Original Research Article

Water requirements of Wheat crops in a small watershed by using CROPWAT

Abstract

A study was carried out to determine the crop water requirement of wheat crops for the area around Tons pump canal. Crop water requirement for the wheat crops was determined by using 2017-2018 climatic data in CROPWAT. Reference crop evapotranspiration (ETo) was determined using the FAO Penman Monteith method. Wheat crops considered, four crop growth stages: Initial stage, Development stage, Mid-season and Late season stage were considered. Crops were planted during the 2017 Rabi Season and the crop coefficient for each was determined. The study shows that for the area under study, reference evapotranspiration (ETo) varied from 1.48 to 3.98 mm/day. Crop evapotranspiration (ETc) and crop water requirement for wheat crop varied from 0.44 to 3.75 mm/day and 1.9 to 39.8 mm/day. The peak water requirement was 0.13 l/s/ha or 1.1 mm/day with an application efficiency of 65%. Irrigation water requirement was estimated at about 27.93 mm/day while the actual water diverted was 81000.29 m^3. Thus, the canal can conveniently supply the water required for irrigation in the area.

Keywords: Crop Evapotranspiration, Reference evapotranspiration, Crop water requirement, Peak water requirement, total crop water requirement, and climatic data.

Abbreviations: l/s/ha_ Litres/Second/Hectare, mm/day_ Millimetre/days, Eta_ Crop Evapo-transpiration, NIWR_Net irrigation water requirement, ETo_Reference crop Evapo-transpiration.

Introduction

Water is important for plant growth and food production. There is competition between municipal, industry users and agriculture for the finite amount of available water, estimating irrigation water requirements accurately is important for water project planning and management (Michael, 1999). The primary objective of irrigation is to apply water to maintain crop evapotranspiration (ETc) when precipitation is insufficient. The finite total amount of available water is crucial for the economy, health and welfare of a very large part of the developing world. Hess (2005) defined crop water requirements as the total water needed for evapotranspiration, from planting to harvesting a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not

limit plant growth and crop yield. FAO (2005) defined crop water requirement (CWR) for a given crop as:

$$\mathbf{CWR = Kc \times ETo}$$

Where, Kc is the Crop coefficient of the given crop and ETo is the Reference evapotranspiration. Each crop has its own water requirements. Net irrigation water requirements (NIWR) in a exact scheme for a given year are thus the sum of individual crop water requirements (CWR) intended for each irrigated crop. Multiple cropping (several cropping periods per year) is thus automatically occupied into account by distinctly computing

crop water requirements for individually cropping period. By dividing by the area of the scheme, a value for irrigation water requirements is obtained and can be expressed in mm or in m3/ha. FAO (1992), Smith et al. (1991) and Smith (1992) reported that CROPWAT is meant as a practical tool to help agrometeorologists, agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation. Broner and Schneckloth (2003) reported that water requirements of crops depend mainly on environmental conditions. Plants use water for cooling purposes and the driving force of this process is prevailing weather conditions. Different crops have different water use requirements, under the same weather conditions. Crops will transpire water at the maximum rate when the soil water is at field capacity. Broner (2003) reported that knowing seasonal crop water requirements is crucial for planning your crop planting mixture especially during drought years. Adequate data on irrigation water requirements of most crops is not available in developing nations of the world. This is one of the reasons why for the failure of large-scale irrigation projects in most developing countries of the world. The objective of this study was to determine crop water requirements of wheat at Harrai.

Materials and methods

Study area

It is located on the banks of the Tons canal within 7 km of Rampur on the Mirzapur highway in Prayagraj. Harrai village come under the Karchhana block. In this village farmers are depending on canals and artificial resources for water supply in agriculture and most of the farmer do the maximum cultivation of wheat and paddy under the cereal-based farming system. Some general class farmers also do animal husbandry along with farming. In which

most of the farmers reared cows and buffaloes. In Harrai village some lower- and middle-class farmer's also rearing pig and goat.

Harrai village lies between the longitude and latitudes are 81.9624 to 81.9813 and 25.2806 to 25.2876.

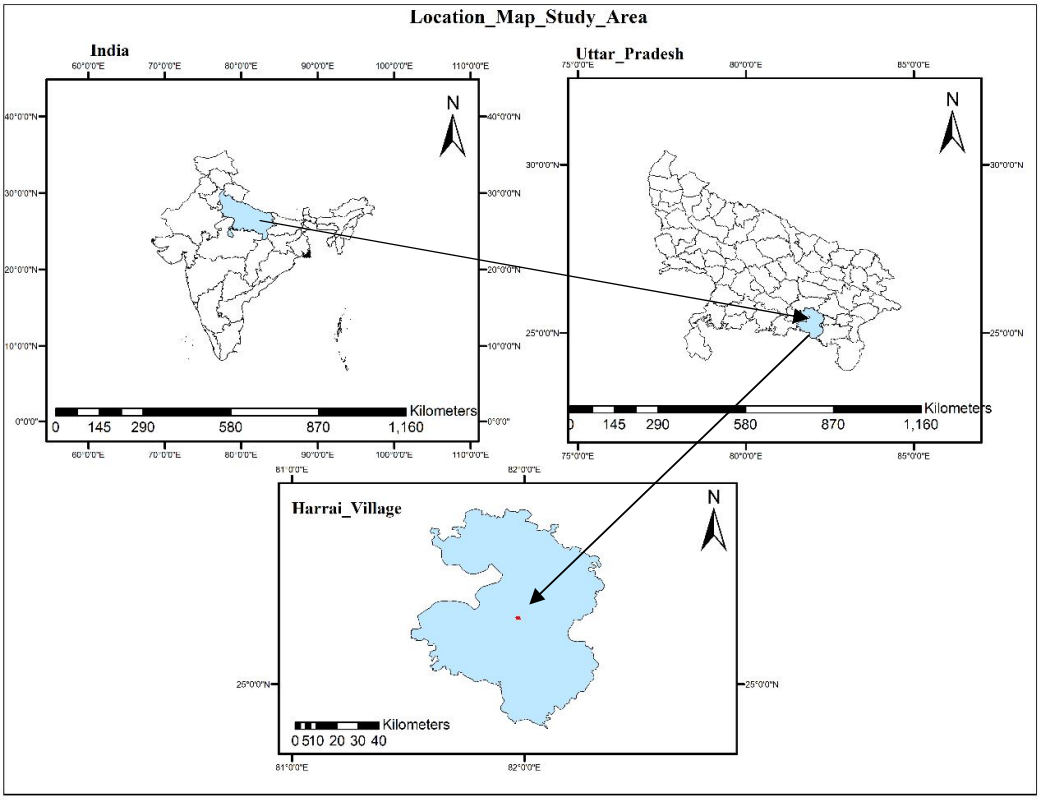

Fig 1: Study areas at Harrai village, Prayagraj

Stages of growth

Four distinct stages of plant growth were used in determining water requirement of the crop. The decades include I, II, and III while the crop growth stages include initial stage, development stage, mid-season and late season stage.

Estimation of water requirement

Crop water requirement was determined from the interrelationships of the ET, soil type, bulk density of the soil, field capacity and permanent wilting point of the soil and the effective root zone of okra plant at the project site. The crop ET (ET_C) was estimated by FAO Penman-Monteith equation (FAO, 1998) Hatfield and Fuchs (1992) and Smith et al.,1991)

$$\mathbf{ETo = ETc = Kc\ (ETo)}$$

where the reference crop ET (mm/day) is as defined in equation below as:

$$ETo = 0.408\Delta(Rn-G) + \gamma\,[900/(T + 273)]\,u2\,(ea - ed)/\Delta + \gamma(1 + 0.34u2)$$

Where, ETo = reference evapotranspiration [mm day^{-1}], Rn = net radiation at the crop surface [MJ m-2 day^{-1}], G = soil heat flux density [MJ m^{-2} day^{-1}], T = mean daily air temperature at 2 m height [°C], u2 = wind speed at 2 m height [ms^{-1}], es = saturation vapour pressure [kPa], ea = actual vapour pressure [kPa], es - ea = saturation vapour pressure deficit [kPa], D = slope vapour pressure curve [kPa $°C^{-1}$], g =psychrometric constant [kPa$°C^{-1}$]. Irrigation frequency was calculated using the relationship discussed by Michael (1999) Irrigation frequency (days) = Field capacity of Soil – Moisture content before irrigation / Daily consumptive use,

$$fi = dg / Cu$$

where, fi = irrigation frequency (days), dg = gross depth of application (mm), and CU = daily consumptive use (mm/day). The CROPWAT programme (version 8.0) developed for the FAO Penman-Monteith method (FAO, 56) was utilized for estimating the crop water requirement of wheat crops studied. To ensure the integrity of computations, the weather measurements were made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground. The climatic data used for the calculations were obtained from a meteorological station located at Lokoja.

Results

Reference crop evapotranspiration

The results obtained when a 2017-2018 period was used with the FAO-Penman Monteith method to determine the reference crop evapotranspiration (ET_O) for the area under study show that ETo varied from a minimum value of 1.48 mm/day in December to the highest value of 3.98 mm/day in April given below in Table 1. The results show that ET_O was lowest during the peak of the winter season to highest during the peak of the summer season.

Table 1. Reference Crop Evapotranspiration

Country: India Meteorological Station: SHUATS Crop: Wheat Duration: 145 days			**Planting date: 27-11-2017**	**Harvesting date: 20-04-2018**		**Altitude: 98m**	
Day	**Min Temp (°C)**	**Max Temp (°C)**	**Humidity (%)**	**Wind (km/day)**	**Sun (hours)**	**Rad (MJ/m^2/day)**	**ETo (mm/day)**
Nov	9	28	38.75	1	8.55	15.425	1.59
Dec	9.7	27.6	42	1	7.5	13.9	1.48
Jan	8.5	25.8	48	1	6.1	13	1.55
Feb	11.7	30.2	43	1	7.2	16.1	2.24
Mar	18.8	36.3	37	1	8.7	20.5	3.31

Apr	24.56	39.31	38.55	2.45	8.04	21.15	3.98

where ETo = Reference Crop Evapotranspiration computed using the FAO Penman-Monteith Method.

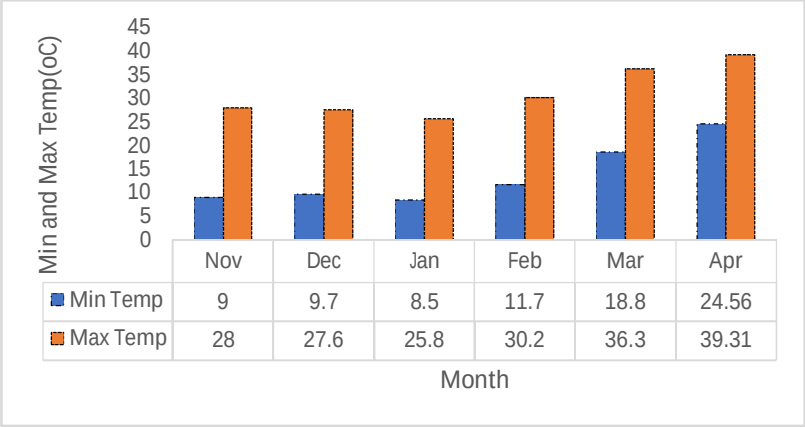

Fig 2: Minimum and Maximum Temperature 2017-2018

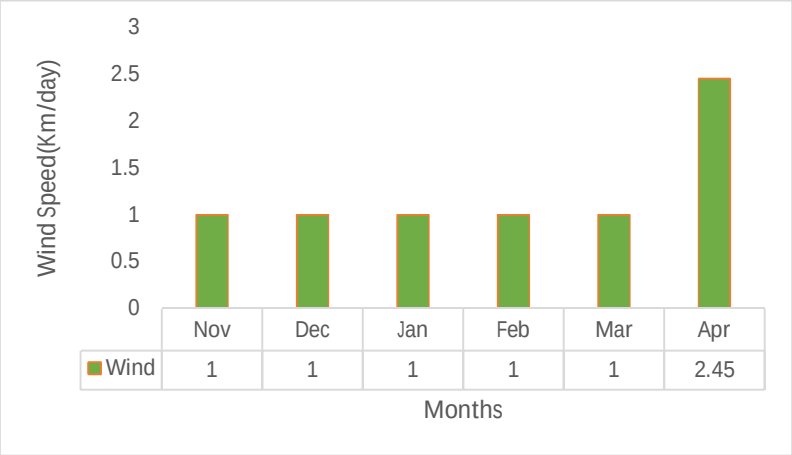

Fig 3: Wind Speed 2017-2018

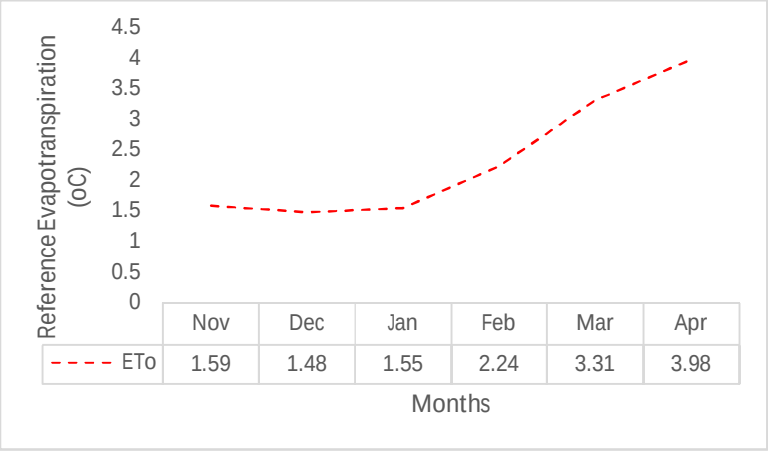

Fig 4: Reference Evapotranspiration 2017-2018

Crop water requirement

Results show that for wheat, crop evapotranspiration (ETc) and crop water requirement for varied from 0.44 to 3.75 mm/day and 0.19 to 3.98 respectively (Table 2).

Table 2. Evapotranspiration and Irrigation Requirement for Wheat 2017-2018.

Month	Decade	Stage	Crop Coeff (Kc)	ETc (mm/day)	ETc (mm/dec)	Eff rain (mm/dec)	IR. Req. (mm/dec)	IR. Req. (mm/day)
Nov	3	Init	0.3	0.48	1.9	0	1.9	0.19
Dec	1	Init	0.3	0.44	4.4	0	4.4	0.44
Dec	2	Init	0.3	0.46	4.6	0	4.6	0.46
Dec	3	Deve	0.33	0.47	5.2	0	5.2	0.52
Jan	1	Deve	0.52	0.65	6.5	0	6.5	0.65
Jan	2	Deve	0.73	1.13	11.3	0	11.3	1.13
Jan	3	Deve	0.95	1.75	19.2	0	19.2	1.92
Feb	1	Mid	1.13	2.23	22.3	0	22.3	2.23
Feb	2	Mid	1.14	2.46	24.6	0	24.6	2.46
Feb	3	Mid	1.14	3.01	24.1	0	24.1	2.41
Mar	1	Mid	1.14	3.35	33.5	0	33.5	3.35
Mar	2	Mid	1.14	3.75	37.5	0	37.5	3.75
Mar	3	Late	0.99	3.62	39.9	0.1	39.8	3.98
Apr	1	Late	0.68	2.5	25	0.2	24.9	2.49
Apr	2	Late	0.38	1.63	16.3	0.3	16.1	1.61

IR = Irrigation Requirement (mm/day), IR = Irrigation Requirement (mm/dec), Kc = Crop Coefficient and ETc = Crop Evapotranspiration (mm/day) and ETc = Crop Evapotranspiration (mm/dec).

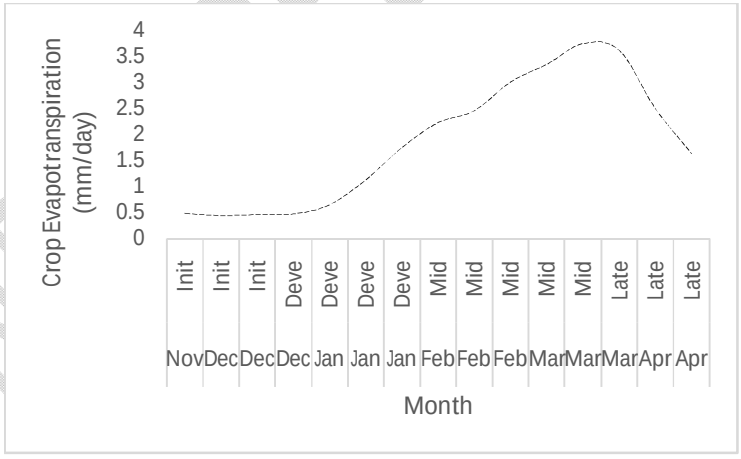

Fig 5: Crop Evapotranspiration 2017-2018

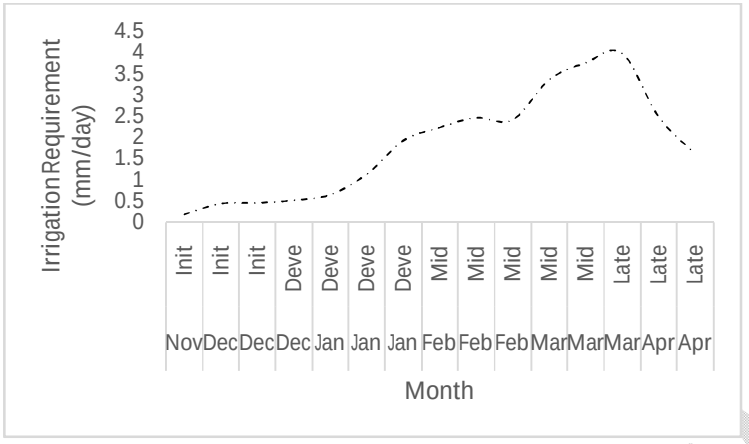

Fig 6: Irrigation Requirements 2017-2018

Scheme irrigation requirement

The estimation of actual irrigation requirement at Harrai village was carried out (Table 3). The net irrigation water requirement is 259.3 mm/season (Table 3). This is summation of the water requirement values from Planting date (27th Nov, 2017 to20th April, 2018). Using an irrigation application frequency of 65%, the gross water requirement of 398.92 mm/season was obtained. Therefore, the entire land area of 94.43 ha will require 0.292 mm/day/ha water. The results show that the canal can conveniently supply the water required for irrigation in the area.

Table 3. Scheme Irrigation Requirements

ETo Station: **SHUATS**		Rain Station: **SHUATS**		Cropping Pattern: **Wheat**		
	Nov	**Dec**	**Jan**	**Feb**	**March**	**April**
Wheat	1.9	14.2	37.1	71.0	110.8	4.09
Net Scheme Irr. Req.						
mm/day	0.1	0.4	1.1	2.4	3.4	1.3
mm/month	1.8	13.3	34.9	66.7	104.1	38.5
l/sec/h	0.01	0.05	0.13	0.28	0.39	0.15
Irrigated area						
Total area (Ha)	102.14	102.14	102.14	102.14	102.14	102.14
Irr. Req. for actual area						
l/sec/h	0.01	0.05	0.14	0.29	0.41	0.16

Discussion

The results showed that reference and crop evapotranspiration (ETo and ET_C) were higher for crops with longer growing season than for those with shorter ones. Also, ETo and ETC were more during the dry season than the winter season. FAO (2005) reported that crops grown in the summer season needs more water than those grown during the winter season. The range of water requirement for small land wheat was particularly high because the water requirement during the peak season (due to large amount of rain water) was very low while that of the peak summer season (no rainfall) was very high.

Conclusion

The study shows that the dam can conveniently supply the water required for irrigation in the area used at present and also in the entire land area. The results obtained from the study can be used as a guide by farmers for selecting the amount and frequency of irrigation water for the crops studied under consideration.

Reference

Allen, R.G., Perrier, L.S., Raes, D. and Smith, M. (1998) Crop Evapotranspiration: Guidelines for Computing Crop Requirements. Irrigation and Drainage Paper No. 56, FAO, Rome, Italy.

Broner I, Schneekloth J (2003) Seasonal Water Needs and Opportunities for Limited Irrigation for Colorado Crops, Newsletter of the Extension Irrigation Services, Dept. of Civil Engineering, Colorado State University. No. 4.718. http:/www.google search/water requirement

Doorenbos, J. and Pruitt, W.O. (1977) Crop Water Requirement: Food and Agriculture Organization of the United Nations. FAO Irrigation and Drainage Paper 24, Rome, 144.

Droogers, P. and Allen, R.G. (2002) Estimating Reference Evapotranspiration under Inaccurate Data Conditions. Irrigation and Drainage Systems, **16**, 33-45.

Edward, P.G., Huete, A.R., Nagler, P.L. and Nelson, S.G. (2008) Relationship between Remotely Sensed Vegetation Indices, Canopy Attributes and Plant Physiological Processes: What Vegetation Indices Can and Cannot Tell Us about the Landscape. Sensors, **8**, 2136-2160. Environment, **48**, 119-126.

Food and Agriculture Organization (FAO) (1992) CROPWAT: A Computer Program for Irrigation Planning and Management, by M. Smith. FAO Irrigation and Drainage Paper No. 46. Rome.

Food and Agriculture Organization (FAO) (2002) Crop Evapotranspiration Guidelines for Computing Crop Water Requirements: Guidelines for Computing Crop Water Requirements (FAO Irrigation and Drainage Paper No.56,)

Food and Agriculture Organization (FAO) (2005) Irrigation water requirements, In: Irrigation Potential in Africa: A Basin Approach, Chapter 5, FAO Corporate Document Repository, FAO, Rome. http://www.fao.org/docrep/W4347E /w4347e00.htm

Hargreaves, G.H. and Samani, Z.A. (1985) Reference Crop Evapotranspiration from Temperature. Applied Engineering in Agriculture, **1**, 96-99.

Hess T (2005) Crop Water Requirements, Water and Agriculture, Water for Agriculture, WCA infoNET, http:// silsoe.cranfield.ac.uk/iwe/dailyet.htm

Huete, A., Didan, K., Van Leeuwen, W., Miura, T. and Glenn, E. (2008) MODIS Vegetation Indices. In Land Remote Sensing and Global Environmental Change, NASA's Earth Observing System and the Science of ASTER and MODIS.

Jehanger WA, Turral H and Masih I (2004) Water Productivity of Rice Crop in Irrigated Areas.

Luca E, Nagy Z, Berchez M (2003) Water Requirements of the Main Field Crops in Transylvania. Journal of Central European Agriculture, Vol 3, No.2. pp 98-102.

Michael AM (1999) Irrigation Theory and Practice. Vikas Publishing House, New Delhi, India. pp 530-539.

Popova, Z., Kercheva, M. and Pereira, L.S. (2005) Validation of the FAO Methodology for Computing ETo with Limited Data. ICID 21st European Regional Conference, Frankfurt, Slubice.

Proceedings of the 4th International Crop Science Congress, Brisbane, Australia (26 Sept – 1 Oct 2004) http:/www.cropscience.org.au

Ryua, S.Y., Baldocchi, D.D., Black, T.A., Dettoc, M., Lawd, B.E., Leuninge, R., Miyataf, A., Reichsteing, M., Vargash, R., Ammanni, C., Beringer, J., Flanagank, L.B., Gul, L., Hutleym, L.B., Kimn, J., McCaugheyo, H., Moorsp, E. J., Rambal, S. and Vesalar, T. (2012) On the Temporal Upscaling of Evapotranspiration from Instantaneous Remote Sensing Measurements to 8-Day Mean Daily Sums. Agricultural and Forest Meteorology, **152**, 212-222.

Schwab GO, Fangmeier DD, Elliot WJ, Frevert RK (1993) Soil and Water Conservation Engineering, 4th ed. John Wiley and Sons. Pg. 390-395

Tasumi, M. and Allen, R.G. (2007) Satellite-Based ET Mapping to Assess Variation in ET with Timing of Crop Development. Agricultural Water Management, **88**, 54-62.

Yoder, B.J. and Waring, R.H. (1994) The Normalized Difference Vegetation Index of Small Douglas-Fir Canopies with Varying Chlorophyll Concentrations. Remote Sensing of Environment, **49**, 81-91.