Computation of Effective Rainfall for Wet Crops – A Case Study on 5th Distributary of Mid Pennar South Canal (MPSC)

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Abstract

Mid Pennar Reservoir (MPR) is located near Penakacherla village, Garladinne Mandal, Anantapur district, Andhra Pradesh, India. Water from MPR is being supplied to the ayacut through Mid Pennar North Canal (MPNC) and Mid Pennar South Canal (MPSC). MPSC is having 30 distributaries among which 5th distributary has been considered for the present study. The total command area under 5th Distributory is 4337.34 Hectares. The command area is being influenced by three rain gauge stations viz. Pamidi, Peddavaduguru and Singanamala. Rain fall particulars have been collected for the influencing rain gauge stations for the years 2011-12 to 2014-15. The weighted rain fall for the study area has been computed by Theissen polygon method. Evapotranspiration (ET0) values and Crop co-efficients (Kc values) for crops grown in the study area have been collected and utilized for computation of Crop water requirement. As per the particulars collected from Irrigation department, the values of actual water utilized are less than the computed values of water requirement which may imply that the actual effective rainfall realised might be more than the percentage of effective rainfall considered in the calculations. There is no possibility of getting increased effective utilization of rain fall by the irrigated dry crops. Hence, the actual effective rainfall realized in case of Wet crops in respective years have been computed. The percentage effective rainfall realized for wet crops in the command area of 5th distributary of Mid Pennar South Canal is in the range of 87% to 90%.

Keywords: Crop co-efficients (Kc), Crop water requirement, Reference Evapotranspiration (ET0), Irrigated Dry crops, Modified Penman method, Theissen polygon and Wet Crops

Abbreviations : Crop co-efficients (Kc), Cubic metres (cum), Hectares (Ha), Mid Pennar North Canal (MPNC), Mid Pennar Reservoir (MPR), Mid Pennar South Canal (MPSC), Millimeters (mm), Million Cubic metres (Mcum) and Rain Gauge Station (RGS), Reference Evapotranspiration (ET_0).

I. INTRODUCTION

Crop water requirement is the water required by the plants for survival, growth, development and to yield production. This requirement can be fulfilled naturally by precipitation or artificially by irrigation. In general, Modified Penman method is followed to compute the crop water requirement for various crops proposed to be grown in the command area under a particular irrigation resource. Same method has been adopted to compute water requirement for various crops grown in the study area. Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves. Reference evapotranspiration (ETo) is a representation of the evapotranspiration rate of a short green crop (grass), completely shading the ground, of uniform height and with adequate water status in the soil profile. It is a reflection of the energy available to evaporate water, and of the wind available to transport the water vapour from the ground, up into the lower atmosphere. Actual evapotranspiration is said to equal reference evapotranspiration when there is ample water. In general, alfalfa crop that is 0.5 m in height with a full cover is considered as reference crop. Crop coefficients are properties of plants used in predicting evapotranspiration (ET). The most basic crop coefficient Kc, is simply the ratio of ET observed for the crop studied over that observed for the well calibrated reference crop under the same conditions. Evapotranspiration for a particular crop (ETc) is determined by the crop coefficient approach whereby the effect of various weather conditions are incorporated into ETo and the crop characteristics into Kc coefficient (ETc = ETo x Kc). Effective rainfall refers to the percentage of rainfall which becomes available to plants and crops. It considers losses due to runoff, evaporation and deep percolation. Actual water to be supplied to the crop can be determined by deducting effective rainfall from Evapotranspiration for the considered crop (Etc). Water conveyance efficiency is the ratio of the quantity of water to be made available at the field to the quantity of water to be supplied at the source. It has been considered as 85% for both wet and irrigated dry crops. Field efficiency is the ratio of amount of water required at root zone of the crop to the amount of irrigation

water applied to the field. It has been considered as 90% for wet crop and 70% for irrigated dry crops. For computation of water requirement, crop season has been divided into four stages which are initial stage, developing stage, mid season stage and late season or harvesting stage.

II. STUDY AREA

Mid Pennar Reservoir(MPR) is situated across river Pennar near, Penakacherla village, Garladinne Mandal, Anantapur district, Andhra Pradesh, India. The dam site is located at about 40 Km from Anantapur town. Water from MPR is being supplied to the ayacut through two main canals, Mid Pennar North Canal (MPNC) and Mid Pennar South Canal (MPSC). MPSC having 30 distributaries, mainly supplies water to the ayacut in Garladinne, Anantapur, B.K. Samudram, Narpala and Singanamala mandals in Anantapur district. Present study is on water utilization for irrigation in 5th distributary of MPSC. 5th Distributory of MPSC is taking off from Km. 15.62 of MPSC and runs for a length of about 28 Km. Total command area under 5th Distributory is 4337.34 Hectares. Study area is situated in between 77° 31' East longitude, 14° 50' North latitude and 77° 45' East longitude, 14° 56' North latitude. An Index Map showing the study area is given in figure 1.

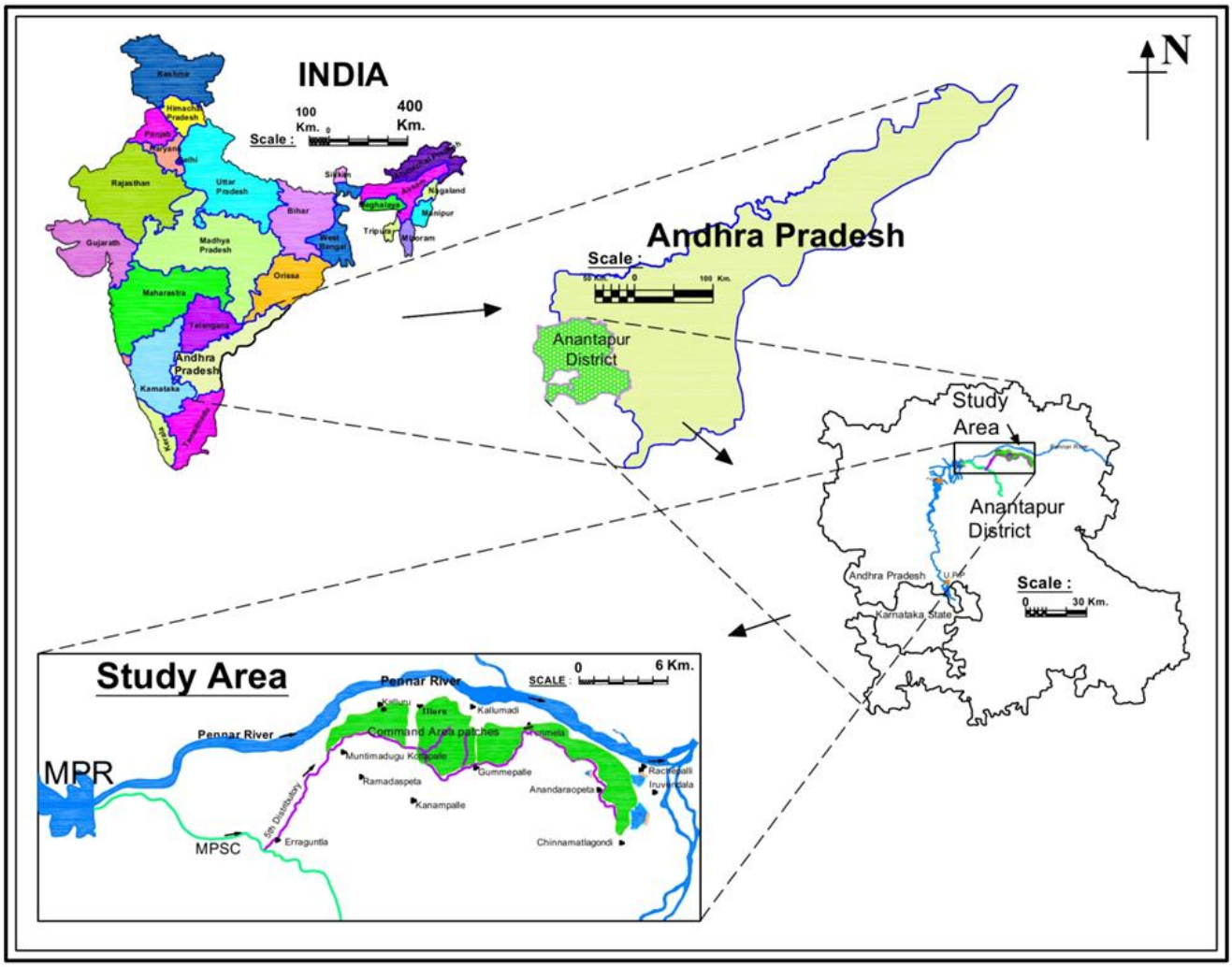

Fig. 1: Index Map showing the study area

III. DATA

Following data has been collected for the present study

1) Rain gauge stations existing in and around the study area have been identified based on Topo sheets with numbers 57F/5, 57F/9 and 57F/13 of scale 1:50,000.
2) Details of area irrigated crop wise and year wise under 5th distributary of MPSC and quantum of water utilized have been collected from Irrigation department.
3) Rain fall particulars of influencing RGS have been collected from Chief Planning Office, Anantapur for the period from 2011-12 to 2014-15.

4) Evapotranspiration (ET_0) values and stage wise crop co-efficients (Kc values) have been collected from Irrigation department.

IV. METHODOLOGY

Rain gauge stations influencing the study area have been determined by constructing Theissen polygons and were presented in figure 2.

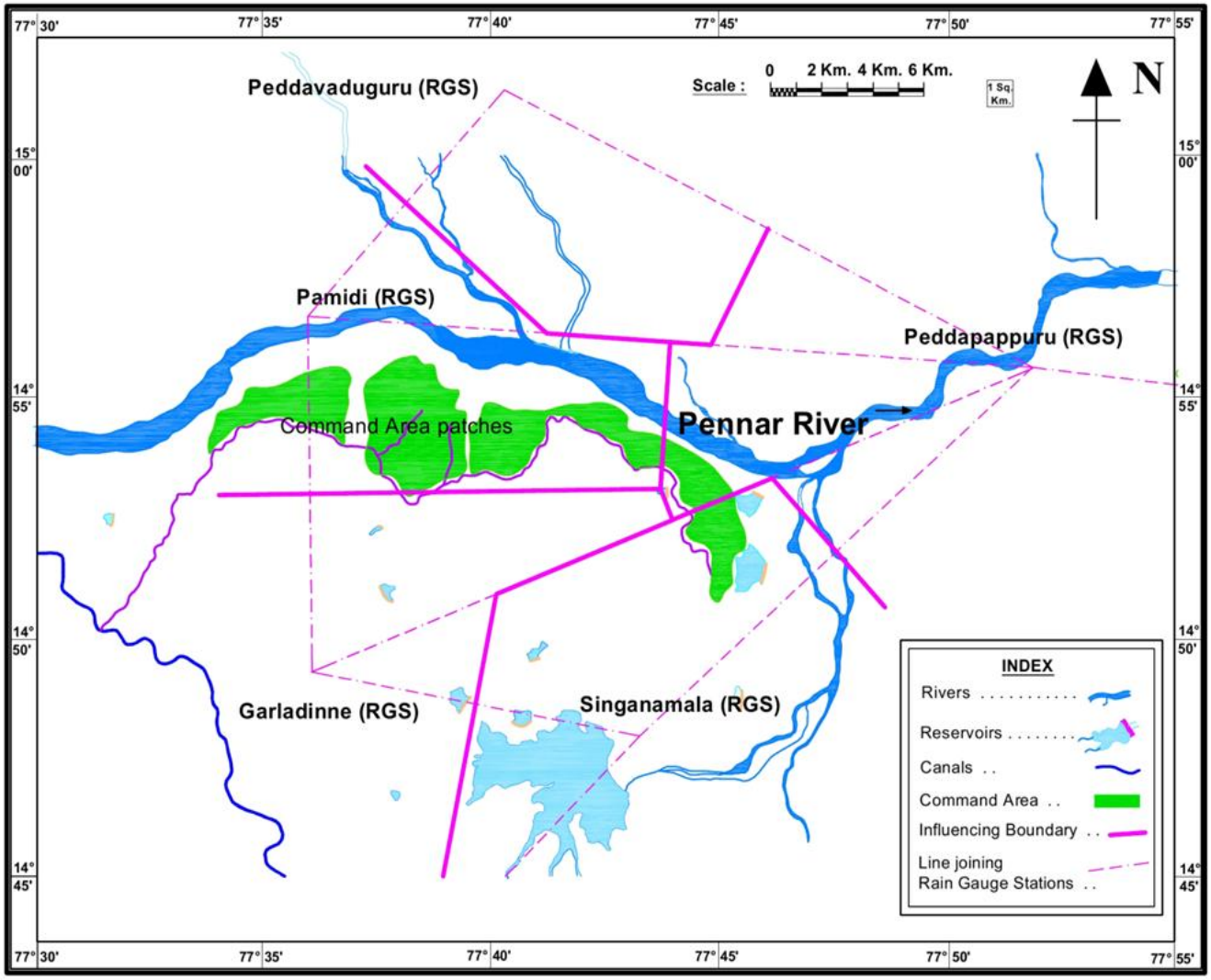

Fig. 2:. Theissen polygons for the study area

From figure 2, it can be observed that three rain gauge stations Pamidi, Singanamala and Peddapappuru are influencing the study area. Percentage of command area being influenced by each rain gauge station has been computed and presented in table 1.

Table 1:
Details of Influencing Rain gauge stations

S. No.	*Name of Rain gauge station (RGS)*	*Command area being influenced in Hectares*	*Percentage area of influence (%)*
1	*Pamidi*	*3483.90*	*80.32*
2	*Singanamala*	*372.80*	*08.60*
3	*Peddapappuru*	*480.64*	*11.08*
	Total :	*4337.34*	*100.00*

Monthly weighted rain fall has been calculated by multiplying the monthly rain fall particulars of the above RGS collected with the percentage influence of respective RGS mentioned in table 1. Sample calculations of weighted rain fall for the month of August, 2011 are given in table 2.

Table 2:
Sample calculations of weighted rain fall for the month of August, 2011

S. No.	*Name of RGS*	*Rain fall for August, 2011in mm*	*Percentage area of influence (%)*	*Weighted rain fall in mm*
1	*Pamidi*	*134.0*	*80.32*	*107.63*
2	*Singanamala*	*57.0*	*08.60*	*4.90*
3	*Peddapappuru*	*147.6*	*11.08*	*16.35*
Total Weight :			*100.00*	*128.88*

Total weighted rain fall for August, 2011 is 128.88 mm or say 128.9 mm. Similarly monthly weighted rain fall has been calculated for entire crop period for the years from 2011-12 to 2014-15 and were shown in table 3.

Table 3:
Monthly weighted rain fall for entire crop period

S. No.	*Year*	*Monthly weighted rain fall in mm*					
		August	*September*	*October*	*November*	*December*	*January*
1	*2011-12*	*128.90*	*39.20*	*91.60*	*25.10*	*0.00*	*7.50*
2	*2012-13*	*126.90*	*106.80*	*71.60*	*47.20*	*2.80*	*0.00*
3	*2013-14*	*102.00*	*204.50*	*78.30*	*16.60*	*0.00*	*0.00*
4	*2014-15*	*35.70*	*57.90*	*55.90*	*21.70*	*4.50*	*0.10*

Monthly weighted rainfall has been used to calculate crop water requirement in the respective months.

A. Computation of Crop Water Requirement:

For computation of crop water requirement, Evapotranspiration (ET_0) values, crop co-efficients (Kc values) and duration of crop stage are required which have been collected from Irrigation department. Monthly ET_0 values are shown in table 4.

Table 4:
Month wise ET_0 Values

S No.	*Month*	*ET_0 (mm)*		*S No.*	*Month*	*ET_0 (mm)*		*S No.*	*Month*	*ET_0 (mm)*
1	*June*	*178.5*		*5*	*October*	*124.8*		*9*	*February*	*142.6*
2	*July*	*160.9*		*6*	*November*	*117.8*		*10*	*March*	*190.4*
3	*August*	*158.1*		*7*	*December*	*114.5*		*11*	*April*	*196.7*
4	*September*	*142.7*		*8*	*January*	*131.0*		*12*	*May*	*199.0*

Crop co-efficients (Kc values) and the duration of crop stage have been shown in table 5.

Table 5:
Crop co-efficients (Kc values) and the duration of crop stage

Name of the Crop	*Initial stage*		*Developing Stage*		*Mid-season stage*		*Harvesting stage*		*Total duration of crop in Days*
	Kc values	*Days*	*Kc values*	*Days*	*Kc values*	*Days*	*Kc values*	*Days*	
Wet (Paddy)	*1.10*	*25*	*1.10*	*30*	*1.05*	*45*	*0.95*	*25*	*125*
Irrigated Dry Crops :									
Groundnut	*0.45*	*20*	*0.75*	*35*	*0.95*	*45*	*0.55*	*25*	*125*
Cotton	*0.35*	*30*	*0.75*	*46*	*1.15*	*50*	*0.65*	*43*	*169*
Maize	*0.35*	*20*	*0.70*	*35*	*1.05*	*40*	*0.55*	*30*	*125*
Pulses	*0.35*	*15*	*0.7*	*25*	*1.05*	*50*	*0.3*	*20*	*110*
Sun flower	*0.35*	*20*	*0.75*	*35*	*1.05*	*45*	*0.4*	*25*	*125*

Details of crops grown and water utilized for 5th distributary of MPSC, collected from irrigation department for the period from 2011-12 to 2014-15 were shown in table 6.

Table 6:
Crops grown and water utilized for 5th distributary of MPSC

S. No.	*Year*	*Crop wise area grown in Hectares*						*Water utilized in M.cum*
		Paddy	*Groundnut*	*Cotton*	*Maize*	*Pulses*	*Sunflower*	
1	*2011-12*	*1290.98*	*323.76*	*182.11*	*-*	*-*	*355.78*	*24.9186*
2	*2012-13*	*829.62*	*728.45*	*364.23*	*-*	*137.6*	*785.07*	*21.8038*
3	*2013-14*	*1621.39*	*303.52*	*161.88*	*-*	*-*	*177.17*	*26.0513*
4	*2014-15*	*877.52*	*364.23*	*728.45*	*202.35*	*95.51*	*123.28*	*24.0691*

Detailed calculations for computation of crop water requirement for wet crop (Paddy) for the year 2011-12 have been presented in table 7.

Table 7:
Computation of crop water requirement for Wet crop (Paddy) for the year 2011-12

S. No.	Description of item	Initial stage		Developing stage		Mid-season stage		Harvesting stage		Total
		Aug (22 to 31)	Sep (1 to 15)	Sep (16 to 30)	Oct (1 to 15)	Oct (16 to 31)	Nov (1 to 29)	Nov 30th	Dec (1 to 24)	
		10 Days	**15 Days**	**15 Days**	**15 Days**	**16 Days**	**29 Days**	**1 Day**	**24 Days**	**125**
1	Evapo transpiration (ETo) values (mm)	51	71.4	71.4	60.4	64.4	113.9	3.9	88.6	
2	Crop Co-efficient (Kc) values	1.10	1.10	1.10	1.10	1.05	1.05	0.95	0.95	
3	Crop water requirement (ETo) x (Kc)	56.1	78.54	78.54	66.44	67.62	119.595	3.705	84.17	
4	Add for Nursery	40								
5	Add for land preparation	160								
6	Add for deep Percolation Losses (3mm / day)	30	45	45	45	48	87	3	72	
7	Add for minimum depth	20	30	30	30	32	58	2	48	
8	Total water Requirement in mm (Sum of rows 3to7)	306.1	153.54	153.54	141.44	147.62	264.595	8.705	204.17	**1379.71 mm**
9	Rain fall in the month	41.58	19.6	19.6	44.32	47.28	24.26	0.84	0	**197.48 mm**
10	Effective Rainfall (50%)	20.79	9.8	9.8	22.16	23.64	12.13	0.42	0	**98.74 Mm**
11	Net Irrigation Requirement (NIR) (8 -10)	285.31	143.74	143.74	119.28	123.98	252.465	8.285	204.17	**1281 mm**
12	Requirement at 90% Field Irrigation efficiency(FIR) (11/0.90)	317.01	159.71	159.71	132.53	137.76	280.52	9.21	226.86	**1423.3 mm**
13	Requirement at Canal head at 85% Conveyance efficiency (12/0.85)	372.95	187.89	187.89	155.92	162.07	330.02	10.84	266.89	**1674.5 mm**
14	Total Requirement in mm	373	188	188	156	162	330	11	267	**1675 mm**
15	Total Requirement per Ha. (cum)	3730	1880	1880	1560	1620	3300	110	2670	**16750 cum**

In the above calculations, water requirement for nursery (40 mm), land preparation (160 mm), deep percolation losses (@ 3 mm /day) and for minimum depth of water (@ 60 mm/ month) has been considered to evaluate the total water requirement. From table 7 it has been observed that total water requirement for entire crop season is 16750 cum.

Total extent of paddy raised during 2011-12 is 1290.98 Ha. (From table 6).

Total water requirement = Extent of crop x water requirement per Ha. = 1290.98 x 16750 = 21623915 cum.

Or 21.6239 M.cum.

Similarly, detailed calculations for computation of crop water requirement for irrigated dry crop (Ground nut) for the year 2011-12 were shown in table 8.

Table 8:
Computation of crop water requirement for irrigated dry crop (Ground nut) for the year 2011-12

S. No.	Description of item	Initial stage		Developing stage		Mid-season stage		Harvesting stage		
		Aug (22 to 31)	Sep (1 to 10)	Sep (11 to 30)	Oct (1 to 15)	Oct (16 to 31)	Nov (1 to29)	Nov 30th	Dec (1 to 24)	Total
		10 Days	**10 Days**	**20 Days**	**15 Days**	**16 Days**	**29 Days**	**1 Day**	**24 Days**	**125 Days**
1	Evapo transpiration (ETo) values (mm)	51	47.6	95.1	60.4	64.4	113.9	3.9	88.6	
2	Crop Co-efficient (Kc) values	0.45	0.45	0.75	0.75	0.95	0.95	0.55	0.55	
3	Crop water requirement (ETo) x (Kc)	22.95	21.42	71.325	45.3	61.18	108.205	2.145	48.73	

4	*Add for initial watering*	*10*								
5	*Total water Requirement in mm (3+4)*	*32.95*	*21.42*	*71.325*	*45.3*	*61.18*	*108.205*	*2.145*	*48.73*	***391.26 mm***
6	*Rain fall in the month*	*41.58*	*13.07*	*26.13*	*44.32*	*47.28*	*24.26*	*0.84*	*0*	***197.48 mm***
7	*Effective Rainfall (50%)*	*20.79*	*6.54*	*13.07*	*22.16*	*23.64*	*12.13*	*0.42*	*0*	***98.75 mm***
8	*Net Irrigation Requirement (NIR) (5 -7)*	*12.16*	*14.88*	*58.255*	*23.14*	*37.54*	*96.075*	*1.725*	*48.73*	***292.51 mm***
9	*Requirement at 70% Field Irrigation efficiency (FIR) (8/0.70)*	*17.37*	*21.26*	*83.22*	*33.06*	*53.63*	*137.25*	*2.46*	*69.61*	***417.86 mm***
10	*Requirement at Canal head at 85% Conveyance efficiency (9/0.85)*	*20.44*	*25.01*	*97.91*	*38.89*	*63.09*	*161.47*	*2.89*	*81.89*	***491.59 mm***
11	*Total Requirement in mm*	*20*	*25*	*98*	*39*	*63*	*161*	*3*	*82*	***491 mm***
12	*Total Requirement per Ha. (cum)*	*200*	*250*	*980*	*390*	*630*	*1610*	*30*	*820*	***4910 cum***

In the above calculations, provision has been made towards initial watering (10 mm) to evaluate the total water requirement. From table it has been observed that total water requirement for entire crop season is 4910 cum.
Total extent of Groundnut raised during 2011-12 is 323.76 Ha. (From table 6).
Total water requirement = Extent of crop x water requirement per Ha. = 323.76 x 4910 = 1589661 cum.
Or 1.5897 M.cum.

Same procedure has been followed for crops Cotton, Sunflower, Maize and Pulses which were grown in the respective years to obtain total water requirement.

V. RESULTS

Year wise quantum of water required for each and every crop has been shown in table 9.

Table 9:
Computed crop water requirement for all crops

S. No.	*Name of Crop*	*Crop water requirement in M.cum during the year*			
		2011-12	*2012-13*	*2013-14*	*2014-15*
1	*Wet (Paddy)*	*21.6239*	*13.4979*	*25.7315*	*14.9793*
Irrigated Dry Crops:					
2	*Groundnut*	*1.5897*	*3.1469*	*1.2110*	*1.9413*
3	*Cotton*	*1.3112*	*2.4331*	*1.0684*	*5.6673*
4	*Maize*	-	-	-	*1.0421*
5	*Pulses*	-	*0.4981*	-	*0.4384*
6	*Sunflower*	*1.7184*	*3.3287*	*0.7051*	*0.6435*
Total water requirement:		***26.2432***	***22.9047***	***28.7160***	***24.7119***

Details of computed water requirement and actual water utilized are shown in table 10.

Table 10:
Computed water requirement and actual water utilized

S. No.	*Year*	*Computed water requirement in M.cum*	*Actual water utilized in M.cum*
1	*2011-12*	*26.2432*	*24.9186*
2	*2012-13*	*22.9047*	*21.8038*
3	*2013-14*	*28.7160*	*26.0513*
4	*2014-15*	*24.7119*	*24.0691*

A graphical representation of the above values is shown in figure 3.

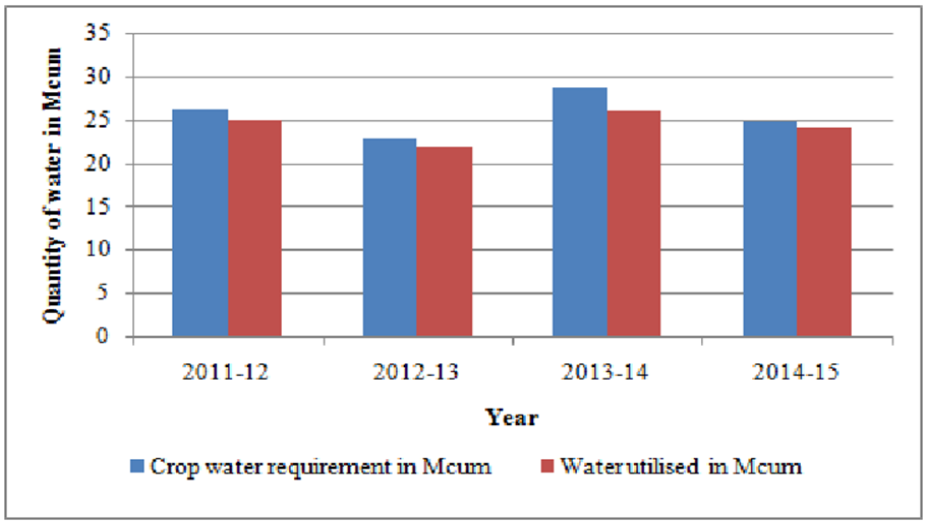

Fig. 3: Comparison of Computed water requirement and actual water utilized

From the figure, it is clear that the actual water utilized is less than the computed water requirement. It may imply that the actual realization of water by plant might be more effective than the computed value. It means that the effective rainfall might be more than the considered effective rainfall (50% of the rain fall occurred during the crop period). In case of irrigated dry crops chances of increase in effective rain fall may not be possible due to dry conditions of the field surface and long spells of water application which may cause more losses and affect the effective utilization of rainfall by the plants. Hence, the possibility to get increased utilization of water by the plants might be in wet crop i.e. Paddy.

The actual effective rainfall for the year, 2011-12 can be calculated as follows.

Water utilised for wet crop = Total water utilised - water requirement for ID crops

= 24.9186 - 4.6193 = 20.2993 M.cum

= 20299300 cum

Area of paddy crop grown during 2011-12 = 1290.98 Ha. = 12909800 Sq.m

Depth of water utilized during the entire crop period (at source) = 20299300 ÷ 12909800 = 1.572395 m

= 1572.395 mm

Depth of water at field (considering the conveyance efficiency as 85%) = 1572.395 x 85 ÷ 100

= 1336.536 mm

Actual water consumed by the crop (considering the field efficiency as 90%) = 1336.536 x 90 ÷ 100

= 1202.882 mm

Actual water requirement as per row No. 8 of table 7 = 1379.71 mm

Effective rainfall useful during the crop period = 1379.71-1202.882 = 176.828 mm

Actual weighted rainfall during the crop period (row No 9 of table 7) = 197.48 mm

Percentage of rainfall effective for the wet (Paddy) crop during 2011-12 = 176.828 ÷ 197.480 = 89.54%

Similarly, the realized effective rainfall has been computed for the years 2012-13, 2013-14, 2014-15 and presented in table 11.

Table 11:
Year wise realized effective rainfall

S. No.	*Year*	*Effective rainfall for wet crop (%)*
1	*2011-12*	*89.54*
2	*2012-13*	*88.02*
3	*2013-14*	*87.69*
4	*2014-15*	*87.17*

As per the results presented in table 11, it can be observed that the realized percentage effective rainfall is in the range of 87% to 90% for wet crops in the command area of 5th distributary of Mid Pennar South Canal.

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