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Short communication

Estimation of crop water requirement based on Penman-Monteith approach under micro-irrgation system

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The crop water requirement depends on age of the crop, season, location of growing and management strategies to be adopted and their computation needs the information on reference crop evapotranspiration, crop coefficient etc. Absence of this information may lead to either under or over application of water. Amongst different methods for estimating evapotranspiration rates, the climatological based methods are widely used. The study was therefore carried out to estimate crop evapotranspiration for different crops growing under surface and microirrigation methods in the command area. A spreadsheet based computer model was developed to estimate the crop evapotranspiration values and compute the water requirement.

The climatological data obtained from meteorological observatory located at All India Co-ordinated Research Project on Water Management, MPKV, Rahuri for the period from 1975 to 2005 was used for this study. The crops considered in this study were papaya, banana, sugarcane, pomegranate, lime, grapes, *kharif* soybean, *rabi* tomato, *kharif* groundnut, *rabi* onion, cotton, gram, potato, *kharif* brinjal, cabbage, summer brinjal, summer cucumber, summer onion, summer okra, summer groundnut and summer chilli. The agronomical details of these crops are presented in Table 1.

The rotational water supply system is followed in the canal command area of Mula Irrigation Project. The irrigation rotation period was of 14 days. The rotation was based on 7 days "ON" and 7 days "OFF" period. Hence, the water requirement under surface irrigation method was estimated considering an irrigation interval of 14 days i.e. total of 26 irrigation indices per year.

Reference crop evapotranspiration values were calculated using the Penman-Monteith method (Allen *et al*., 1998). This method is recommended by FAO and many researchers found that this method is close to the actual measurement of ETo compared to other methods (Patil and Gorantiwar, 2009). The crop evapotranspiration (ETc) values were calculated on daily basis using a one dimensional empirical model as follow:

$$ETc = ETo * Kc \quad (2)$$

where,

ETc = maximum crop evapotranspiration (mm day^{-1})

Kc = daily crop coefficient

The water requirement (WR) by the surface irrigation methods is equal to the crop evapotranspiration. However water requirement by the micro irrigation method is less than the water requirement by the surface irrigation methods. This is due to the fact that under microirrigation methods unlike in surface irrigation methods, it is possible to apply water to the effective root zone only. Hence, the daily water requirements for different crop under microirrigation methods were estimated as follows:

$$WR = \frac{ETc * Wa}{100} \quad (3)$$

where,

WR = daily water requirement (mm)

Wa = percentage of the total area the area to be wetted

The wetted area considered for estimation of water requirement of different crops is presented in Table 1.

The stage wise crop coefficient for papaya, banana, sugarcane, cucumber, grape, papaya, brinjal and cabbage were adopted from Allen *et al*., (1998) and the stage wise crop coefficient for onion, cotton, soybean, potato and tomato were adopted from the Doorenbos and Kassana (1979) since the location specific data on the stage wise crop coefficient for these crops were not available. However for gram, groundnut, chilli and okra, the location specific data were available (Patil and Gorantiwar, 2009) and hence these data were adopted for this study. The crop coefficient equation developed for calculating daily Kc values are presented in Table 2.

The daily reference crop evapotranspiration values

Table 1: Agronomical details of crop and % wetted area under microirrigation methods

Crop	Planting date	Spacing	Crop duration, (days)	Wetted area, %
Banana	22nd Jan.	1.5 m x 1.5m	365	0.6
Brinjal *(Kharif)*	15th June	90 cm x75 cm	200	0.6
Brinjal(Summer)	15th Jan	90 cm x75 cm	200	0.6
Cabbage	15th Sep.	45 cm x 30 cm	80	0.7
Chilli (Summer)	15th Feb.	60 cm x 45 cm	200	0.6
Cotton	1st April	60 cm x 90 cm	180	0.6
Cucumber	15th Feb.	100 cm x 50 cm	120	0.6
Gram	15th Oct.	30 cm x 10 cm	120	1
Grapes	15th June	3 m x 1.5 m	365	0.5
Groundnut (*Kharif*)	15th June	45 cm x15 cm	110	1
Groundnut (Summer)	15th Jan.	45 cm x15 cm	125	1
Lime	15th June	6 m x 6 m	365	0.2
Okra (Summer)	15th Jan.	30 cm x 20 cm	125	0.8
Onion (*Rabi*)	15th Nov.	12.5cm x 7.5 cm	120	1
Onion (Summer)	15th Jan	12.5cm x 7.5 cm	120	1
Papaya	15th June	2.25 m x 2.25m	365	0.4
Pomegranate	15th June	4.5 m x 3 m	365	0.2
Potato (*Rabi*)	15th Oct.	45 cm x 30 cm	110	1
Soybean (*Kharif*)	1st June	30 x 10 cm	100	0.6
Tomato (Rabi)	15th Sep.	90 cm x 30 cm	160	0.7

Table 2: Crop coefficient equations for different crops

Sr.No.	Crop	Equation
1	Banana	$Kc_t = 5.5216\left(\frac{t}{T}\right)^3 + 9.3442\left(\frac{t}{T}\right)^2 \; 3.7538\left(\frac{t}{T}\right)^1 + 0.9312$
2	Brinjal	$Kc_t = -0.0559\left(\frac{t}{T}\right)^3 + 0.3221\left(\frac{t}{T}\right)^2 - 0.3363\left(\frac{t}{T}\right)^1 + 0.6706$
3	Cabbage	$Kc_t = -2.5173\left(\frac{t}{T}\right)^3 + 3.2709\left(\frac{t}{T}\right)^2 - 0.4504\left(\frac{t}{T}\right)^1 + 0.6548$
4	Chilli	$Kc_t = 18.934\left(\frac{t}{T}\right)^4 \; 46.851\left(\frac{t}{T}\right)^3 + 37.563\left(\frac{t}{T}\right)^2 \; 10.009\left(\frac{t}{T}\right)^1 + 0.3751$
5	Cotton	$Kc_t = -3.531\left(\frac{t}{T}\right)^3 + 3.3511\left(\frac{t}{T}\right)^2 + 0.4907\left(\frac{t}{T}\right)^1 + 0.3283$
6	Cucumber	$Kc_t = -3.0591\left(\frac{t}{T}\right)^3 - 3.4174\left(\frac{t}{T}\right)^2 - 0.1636\left(\frac{t}{T}\right)^1 - 0.5257$
7	Gram	$Kc_t = 2.3265\left(\frac{t}{T}\right)^5 + 8.5506\left(\frac{t}{T}\right)^4 \; 24.573\left(\frac{t}{T}\right)^3 + 14.708\left(\frac{t}{T}\right)^2 \; 1.8175X\left(\frac{t}{T}\right)^1 + 0.8955$
8	Grape	$Kc_t = -2.4273\left(\frac{t}{T}\right)^3 + 1.8015\left(\frac{t}{T}\right)^2 + 0.5551\left(\frac{t}{T}\right)^1 + 0.2176$
9	Groundnut	$Kc_t = -10.010\left(\frac{t}{T}\right)^5 + 13.509\left(\frac{t}{T}\right)^4 - 2.309\left(\frac{t}{T}\right)^3 - 2.6603\left(\frac{t}{T}\right)^2 - 2.0073\left(\frac{t}{T}\right)^1 + 0.4958$
10	Okra	$Kc_t = 6.658\left(\frac{t}{T}\right)^3 + 11.421\left(\frac{t}{T}\right)^2 \; 4.9514\left(\frac{t}{T}\right)^1 + 1.0685$
11	Onion	$Kc_t = -2.0254\left(\frac{t}{T}\right)^3 + 1.6824\left(\frac{t}{T}\right)^2 + 0.7475\left(\frac{t}{T}\right)^1 + 0.3761$
12	Papaya	$Kc_t = -1.8068\left(\frac{t}{T}\right)^3 - 1.9361\left(\frac{t}{T}\right)^2 - 0.2367\left(\frac{t}{T}\right)^1 - 0.6404$
13	Potato	$Kc_t = -3.9004\left(\frac{t}{T}\right)^3 - 4.3672\left(\frac{t}{T}\right)^2 - 0.1176\left(\frac{t}{T}\right)^1 + 0.3575$
14	Soybean	$Kc_t = 2.7420\left(\frac{t}{T}\right)^4 \; 10.583\left(\frac{t}{T}\right)^3 + 8.5733\left(\frac{t}{T}\right)^2 \; 0.5305\left(\frac{t}{T}\right)^1 + 0.2471$
15	Sugarcane	$Kc_t = -1.7221\left(\frac{t}{T}\right)^3 - 0.3629\left(\frac{t}{T}\right)^2 + 2.7115\left(\frac{t}{T}\right)^1 + 0.1234$
16	Tomato	$Kc_t = -5.2792\left(\frac{t}{T}\right)^3 - 5.0941\left(\frac{t}{T}\right)^2 - 0.1121\left(\frac{t}{T}\right)^1 - 0.3947$

Where,

Kc_t = crop coefficient of t^{th} day.

t = day considered.

T = total period of crop growth from sowing to harvesting (days).

a_0, a_1, a_2 …= constants of equations.

(Note: R^2 value for above equation is greater than 0.8)

Table 3: Water requirement (mm) of crops under microirrigation method

Period No.	Papaya	Banana	S. Cane	Pomegranate	Lime	Grapes	Kh. Soybean	K. Gnut	Cotton	K. Brinjal	R. Tomato	R. Onion	Gram	Potato	Cabbage	S. Brinjal	S. Cucumber	S.Onion	S. Okra	S. Gnut	S.Chilli
1	20.29	29.11	4.98	6.93	7.40	19.43	-	-	-	-	36.88	40.33	36.35	49.00	-	-	-	-	-	-	-
2	23.18	29.40	8.74	7.74	8.25	22.14	-	-	-	-	36.71	50.19	21.86	47.34	-	20.37	-	22.25	33.75	31.45	-
3	26.50	27.63	13.28	8.67	9.25	25.10	-	-	-	-	31.39	59.22	8.02	11.83	-	22.13	-	32.04	24.40	44.49	-
4	30.14	26.90	18.68	9.71	10.36	28.15	-	-	-	-	14.79	65.25	-	-	-	24.11	16.31	44.88	22.59	56.59	30.33
5	34.73	27.12	25.49	11.07	11.81	31.79	-	-	-	-	-	66.71	-	-	-	26.84	25.42	61.15	28.80	70.39	27.08
6	38.64	27.13	32.68	12.25	13.06	34.42	-	-	-	-	-	13.04	-	-	-	29.11	33.11	76.90	40.94	84.74	20.94
7	42.32	27.65	40.41	13.41	14.30	36.40	-	-	10.62	-	-	-	-	-	-	31.39	43.04	90.52	56.82	100.97	22.45
8	46.57	29.38	49.61	14.84	15.83	38.24	-	-	23.45	-	-	-	-	-	-	34.34	55.04	101.17	74.26	117.68	30.80
9	51.53	32.63	60.63	16.62	17.73	39.88	-	-	32.22	-	-	-	-	-	-	38.19	67.73	105.56	88.53	123.02	44.73
10	50.64	33.38	65.49	16.66	17.77	36.24	-	-	39.60	-	-	-	-	-	-	38.15	69.91	51.37	76.32	66.60	55.88
11	50.01	35.39	70.75	16.91	18.04	32.26	3.47	-	48.14	-	-	-	-	-	-	38.75	66.97	-	-	-	66.31
12	34.78	29.16	57.83	13.13	14.00	19.23	14.67	8.64	43.43	6.64	-	-	-	-	-	30.20	36.04	-	-	-	56.63
13	19.95	27.51	52.96	11.50	12.27	9.34	22.47	50.96	43.15	30.07	-	-	-	-	-	26.65	-	-	-	-	51.76
14	18.27	26.51	48.90	10.26	10.95	9.65	31.37	56.04	42.07	25.68	-	-	-	-	-	24.02	-	-	-	-	45.80
15	17.66	26.88	46.97	9.60	10.24	10.40	38.49	58.93	41.59	23.71	-	-	-	-	-	22.77	-	-	-	-	40.75
16	17.93	28.41	46.75	9.39	10.01	11.59	41.35	63.34	41.31	22.54	-	-	-	-	-	6.56	-	-	-	-	36.99
17	18.97	31.08	47.95	9.53	10.17	13.31	38.00	70.96	40.70	22.66	-	-	-	-	-	-	-	-	-	-	35.03
18	19.22	32.31	46.59	9.26	9.87	14.45	22.66	73.29	36.02	21.67	-	-	-	-	-	-	-	-	-	-	16.22
19	20.30	34.73	46.77	9.37	9.99	16.16	-	67.31	30.41	21.46	11.29	-	-	-	17.92	-	-	-	-	-	-
20	19.91	34.39	43.11	8.79	9.38	16.63	-	24.76	6.54	20.27	18.76	-	-	-	27.96	-	-	-	-	-	-
21	21.59	37.34	43.55	9.13	9.74	18.75	-	-	-	20.92	24.10	-	25.87	10.89	34.79	-	-	-	-	-	-
22	20.70	35.58	38.48	8.40	8.97	18.56	-	-	-	19.07	27.69	-	48.03	23.09	38.26	-	-	-	-	-	-
23	19.85	33.62	33.59	7.75	8.27	18.25	-	-	-	17.76	30.99	5.56	51.32	28.54	38.99	-	-	-	-	-	-
24	18.83	31.13	28.55	7.08	7.55	17.63	-	-	-	16.36	32.99	21.82	54.22	34.79	34.47	-	-	-	-	-	-
25	18.69	29.87	24.93	6.79	7.24	17.72	-	-	-	15.86	35.09	26.77	54.47	41.66	2.19	-	-	-	-	-	-
26	20.11	30.67	22.87	7.07	7.54	19.22	-	-	-	16.89	38.41	34.73	51.37	49.19	-	-	-	-	-	-	-
Water Saving (%)	75	62	64	88	88	73	68	43	65	70	61	51	48	53	63	65	63	40	52	38	63

(Note: R=Rabi, K= Kharif, S= Summer, Period no. 1= 1-14th Jan and subsequent periods are fortnight of every subsequent two weeks) computed by Penman-Monteith method for thirty one years (1975- 2005). The was observed to vary between 2.85 mm to 8.33 mm day^{-1}.

Usually the surface irrigation systems are designed for 60% efficiency. Hence the values of water to be applied to different crops under surface irrigation method were estimated based on this efficiency. Similarly, the values of water to be applied to different crops under microirrigation method are estimated based on 95% efficiency. The depths of water to be applied to different crops under microirrigation methods are presented in Tables 3. The crop water requirement under microirrigation methods is less than surface irrigation methods. The saving in water for microirrigation method was observed to be maximum under pomegranate and lime (88%) and minimum for the summer groundnut (38%) when compared to the surface method of irrigation. Similar saving in water was also observed for other crops under microirrigation methods. The per cent saving in microirrigation methods was observed to be 75 % for papaya, 62 % for banana, 64 % for sugarcane, 73 % for grapes, 68 % for *kharif* soybean, 61 % for *rabi* tomato, 43 % for *kharif* groundnut, 51 % for *rabi* onion,65 % for cotton, 48% for gram, 53 % for potato, 70 % for *kharif* brinjal, 63 % for cabbage, 65 % for summer brinjal, 63 % for summer cucumber, 40 % for summer onion, 52 % for summer okra and 63 % for summer chilli when compared to the water requirement under surface method of irrigation. Thus there is a saving of at least 50% of water if drip irrigation method is used instead of surface irrigation method. This indicates that in case of water scarcity there is possibility of bringing additional area under irrigation by using the saved amount of water.

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