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Short communication

Assessment of irrigation water requirements for different crops in central Punjab, India

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In Indian Punjab, where more than 85 per cent area is under agriculture (with net irrigated area of nearly 98%), about 72 per cent area is irrigated with groundwater accounting for more than 80% area under depleted groundwater resources, whereas only 28% area is irrigated with surface water. The groundwater resources in the Punjab are depleting at an alarming rate of 0.54 m annually due to over-exploitation of groundwater and injudicious surface irrigation water policies (Aggarwal *et al.,* 2020). Thus, the water management particularly for major field crops of the state is highly needed in relation to irrigation scheduling and saving of irrigation water to be applied. This can be achieved by various techniques one of which is the study of crop evapotranspiration.

Evapotranspiration is affected by meteorological parameters, crop characteristics and field management practices (Allen *et al*., 1998). Thus, an accurate estimation of ET_o is required for computing the net irrigation requirement, regional water resources planning and management. ET_o can be computed either directly using lysimetric approach (Kingra *et al.,* 2004) or indirectly using the energy balance approach (or empirical models). However, the lysimetric approach is time-consuming and requires precise instrumentation, whereas the indirect approach is based on site specific meteorological data. In the indirect approach, the FAO 56 Penman Monteith equation is considered as the most suitable method for accurate estimation of ET_o (Saxena *et al*., 2020; Kumar 2017; Tabari *et al*., 2013; Widmoser, 2009). Keeping the above information in view, the present study was undertaken to compute the seasonal (*kharif* and *rabi* crops) water requirements for different field crops of Central Indian Punjab using FAO-Penman-Monteith equation.

Description of the study area

The present study was undertaken to compute the crop water requirement for different crops grown in Central Punjab (India). The climatic data for 25 years (1995-2019) was obtained from the agrometeorological observatory of PAU, Ludhiana located at 30°54' N latitude and 75°48'E longitude with an altitude of 247 m amsl. The area is characterized by semi-arid, sub-tropical climate with very hot summer during April-June and cold winters during December-January. The average annual rainfall in Ludhiana is 759 mm, 75-80 per cent of which is received during the period from June to September. Fig. 1 demonstrate the climate of the study region. Penman-Monteith equation (Allen *et al*., 1998) was used to compute reference evapotranspiration (ET_o) using the climatic data.

Selected crops (*kharif* and *rabi*) for computation of their water requirements, their crop coefficients, growing period, date of sowing and methods of establishment have been given in Table 1. The *kharif* season was considered from March to September and *rabi* season was considered from October to February. Further, spring season was considered from March to May and summer season from June to August. The crop coefficients (K_c) of the selected crops have been taken from FAO-56 and crop evapotranspiration (ET_c) was estimated.

In this case, crop water requirement (CWR) and ET_c were used interchangeably as the amount of water required for the metabolic activities has been considered as negligible.

CWR or ETc = NIWR + ER + S

Where, NIWR= net irrigation water requirement (mm), ER=effective rainfall (mm) and S=soil moisture storage and groundwater contribution (mm)

The daily effective rainfall (ER) was estimated using CROPWAT 8.0 where USDA Soil Conservation Service method was used. The average groundwater depth in the district of Ludhiana is 25.67 m (Aggarwal *et al*.,

Table 1: Major crops, their crop coefficients, growing periods, sowing dates and establishment methods

Crop	Crop coefficient			Growing period, days	Date of sowing/transplanting	Method of crop establishment
	Initial	Mid	End			
Chili	0.5	1.1	0.65	100	March 01	Transplant
Potato	0.5	1.1	0.95	90-100	October 05	
Onion	0.7	1.05	0.75	150	*kharif*-August 04 *rabi*-December 04	Transplant
Tomato	0.6	1.15	0.8	120	November 03	Transplant
Garlic	0.7	1.05	0.95	170	October 05	Transplant
Cauliflower	0.7	1.05	0.95	100	October 05	
Peas	0.4	1.15	0.55	90	November 01	
Watermelon	0.2	1.3	0.43	120	January 15	
Brinjal	0.6	1.15	0.8	85	November 02	Transplant
Cabbage	0.7	1.05	0.95	90	October 03	
Root crops	0.5	1.1	0.95	90	November 05	
Sugarcane	0.4	1.25	0.75	320	February 28	
Maize	0.45	1.2	0.6	100	June 28	
Rice	1.15	1.26	0.75	130	June 20	Transplant
Wheat	0.7	1.15	0.4	150	November 15	

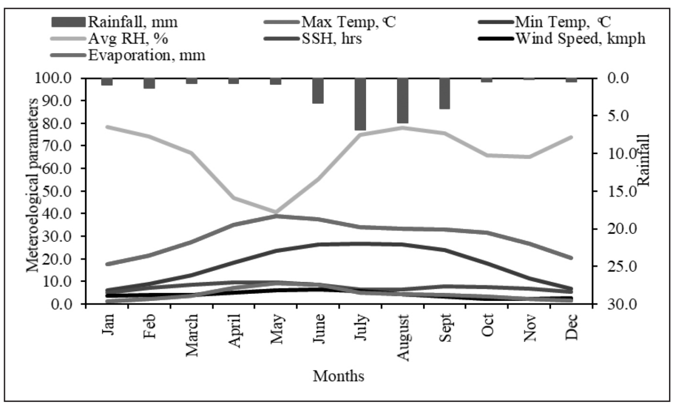

Fig. 1: Climatic conditions of study domain

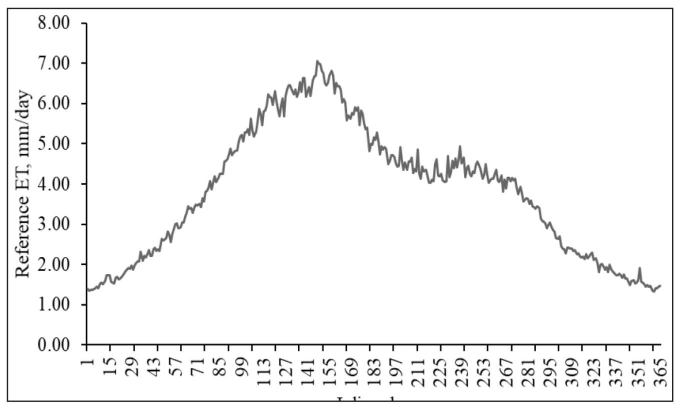

Fig. 2: Daily variation in reference evapotranspiration

2020). So in the present study, the soil moisture storage and groundwater contribution were taken as nil.

The three water application efficiencies *viz.* 40, 50 and 60 per cent were considered to determine the gross irrigation water requirement (GIWR) with and without taking ER in to account.

Daily reference evapotranspiration (ET_o)

During winter season, average computed ET_o for the study period was as less as 1.34 mm/day. However, as the temperature increased with the arrival of Spring, the ET_o value also significantly increased. The highest value of ET_o (6.97 mm/day) was recorded during the last week of last month of the Spring season (29th May) just before arrival of Summer season. The average ET_o was observed to be highest during Spring followed by Summer and least during winter season. The lower ET_o values during Summer as compared to Spring season may be due to the higher frequency of rainfall events during June to August which helps to lower the temperature. Computed daily variations in ET_o has been depicted in Fig 2.

Crop evapotranspiration of kharif and rabi crops

In the present study, the *kharif* crops included chilli, sugarcane, onion, maize and rice and *rabi* crops included potato, onion, tomato, garlic, cauliflower, peas, watermelon, brinjal, cabbage, root crops *viz.* carrot, radish and sweet potato and wheat and the stage wise crop coefficients are presented in Table 1. The daily ET_c demand for the study region lies in range of 1.0-8.7 mm/day. Among the selected crops (maize, rice, sugarcane, chilli and onion), the highest daily ET_c demand was recorded to be 8.7 mm for sugarcane (Fig. 3). During *rabi* season, the daily ET_c demand for the study region lies in range of 0.3- 7.2 mm/day (Fig. 4) with being highest (7.2 mm/day) for watermelon during mid-April.

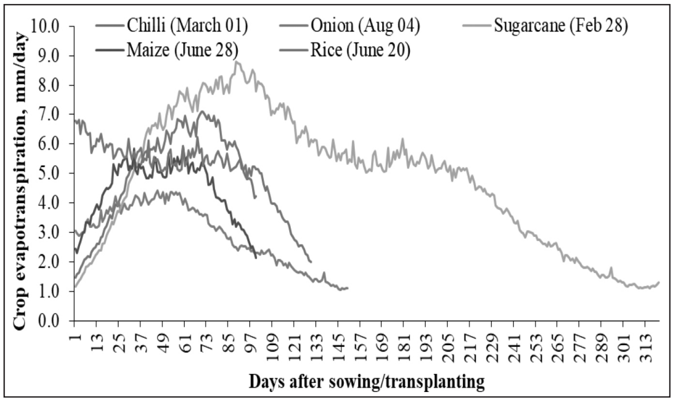

Fig. 3: Crop evapotranspiration for *kharif* crops

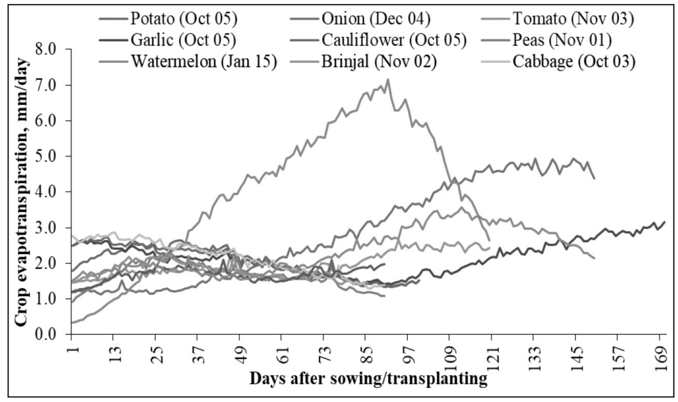

Fig. 4: Crop evapotranspiration for *rabi* crop

Table 2: Crop-wise seasonal net and gross irrigation demands (NIWR and GIWR)

Crop	GIWR (mm)		GIWR (mm)					
			For E_a=40 %		For E_a=50 %		For E_a=60 %	
	WER	WoER	WER	WoER	WER	WoER	WER	WoER
Chili	435	511	1088	1278	870	1022	725	852
Potato	163	203	408	508	326	406	272	338
Onion (*kharif*)	192	360	480	900	384	720	320	600
Onion (*rabi*)	310	397	775	993	620	794	517	662
Tomato	152	234	380	585	304	468	253	390
Garlic	259	368	648	920	518	736	432	613
Cauliflower	164	203	410	508	328	406	273	338
Peas	103	149	258	373	206	298	172	248
Watermelon	373	482	933	1205	746	964	622	803
Brinjal	108	151	270	378	216	302	180	252
Cabbage	162	195	405	488	324	390	270	325
Root crops	99	152	248	380	198	304	165	253
Sugarcane	994	1529	2485	3823	1988	3058	1657	2548
Maize	56	442	140	1105	112	884	93	737
Rice	251	666	628	1665	502	1332	418	1110
Wheat	244	352	610	880	488	704	407	587
Total	4065	6394	10166	15989	8130	12788	6776	10656

WER - with effective rainfall, WOER - without effective rainfall

Net irrigation water requirement (NIWR) of kharif crops

Among the *kharif* crops, the CWR was computed to be the highest (1529 mm) for sugarcane, as it is an annual crop (Table 2), followed by rice (666 mm), chilli (511 mm), maize (442 mm) and onion (435 mm). Table 2 obviously indicated that the CWR of sugarcane was around 2.3, 3.0, 3.5 and 3.5 times higher when compared with rice, chilli, maize and onion, respectively. For rice crop, the actual CWR was 666 mm, whereas the gross irrigation water requirement was 1600 mm. Thus, about 950 mm water was required for meeting the special needs and unavoidable losses in rice. In case of maize and rice, the ER was highest as the most of the crop duration falls in rainy season and in the maize crop, net irrigation water requirement was found to be least.

The seasonal CWR of most of the *rabi* crops was less than that of the *kharif* crops for the same duration. This was due the lower temperature, less sunshine hours and low wind speed during the winter/*rabi* season. The watermelon and peas have the highest and lowest seasonal

CWR of 477 and 149 mm, respectively (Table 2).

Irrigation water demand for the study region

The seasonal net and gross irrigation water demand were calculated based on the seasonal ET_c for each crop with and without considering ER (Table 2). With consideration of ER, the net and gross water demand were recorded to be highest for wheat crop may be due to the less rainfall during the crop period. The total net annual irrigation demand was computed to be 4065 mm, whereas the total gross irrigation demand was computed to be 10166, 8130 and 6776 mm for water application efficiency of 40, 50 and 60 per cent, respectively (Table 2). In contrast, when ER was not taken into consideration, the net and gross water demand was recorded to be highest for rice crop. The total net irrigation demand was recorded to be 6394 mm, whereas the total gross irrigation demand was computed to be 15989, 12788 and 10656 mm for water application efficiency of 40, 50 and 60 per cent, respectively (Table 2). Table 2 indicate decreased GIWR with increase in water application efficiency.

The study revealed that $ET_c$was significantly affected by growing seasons, recording highest values under sugarcane (1418 mm) followed by rice (606 mm) during *kharif* season. The higher ET_c for sugarcane as compared to other crops including rice was mainly due to its extended growing duration (annual crop). However, during *rabi* season, the maximum ET_c value was recorded for watermelon (458 mm) and for other crops it varied in the range of 110-393 mm. The maximum ET_c values during *kharif* season were mainly due to higher temperature in relation to the increased sunshine hours and intensity of solar radiation as compared to *rabi* season. Taking rice crop as an example, the actual ET_c (666 mm) was significantly lower as compared to the reported CWR (1600 mm), requiring about 1000 mm surplus water to meet the special needs and unavoidable losses. The total NIWR was recorded to be 4065 and 6394 mm with and without considering effective rainfall, respectively. By considering ER, GIWR was recorded to be least (6776 mm) for the water application efficiency 60 per cent, however, when ER was not taken under consideration, GIWR was computed to be least (10656 mm) for the water application efficiency of 60 per cent. Thus, the prior knowledge of crop water and net irrigation requirements using long-term climatological data can help to plan different crop types, schedule irrigation and save a substantial amount of irrigation water used.

Conflict of Interest Statement: The author(s) declare(s) that there is no conflict of interest.

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