ESTIMATION OF CROP WATER REQUIREMENT FOR VENNA BASIN, MAHARASHTRA

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ABSTRACT
Estimating the water availability in a river basin has always been a major issue in the management of water resources of a basin. The estimation of crop water requirement i.e. the water required for irrigating the crops over and above the requirement met from rainfall is very much essential for proper management of the crop water supply and achieving maximum yield. The present study aims to estimate the crop water requirement of Venna river basin by Modified Pennman method. Food and Agriculture Organization (1984) Modified Pennman method is a globally accepted method for crop water requirement estimation which gives the most accurate results.
Index terms: Crop water requirement, Evapotranspiration, Modified Pennman method.

I. Introduction

Water and Food have always been a matter of concern for the mankind ever since its evolution. As the populations grew, the utilisation of water increased manifold and so the food requirement. For growing healthy crops and achieving maximum yield, the water requirement for every crop should be fulfilled. The estimation of the crop water requirement is a vital parameter in overall management of the water resources in the river basin. The correct and assured supply of water for crops ensures the better yield and good quality produce. Food and Agricultural Organization FAO (1984) United States has defined crop water as 'the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease free, growing in large fields under non restricting conditions and achieving full production under given growing environment'.

A. The Study Area

The present study was carried for Venna river basin in Vidarbha, Maharashtra, India. The study area lies between 21^0 00'00" N and 23^0 01'00" N latitude and 78^0 18'00" E and 79^0 06'15" E longitude. The basin is spread in Wardha, Nagpur and Chandrapur districts of Vidarbha, Maharashtra. The total area of the basin is 5674.57 Sq. Km out of which, Wardha district contributes 3278.96 Sq. Km, Nagpur 2120.99 Sq. Km while Chandrapur district contributes a small area of 274.63 Sq. Km. Most of the area within the basin is underlain with basaltic formation, whereas small areas have alluvium, limestone and sandstone. Average annual monsoon rainfall over the basin ranges from 900 – 1100 mm. Venna river originates at village Khairi in Katol tehsil of Nagpur districts and after flowing a distance of 163 km, and meets Wardha river at village Dindora in Warora tehsil of Chandrapur district.

A. Input Data:

The data for various Kharif and Rabi crops like tehsil wise sown area, yield and productivity was collected for the year 2000 – 2015 from Agriculture department, Govt. of Maharashtra. This input was used for the calculations of crop water requirement for various crops. Wheat and Gram are the major Rabi crops where as Soybean and Cotton are major Kharif crops in the basin. The daily rainfall data and the crop coefficients were taken from Agriculture department Govt of Maharashtra. Similarly, the data for fortnightly

evapotranspiration was collected from Water Resources Department, Govt of Maharashtra.

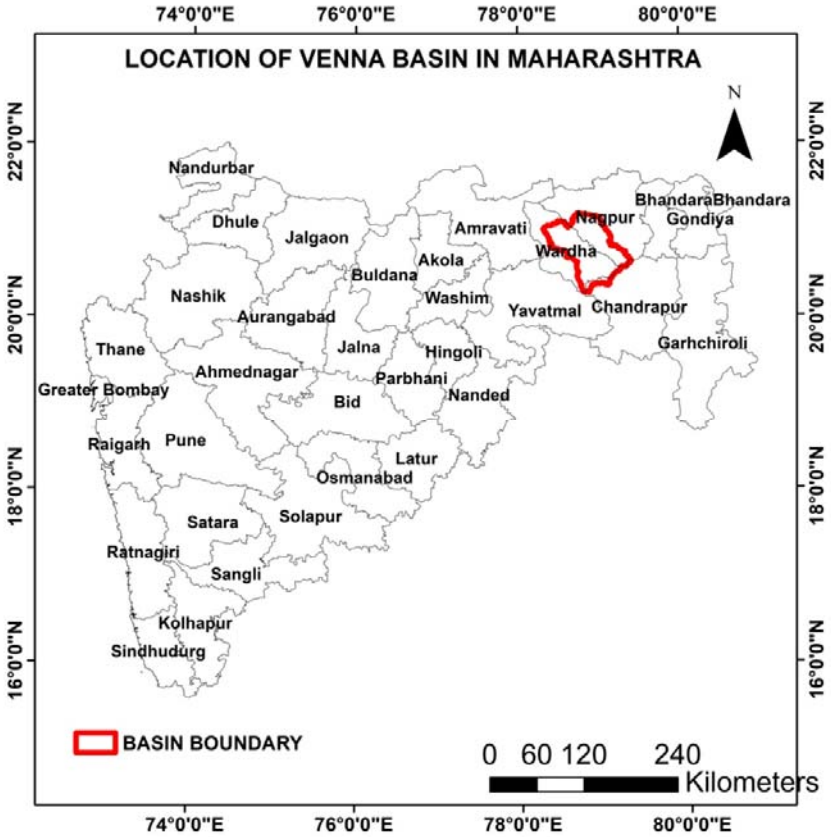

Fig 1: Location map of Venna Basin in Maharashtra

II. Material and Methods:

B. Crop water requirement estimation:

The water required for the healthy growth of the crops is called as the Crop water requirement. The required water is defined as the amount of water needed to meet the loss of water through evapotranspiration. The water supplied through irrigation includes other losses like lateral run off, leakages etc. but is not accounted for in the estimation. Food and Agricultural Organization FAO (1984) defined crop water as 'the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease free, growing in large fields under non restricting conditions and achieving full production under given growing environment'.

Evapotranspiration (ET) is the process by which water is released into the air by evaporation from the soil and transpiration from plant surfaces. Evapotranspiration is the total movement of water vapour into the air from land which supports plant life. It includes transpiration from the plants, evaporation from soil and evaporation from any open water that may be present in ponds following irrigation or heavy rainfall. It is expressed in terms of depth of water (millimetres), and the rate of evapotranspiration in millimetres per hour. Out of the total evapotranspiration, evaporation account for about 10 percent and plant transpiration for the remaining 90 percent [1]. Evapotranspiration is caused by an energy gradient difference between water in plants and soil and water in the atmosphere. It is influenced by climatic factors, such as sunshine, temperature, humidity and wind speed. Hence the crop water requirement includes all losses like:

a) Transpiration loss through leaves (T)

b) Evaporation loss through soil surface in cropped area (E)

c) Amount of weather used by plants (WP) for its metabolism.

Potential evapotranspiration is defined as "the rate of evapotranspiration from an extensive

surface of 8 to 15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water" [2]. As the definition suggests that the PET is for a grass reference ETo. The concept of reference ET is being used to avoid ambiguities associated in the definition of PET [3] [4]. There are many methods of estimation of crop water requirement but Penman- Monteith equation for calculation of PET is recommended as the standard equation by the Food And Agriculture Organisation (FAO). Reference [5] compared various method of estimation of evapotranspiration and compared the results with Modified Penmann method. Reference [6] compared the temperature based and radiation based of estimation of evapotranspiration with Penmann method and concluded that radiation based methods are more suitable.

FAO-24 Modified Penman (1977) Method

$$PET = [WRn + (1-w)\, f(u)(ea-ed)]\, c$$

Where,
PET = potential evapotranspiration (mm/day)
W = temperature related weighing factor
Rn = net radiation (mm/day)
f(u) = wind related function
(ea-ed) = difference between saturation vapour pressure S.V.P. at mean air temperature and mean actual vapor pressure of air (mb)
c = correction factor

The agricultural crop year in India is from July to June. The Indian cropping season is classified into two main seasons-(i) Kharif and (ii) Rabi based on the monsoon.

a) Kharif: Crops are sown at the beginning of the south-west monsoon and harvested at the end of the south-west monsoon.

Sowing seasons - May to July
Harvesting season-September to October
Important crops: Cotton, Soybean, Jowar, bajra, rice, maize, groundnut, sugarcane etc.

b) Rabi: Crops need relatively cool climate during the period of growth but warm climate during the germination of their seed and maturation.
Sowing season - October-December
Harvesting season - February-April
Important crops: wheat, gram, barley, linseed, mustard, masoor, potatoes etc.

II. Result And Discussion:

A. Crop Water requirement estimation

The crop water requirement for total ten crops including Kharif Jowar, Tur/Mung/ Udid, Groundnut, Soybean, Cotton, Sugarcane, Kharif Paddy, Maize, Wheat and Gram was computed in the study. However, in Venna basin, Soybean and Cotton are major Kharif crops whereas, Wheat and Gram are the major Rabi crops. The crop water requirement was computed for 8 crops of kharif and 2 crops of Rabi, but it was observed that the sown area of other crops excluding soybean and cotton in kharif, and wheat and gram in Rabi, is less than 5-8%. The crop water requirement for these ten crops was computed by FAO-24 Modified Penman method. The crop water requirement is computed tehsil wise for these crops for the period from year 2000 -2015. The Venna basin is spread over 14 tehsils and the details about the tehsil wise crops sown was collected from the Agricultural department, Govt of Maharashtra. The crop sown area for the year 2001-02 for 14 tehsils of the basin is given below.

Table 1: Crop sown area for various crops in Venna Basin for year 2001-2002

2001-02 (AREA SOWN IN HA) TAHSIL NAME	KJ	T/M/U	GN	SB	C	SG	KP	M	W	G
ARVI	6150	8157	75	14250	22875	0	15	0	1110	1115
KARANJA	4350	5620	1540	19550	11510	0	40	0	2075	2810
WARDHA	8372	14523	9	11153	18472	0	94	0	1987	2750
SELOO	4215	6135	0	11135	21865	0	0	0	3410	1980
HINGANGHAT	7415	11965	10	14680	22120	0	50	0	4800	4860
SAMUDRAPUR	3010	10395	0	29010	25250	0	45	0	4210	5155
NAGPUR	3200	3894	10	11444	12554	240	27	0	3808	2878

HINGNA	6750	4998	10	5563	18250	50	15	0	1298	718
KATOL	12950	9775	4900	14225	10800	0	35	0	1658	3850
KALMESHWAR	9530	6670	1200	7730	13500	116	0	0	2980	1420
UMRER	134	3655	0	29115	7620	219	1910	0	6286	5546
BHIWAPUR	0	2040	0	21810	1425	0	3070	0	5058	1900
WARORA	1680	6100	0	18000	24000	500	3310	0	7500	5870
CHIMUR	0	4920	0	25000	1200	0	17700	0	5030	2730
TOTAL in Ha.	**67756**	**98847**	**7754**	**232665**	**211441**	**1125**	**26311**	**0**	**51210**	**43582**

KJ- Kharif Jowar, T/M/U- Tur/Mung/ Udid, GN- Ground Nut, SB-Soya Bean, C-Cotton, SC-Sugar-Cane, KP- Kh. Paddy, M- Maize, W- Wheat, G- Gram

The FAO-24 Modified Penman method uses average rainfall for a fortnight, hence, the daily rainfall data was averaged at every fortnight for all the months of the year from 2000 – 2015 and is presented in the following Table 2.

Table 2: Average fortnightly rainfall for Venna Basin Tehsils for year 2000 – 2015

AVG RF 2000 - 2015 (mm)	**ARVI**		**KARANJA**		**WARDHA**		**SELOO**		**HINGANGHAT**	
FORTNIGHT	I	II	I	II	I	II	I	II	I	II
Jan	1.07	1.67	2.66	2.81	3.10	5.20	2.08	2.88	2.51	7.83
Feb	1.40	2.00	1.19	1.78	2.06	2.29	1.54	2.60	2.08	2.54
March	9.60	1.97	8.21	2.02	7.06	5.17	8.02	3.62	6.18	3.53
April	3.00	1.63	0.06	0.25	3.07	1.98	2.21	1.06	1.40	1.80
May	4.43	6.36	3.35	4.99	4.71	3.77	4.26	9.28	3.57	4.19
June	87.46	109.32	46.76	113.54	53.80	119.81	54.20	133.19	64.73	137.40
July	118.90	167.05	108.37	160.48	121.36	152.85	118.08	171.65	126.41	171.93
August	130.21	114.61	117.31	106.29	129.21	120.97	114.50	135.25	144.79	138.20
September	106.70	44.74	105.45	50.65	112.79	45.46	114.16	58.52	109.60	52.29
October	35.21	11.84	37.49	12.53	34.19	16.49	36.61	15.77	45.30	9.56
November	6.57	5.82	8.31	9.00	6.71	4.61	7.94	5.61	9.44	1.68
December	2.09	1.96	2.65	3.13	4.53	3.58	3.70	2.63	2.16	1.64

AVG RF 2000 - 2015	**SAMUDRPUR**		**NAGPUR**		**HINGNA**		**KATOL**		**KALMESHWAR**	
FORTNIGHT	I	II	I	II	I	II	I	II	I	II
Jan	5.73	7.33	2.54	7.15	1.81	4.31	2.82	3.16	2.95	3.26
Feb	2.56	2.74	4.06	2.12	6.89	2.66	2.78	1.41	6.74	2.64
March	3.83	3.59	8.35	5.74	5.44	5.77	7.60	3.07	10.96	6.11
April	2.76	3.12	3.12	2.78	3.73	3.25	3.13	1.00	4.24	3.84
May	4.63	4.91	4.94	5.55	4.32	5.67	2.91	2.55	7.01	5.17
June	61.20	138.01	51.24	126.10	50.68	114.64	27.11	104.03	35.73	111.44
July	150.74	167.28	142.38	195.80	125.75	176.56	120.43	145.26	112.19	159.55

August	124.80	125.14	135.36	141.10	122.90	117.18	94.40	102.55	113.01	120.63
September	120.47	57.05	125.50	68.33	101.78	54.01	91.79	42.95	90.71	51.20
October	48.60	11.51	35.39	14.05	25.94	13.36	21.43	20.13	23.91	19.54
November	7.79	2.38	7.12	5.52	4.96	3.89	5.25	10.76	6.95	8.24
December	3.78	3.22	3.06	3.71	3.41	2.83	3.06	2.19	2.85	2.63

AVG RF 2000 - 2015	**UMRER**		**BHIWAPUR**		**WARORA**		**CHIMUR**	
FORTNIGHT	I	II	I	II	I	II	I	II
Jan	4.42	10.26	5.39	7.56	0.52	6.57	0.15	4.67
Feb	1.92	3.36	1.23	1.42	3.54	0.11	2.81	0.00
March	8.65	3.43	9.45	6.35	3.43	3.48	1.66	1.09
April	4.11	3.25	5.13	4.33	0.85	0.94	1.68	0.86
May	3.24	3.57	7.98	5.50	2.43	6.09	3.01	0.07
June	38.87	125.51	34.40	125.40	52.78	126.75	43.06	102.41
July	127.00	184.39	140.39	176.33	134.34	185.74	129.18	160.04
August	125.98	136.36	122.53	145.63	137.00	137.17	135.76	127.64
September	105.88	45.01	113.17	59.07	90.77	56.92	106.24	35.24
October	30.76	17.09	32.48	22.06	33.90	15.76	31.98	16.56
November	6.94	2.21	4.56	3.44	6.76	1.01	6.33	0.45
December	3.29	1.27	2.59	2.20	0.00	0.00	0.00	0.19

Table 3 Crop coefficients for various crops

SR. NO.	**NAME OF CROP**	**FORTNIGHT**	**CROPPING PERIOD IN FORTNIGHT**	**CROP COEFFICIENTS**							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
I	**KHARIF CROP**										
2	Rice Transport (flooded)	June-II	8	1.06	1.14	1.15	1.15	1.15	1.15	1.04	0.98
5	Groundnut	June-II	8	0.48	0.54	0.82	0.97	1	1	0.93	0.69
6(a)	Maize	June-II	7	0.49	0.59	0.91	1.1	1.1	1	0.72	
7	Pulses	July-I	5	0.5	0.75	1.1	1.1	0.65			
10	Soybean (120 days)	July-I	8	0.15	0.22	0.52	0.84	1.02	1.02	0.94	0.62
II	**RABI CROPS**										
1	Wheat	Nov-I	8	0.28	0.56	1.02	1.15	1.15	1.15	0.94	0.42
4	Gram	Oct-II	7	0.29	0.39	0.85	1.1	1.1	0.84	0.43	
IV	**TWO SEASONALS CROPS**										
1	Cotton L.S	April-I	13	0.22	0.27	0.39	0.61	0.86	1.06	1.1	1.1
				1.1	1.05	0.94	0.83	0.71			
	PERRINIAL CROPS										
1	Sugarcane	Jan-I	24	0.75	0.75	0.8	0.86	0.91	0.96	1.01	1.05
				1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.01
				0.98	0.97	0.97	0.94	0.82	0.7	0.72	0.74

The crop coefficient data for every fortnight was collected from the agricultural department Govt. of Maharashtra is shown in Table 3 above. The fortnightly evapotranspiration values for the basin area were collected from Water Resources Department, Govt. of Maharashtra as given in Table 4 and the mean fortnightly consumptive use is computed and shown in Table 5. Reference [7] prepared a computer model for computing crop water requirement and concluded that the results were comparable with the traditional methods.

Table 4: Fortnightly evapotranspiration for Venna Basin

SN	FORTNIGHT	ET_O (MM)	SN	FORTNIGHT	ET_O (MM)
1	JAN I	73.08	13	JULY I	72.14
2	JAN II	86.26	14	JULY II	64.56
3	FEB I	89.81	15	AUG I	59.85
4	FEB II	80.90	16	AUG II	69.56
5	MARCH I	95.74	17	SEPT I	65.31
6	MARCH II	107.92	18	SEPT II	77.98
7	APRIL I	103.71	19	OCT I	87.02
8	APRIL II	105.95	20	OCT II	95.28
9	MAY I	122.43	21	NOV I	84.36
10	MAY II	147.36	22	NOV II	78.32
11	JUNE I	123.51	23	DEC I	73.77
12	JUNE II	85.56	24	DEC II	78.67

Table 5 Mean fortnightly consumptive use , mm (ET crop)

Fortnightly Mean rainfall mm	Mean fortnightly consumptive use ,mm (ET crop)									
	12.5	25	37.5	50	62.5	75	87.5	100	112.5	125
	Mean fortnightly effective rainfall,mm									
6.25	3.80	4.00	4.40	4.50	4.60	5.00	5.30	5.60	5.90	6.25
12.50	7.50	8.10	8.80	9.00	9.30	9.90	10.30	11.00	12.30	12.50
18.75	11..0	12.00	13.10	13.80	14.10	14.60	15.50	16.50	18.50	18.75
25.00	12.50	16.10	17.30	17.90	18.40	19.50	20.30	21.90	23.50	25.00
31.25		19.90	21.30	22.30	23.00	24.30	25.30	26.90	28.00	31.25
37.50		23.10	24.90	26.40	27.50	28.80	30.10	31.90	33.80	36.90
43.75		25.00	28.40	30.10	31.90	33.00	34.90	36.90	38.90	42.30
50.00			31.90	33.90	36.00	37.10	39.40	41.50	43.90	47.50
56.25			35.30	37.50	40.10	41.30	43.00	46.40	49.00	52.50
62.50			37.50	40.80	43.90	45.30	47.90	51.00	54.00	57.50
68.75				44.40	47.60	49.40	52.00	55.50	59.00	63.00
75.00				47.00	51.00	53.00	56.00	60.00	63.50	68.00
81.25				50.00	54.50	56.50	60.00	64.00	67.50	72.50
87.50					57.50	60.00	63.50	67.50	71.50	77.00

93.75					60.50	63.00	67.00	71.00	75.50	80.50
100.00					62.50	66.50	70.00	74.00	79.00	84.00
112.50						72.00	71.50	88.00	85.50	91.00
125.00						75.00	80.00	85.00	91.50	97.00
137.50							87.50	90.50	97.00	102.50
150.00								95.50	101.50	107.50
162.50								99.00	106.50	112.00
175.00								100.00	110.00	116.00
187.50									112.50	120.00
200.00										123.00
212.50										125.00
225.00	12.50	25.00	37.50	50.00	62.50	75.00	87.50	100.00	112.50	125.00

Annual crop water requirement for each crop is computed for the year 2000 – 2015 using the spatial and digital data. The calculations for crop water requirement for Soybean for the year 2001-02 in Hingna tehsil is given in the following Table 6. The data was plotted spatially based on the maps prepared from remote sensing data and tehsil maps (Fig. 3). Reference [8] explained that estimation of evapotranspiration by remote sensing yield very good results.

Table 6: Crop water requirement calculation for soybean in hingna tehsil

CROP WATER REQUIREMENT CALCULATION FOR SOYBEAN IN HINGNA TEHSIL								
Year 2001-02	**JULY FORTNIGHT**		**AUG. FORTNIGHT**		**SEPT. FORTNIGHT**		**OCT. FORTNIGHT**	
	I	**II**	**I**	**II**	**I**	**II**	**I**	**II**
AVG RF (MM)	125.75	176.56	122.90	117.18	101.78	54.01	25.94	13.36
CROP COEFF. (Kc)	0.15	0.22	0.52	0.84	1.02	1.02	0.94	0.62
ET_O (FORTNIGHTLY)	72.14	64.56	59.85	69.56	65.31	77.98	95.28	95.28
CONSUMPTIVE USE ETC $=ET_O$ x Kc	10.82	14.20	31.12	58.43	66.62	79.54	89.56	59.07
Land preparation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nursery requirement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deep percolation loses 3mm/day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total water requirement (mm)	10.82	14.20	31.12	58.43	66.62	79.54	89.56	59.07
Effective rainfall in (mm)	10.82	14.20	31.12	58.43	64.08	40.49	21.32	9.88
Net irrigation requirement NIR (mm)	0.00	0.00	0.00	0.00	2.54	39.05	68.24	49.19
GROSS IRRIGATION Requirement (MM3) GIR = NIR/ (field efficiency 50%)	0.00	0.00	0.00	0.00	5.07	78.10	136.49	98.39
CROP AREA	5563	5563	5563	5563	5563	5563	5563	5563
GROSS IRRIGATION REQ (MM3)	0.00	0.00	0.00	0.00	0.28	4.34	7.59	5.47
TOTAL	17.69	MM3						

Similar computations were done for other crops for fifteen years from 2000-2015. The tehsil wise area for Venna basin was calculated and the crop water requirement for each tehsil

for the basin area is calculated. Yearly crop water requirement for Hingna tehsil for the years 2000 – 2015 is given in the following Table 7.

Table 7: The crop water requirement for Hingna Tehsil for fifteen years

HINGNA	WHEAT	GRAM	KH. JOWAR	TUR/MUNG/UDID	GROUNDNUT	SOYBEAN	COTTON	SUGARCANE	KH. PADDY	MAIZE	TOTAL	TEHSIL AREA	BASIN TEHSIL AREA	TEHSIL BASIN CWR	AVG CWR (MM^3)
2001-02	13.3	5.3	1.7	0.3	0.0	17.7	118.2	1.4	0.2	0.0	158.1	999	849	134.4	174
2002-03	17.5	6.1	1.5	0.3	0.0	23.9	115.6	1.1	0.1	0.0	166.1			141.2	
2003-04	20.1	18.9	1.2	0.3	0.0	39.9	109.8	1.7	0.0	0.0	192.0			163.1	
2004-05	15.1	10.3	1.3	0.3	0.0	165.4	109.2	0.0	0.0	0.0	301.5			256.2	
2005-06	21.9	10.1	1.1	0.3	0.0	39.0	106.2	0.0	0.1	0.0	178.6			151.8	
2006-07	22.0	16.1	0.9	0.3	0.0	44.3	103.4	0.0	0.1	0.0	187.0			158.9	
2007-08	22.7	16.6	0.6	0.3	0.0	55.3	88.7	0.0	0.1	0.0	184.3			156.6	
2008-09	21.7	19.7	0.4	0.3	0.0	64.0	64.7	0.0	0.0	0.0	170.9			145.3	
2009-10	42.7	20.3	0.4	0.2	0.0	49.5	92.6	0.0	0.0	0.0	205.6			174.8	
2010-11	44.3	22.9	0.2	0.3	0.0	35.2	118.6	0.0	0.0	0.0	221.6			188.3	
2011-12	44.5	19.3	0.1	0.3	0.0	46.3	118.9	1.0	0.0	0.0	230.3			195.7	
2012-13	40.5	18.1	0.2	0.3	0.0	40.0	121.7	1.0	0.0	0.0	221.8			188.5	
2013-14	54.5	22.6	0.1	0.3	0.0	38.9	114.5	1.0	0.0	0.1	232.0			197.1	
2014-15	32.7	9.1	0.0	0.2	0.0	17.6	158.7	1.0	0.0	0.1	219.6			186.6	
2015-16	25.8	6.1	0.1	0.3	0.0	14.6	153.7	0.8	0.0	0.0	201.4			171.1	

Table 8. Tehsil wise Annual crop water requirement for Venna basin

TEHSIL WISE ANNUAL CROP WATER REQUIREMENT FOR VENNA BASIN															
YEAR / TEHSIL	ARVI	KARANJA	WARDHA	SELOO	HINGANGHAT	SAMUDRAPUR	NAGPUR	HINGNA	KATOL	KALMESHWAR	UMRER	BHIWAPUR	WARORA	CHIMUR	ANNUAL CWR (MM^3)
2001-02	89.6	57.3	80.0	215.8	155.1	305.9	87.5	134.4	35.8	20.1	145.6	52.8	88.1	9.3	1477.2
2002-03	79.4	50.7	78.6	194.9	137.5	280.6	75.1	141.2	35.9	19.4	129.7	43.6	60.8	8.4	1335.9
2003-04	78.7	51.3	82.3	195.7	137.8	274.5	81.2	163.1	39.8	21.0	161.2	52.1	78.3	9.8	1426.8
2004-05	77.0	43.7	66.3	193.4	125.8	224.9	71.6	256.2	35.3	18.9	131.6	50.9	63.0	9.4	1368.1
2005-06	80.9	51.5	78.4	215.4	146.9	244.4	80.5	151.8	40.4	21.4	156.4	60.4	68.2	8.4	1405.0

2006-07	86.6	52.6	80.2	214.8	144.5	264.8	78.3	158.9	44.1	22.1	144.8	55.4	75.6	9.2	1431.9
2007-08	87.2	55.8	81.6	222.1	156.6	266.3	74.8	156.6	43.0	22.5	134.3	41.1	72.8	10.3	1425.0
2008-09	78.4	43.8	83.8	190.8	129.6	240.6	59.4	145.3	41.4	19.7	127.8	49.0	93.0	9.2	1311.7
2009-10	89.6	54.5	93.2	254.7	165.7	345.6	65.9	174.8	49.7	22.5	196.6	96.9	66.5	8.2	1684.4
2010-11	98.5	64.8	103.1	257.2	207.1	442.6	80.7	188.3	53.2	25.8	195.0	104.5	114.4	9.6	1944.9
2011-12	107.3	54.9	106.1	232.2	180.2	364.3	64.7	195.7	46.4	21.1	155.1	101.5	95.7	9.3	1734.5
2012-13	105.3	58.0	144.2	255.0	223.8	379.9	65.2	188.5	53.8	25.1	181.7	109.1	97.9	10.5	1897.9
2013-14	104.9	60.8	145.3	267.4	224.8	387.4	72.8	197.1	57.2	25.3	183.7	111.4	95.6	12.2	1945.7
2014-15	112.5	65.0	126.3	279.4	211.9	331.6	76.4	186.6	61.8	29.2	163.7	78.7	85.0	10.2	1818.4
2015-16	109.6	67.7	125.6	298.5	213.7	369.7	76.4	171.1	64.1	27.3	173.5	72.9	85.4	12.2	1867.9

Table 9 Tehsil wise Annual crop water requirement for Venna basin

CWR: Crop Water Requirement

The tehsil wise crop water requirement is shown in Fig 2 in ascending order. The crop water requirement is minimum for Chimur tehsil while it is maximum for Samudrapur tehsil. The requirement is for the portion of tehsil inside the Venna river basin area. The crop water requirement is the demand of water for irrigation over and above the water received by crops from rainfall. Hence, from the study of fifteen years from 2000-15, it is observed that in the Samudrapur tehsil, the monsoon and the available resources are insufficient and hence water requirement from the external source is high followed by Seloo and Hingna tehsils. The tehsil wise crop water requirement is shown in spatial form in Fig 3 It shows that the major tehsils like Hingna, Seloo, Umrer and Hinganghat have crop water requirement in the range of 98 to 234 MM3 and Samudrapur has crop water requirement of more than 234MM3.

Table 9 Tehsil wise average crop water requirement for Venna basin

SR No.	TEHSIL	AVG CROP WATER REQUIREMENT FOR 2000 - 2015 (MM^3)
1	Chimur	9.75
2	Kalmeshwar	22.75
3	Katol	46.80
4	Karanja	55.50
5	Bhiwapur	72.02
6	Nagpur	74.04
7	Warora	82.69
8	Arvi	92.35
9	Wardha	98.33
10	Umrer	158.72
11	Hinganghat	170.72
12	Hingna	173.98
13	Seloo	232.49
14	Samudrapur	314.88

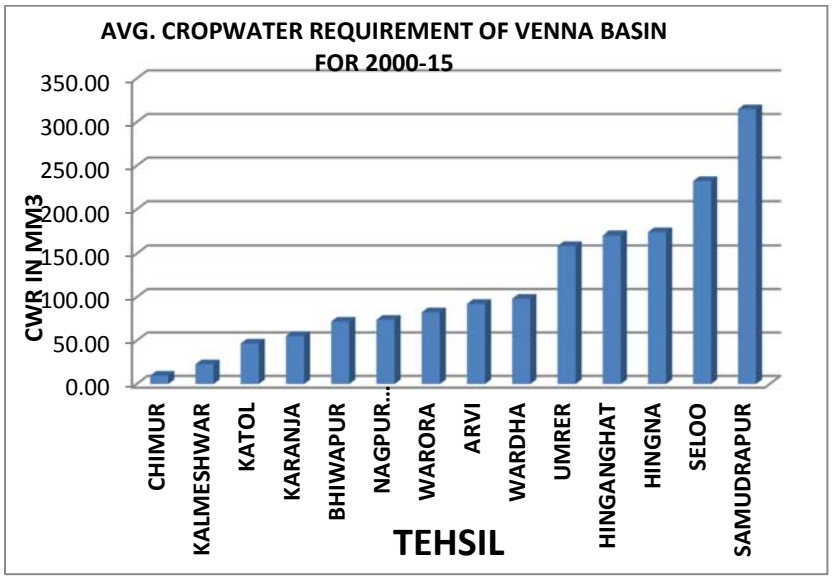

Fig 2 Tehsil wise average crop water requirement of Venna basin for year 2000 – 2015

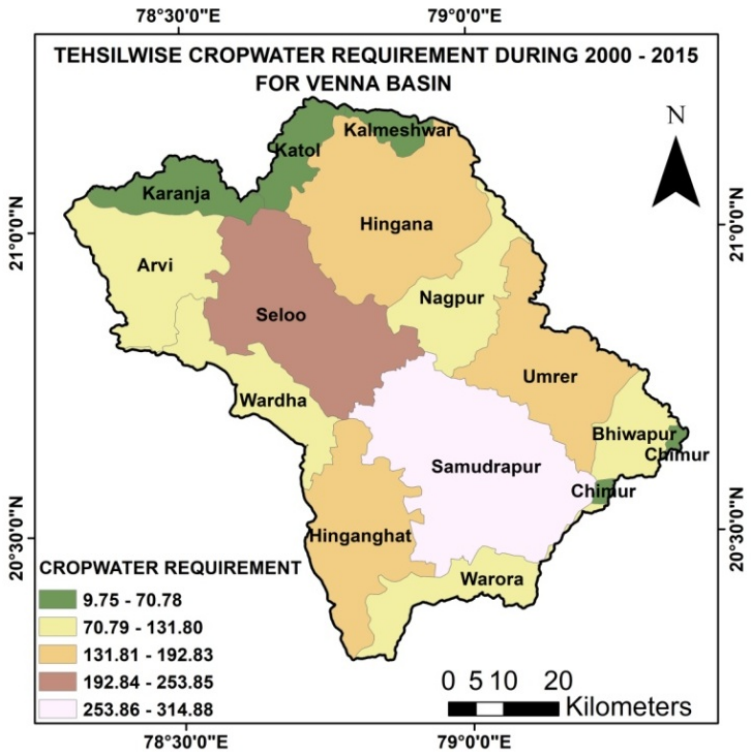

Fig 3 Tehsil wise average crop water requirement of Venna basin for year 2000 – 2015

IV. Conclusions

Evapotranspiration is an important governing factor in a hydrologic cycle. Assessment of evapotranspiration and ultimately the crop water requirement is essential for assessing the water to be supplied to crops by irrigation. The estimation of crop water requirement based on the modified Pennman coefficients gives values closer to accuracy. Accurate estimation of crop water requirement helps in managing the watering schedule for the crops through irrigation which leads to the maximum yield in limited water resources.

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