Short communication

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

SANJAY SATPUTE*, MAHESH CHAND SINGH and SUNIL GARG

Department of Soil & Water Engineering, Punjab Agricultural University, Ludhiana, India

*Corresponding Author email: sanjay4471@pau.edu

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\textsubscript{o} is required for computing the net irrigation requirement, regional water resources planning and management. ET\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{c}) of the selected crops have been taken from FAO-56 and crop evapotranspiration (ET\textsubscript{c}) was estimated.

In this case, crop water requirement (CWR) and ET\textsubscript{c} were used interchangeably as the amount of water required for the metabolic activities has been considered as negligible.

CWR or ET\textsubscript{c} = 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.,...
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)**

During winter season, average computed ET for the study period was as less as 1.34 mm/day. However, as the temperature increased with the arrival of Spring, the ET value also significantly increased. The highest value of ET (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 was observed to be highest during Spring followed by Summer and least during winter season. The lower ET 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 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 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 demand was recorded to be 8.7 mm for sugarcane (Fig. 3). During rabi season, the daily ET 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.
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

---

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

| Crop          | GIWR (mm)  |
|---------------|------------|
|               | WER    | WoER |
| Sugarcane     | 994    | 1529 |
| Rice          | 251    | 666  |
| Wheat         | 244    | 352  |
| Root crops    | 99     | 152  |
| Cabbage       | 162    | 195  |
| Brinjal       | 108    | 151  |
| Watermelon    | 373    | 482  |
| Peas          | 103    | 149  |
| Cauliflower   | 164    | 203  |
| Garlic        | 259    | 368  |
| Tomato        | 152    | 234  |
| Onion (rabi)  | 310    | 397  |
| Onion (kharif)| 192    | 360  |
| Potato        | 163    | 203  |
| Chili         | 435    | 511  |

**GIWR (mm)**

| Crop          | GIWR (mm)  |
|---------------|------------|
|               | WER | WoER |
| Total         | 4065| 6394 |

**For E<sub>a</sub>=40 %**

| Crop          | GIWR (mm)  |
|---------------|------------|
|               | WER | WoER |
| Total         | 10166| 15989|

**For E<sub>a</sub>=50 %**

| Crop          | GIWR (mm)  |
|---------------|------------|
|               | WER | WoER |
| Total         | 8130| 12788|

**For E<sub>a</sub>=60 %**

| Crop          | GIWR (mm)  |
|---------------|------------|
|               | WER | WoER |
| Total         | 10656| 15989|

WER - with effective rainfall, WOER - without effective rainfall
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 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.

**Disclaimer:** The contents, opinions, and views expressed in the research article published in the Journal of Agrometeorology are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

**Publisher’s Note:** The periodical remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**REFERENCES**

Aggarwal, R., Kaur, S. and Gill, A. K. (2020). *Ground-water depletion in Punjab: Tech Bull PAU/2020/F/773/E, 1\(^{st}\)edn.* Pp 1-37. Punjab Agricultural University, Ludhiana, India.

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. (1998). *Crop evapotranspiration guidelines for computing crop water requirements.* FAO Irrigation and Drainage Paper No. 56, FAO, Rome, Italy, p. 300.

Kingra, P. K., Hundal, S. S. and Sharma, P. K. (2004). *Characterization of crop coefficients for wheat and rice crops in Punjab.* *J. Agrometeorol.*, 6: 58–60.

Kumar, S. (2017). *Reference evapotranspiration (ETo) and irrigation water requirement of different crops in Bihar.* *J. Agrometeorol.*, 19(3): 238-241.

Saxena, R., Tiwari, A., Mathur, P. and Chakravarty, N. V. K. (2020). *An investigation of reference evapotranspiration trends for crop water requirement estimation in Rajasthan.* *J. Agrometeorol.*, 22 (4): 449-456.

Tabari, H., Grismer, M.E. and Trajkovic, S. (2013). *Comparative analysis of 31 reference evapotranspiration methods under humid conditions.* *Irrig. Sci.*, 31: 107–117.

Widmoser, P. (2009). *A discussion on an alternative to Penman–Monteith equation.* *Agric. Water Manage.*, 96: 711-721.