.12
	Average	339.39	524.19	585.78	483.12

TABLE 6
WEEKLY AVERAGE IRRIGATION WATER REQUIREMENT VALUES OF CHILLIES (RABI)

S. No	Week	Gross irrigation water requirements, mm			Average
		2015-16	2016-17	2017-18	
1	26	17.05	19.19	19.56	18.6
2	27	17.69	15.36	19.15	17.4
3	28	11.49	18.87	19.56	16.64
4	29	9.57	18.97	19.38	15.97333
5	30	13.53	18.62	19.09	17.08
6	31	35.56	37.12	45.91	39.53
7	32	35.53	45.66	45.85	42.34667
8	33	40.62	36.75	45.81	41.06
9	34	35.55	37.12	52.55	41.74
10	35	33.37	38.34	46.9	39.53667
11	36	33.01	38.09	47.17	39.42333
12	37	33.02	38.13	46.8	39.31667
13	38	32.99	38.34	46.59	39.30667
14	39	7.04	12.68	17.71	12.47667
15	40	8.03	12.35	18	12.79333
16	41	5.69	12.89	55.36	24.64667
17	42	9.47	15.63	36.25	20.45
18	43	9.57	12.8	44.25	22.20667
19	44	7.76	14.41	16.31	12.82667
20	45	6.3	15.83	16.3	12.81
21	46	10.65	14.85	17	14.16667
22	47	9.15	17.23	17.53	14.63667
23	48	8.04	13.3	14.78	12.04
24	49	8.18	15.37	24.65	16.06667
25	50	10.29	37.24	20.7	22.74333
26	51	9.61	19	20.03	16.21333
27	52	9.77	21	20	16.92333
28	1	14.7	19.48	21.04	18.40667
29	2	16.58	25	26.15	22.57667
30	3	20.24	28	28	25.41333
31	4	25.35	26.5	27	26.28333
32	5	12.69	29	24.21	21.96667
33	6	13.44	28.5	23.25	21.73
34	7	20.81	17	24.26	20.69
35	8	16.88	17	21.6	18.49333
36	9	13.18	17.47	24.2	18.28333
37	10	15.41	20	27	20.80333
38	11	18.5	20.5	22.48	20.49333
39	12	28.21	21	25.36	24.85667
	Total	684.5	904.62	1107.73	898.95

IV. CONCLUSIONS

The weekly irrigation water requirements of the major crops were estimated in the selected Chintakani major distributary of NSP during the years 2015 to 2018 using FAO Penmen – Monteith method. The average gross irrigation requirements of Maize and Chillies of Rabi season were found 483.12 and 898.95 mm. The yearly demands of crops during 2015-16 to 2017-18 are 1086880, 7956889, 8048374 m^3 and canal water supplies are 949440, 7891552.46, 6986024.89 m^3. There was a severe deficit of water during the years 2015-16 and 2017-18 due to less amount of rainfall.

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