**Estimation of water requirement of different field crops grown in *Tons* pump canal command area of eastern Uttar Pradesh**

**ABSTRACT**

 Estimation of water requirement of different field crops was carried out based on twenty-five years meteorological data at *Tons* pump canal command area of eastern Uttar Pradesh. These crops include as wheat, paddy, barley, millet, pea, potato, sugarcane, mustard, *till*, *Arhar* and gram. Reference evapotranspiration was calculated using Penman Monteith Equation. The estimated daily average reference evapotranspiration (ETo) ranged from 2.27 mm to 6.80 mm. The estimated crop water requirement of wheat, paddy, barley, pea, potato, sugarcane, mustard, *till*, *Arhar* and gram crops were 53.84, 16.43, 32.88, 6.38, 25.39, 70.02, 33.31, 150.23, 38.38, 3.57, 4.98, and 26.79 cm, respectively. There was no need of irrigation water requirements for millet crop.

**Key words:** Estimation, Crop water requirement, Evapotranspiration, *Tons* pump canal.

**INTRODUCTION**

 It is common knowledge that water and land are two most critical requirements for human life in which water is depleting at an alarming rate due to rapid urbanization and intensive irrigation systems. India has of 328 million hectares area, accounting for 2.5 percent of the world's area. After the United States, India has the world's second-largest arable land area of 159.7 million hectares (394.6 million acres). It has the world's highest gross irrigated crop area of 82.6 million hectares (215.6 million acres). Irrigation uses two-thirds of the world's fresh water, with groundwater supplies contributing significantly. Agricultural water needs cannot depend alone on surface water due to irregular rainfall and insufficient access to water from rivers. Groundwater is a reasonable option for meeting agricultural needs but overexploitation should be avoided, as the decrease in groundwater levels in India as well as many other parts of the world, has been critical issue.

 Surface water, such as rivers, canals, fresh water lakes and streams and ground water, such as well and borewell water are the two major sources of water (Khan and Rehman, 2017). Large-scale canal irrigation was introduced by the British and continued in independence India, and it was the most commonly used irrigation system at the time. The net area irrigated by canals in India is approximately 15.8 million hectares. The major canal irrigated areas of India are in the northern plains, with UP, Haryana, Punjab, Rajasthan, and Bihar accounting for nearly 60% of the country's canal irrigated area. Andhra Pradesh, Maharashtra, Karnataka, Madhya Pradesh, Chhattisgarh, Orissa, and Tamil Nadu are important canal irrigation states in south and central India. To maintain remaining groundwater and prevent overexploitation, it is essential to predict irrigation requirements and apply the appropriate amount of water to crops for optimal productivity. Adequate moisture is necessary for good crop establishment, good growth, good yields and good quality. The amount of water needed during a growing season depends on the crop, yield goal, soil, temperature, solar radiation and other cultural factors. Sufficient moisture is essential for healthy crop establishment, growth, yields, and quality. The amount of water required throughout a growing season varies according to the crop, yield target, soil, temperature, solar radiation, and other cultural factors. The area of Prayagraj district, selected in the present study, lacks reliable information on the changes in rainfall.

 This study will immensely benefit in agricultural applications such as water project planning and management. Keeping these aspects in mind, the present study was conducted in the *Tons* pump canal command area of eastern Uttar Pradesh, and the objective of this study is to estimate water requirements of different crops.

**MATERIAL AND METHODS**

**Study Area**

 The *Tons* pump canal command area of Eastern Uttar Pradesh is located in Karchhana Tehsil of Prayagraj district as shown in Fig. 1. There are total three blocks comes under the Karchhana tehsil namely - Chaka, Karchhana, Kondhiyaar. Prayagraj district lies between 24˚47' and 25˚43' N latitude and 81˚31' and 82˚21' E longitude. The total geographical area of Prayagraj district is 5482.00 km2. The *Tons* pump canal command area of Karchhana Tehsil lies between 25˚09'15'' and 25˚25'02'' N latitude and 81˚48'25'' and 82˚04'45'' E longitude. The total geographical area of the study area is 546.03 km2.



**Figure 1. Index map of the study area.**

**Climate**

 Prayagraj district has a [humid subtropical climate](https://en.wikipedia.org/wiki/Humid_subtropical_climate) which is characterized by three seasons: a hot dry summer, a cool dry winter and a hot humid monsoon. The winter usually extends from mid-November to last week of February and is followed by the summer which continues till about the middle of June. The normal rainfall of Prayagraj district is 1027 mm (40.43 inch) and approximately 88% of the annual rainfall received during the monsoon season but the variation from year to year is appreciable. There are approximately 48 rainy days in a year. The yearly rainfall trend in the study area from 1997 to 2021 is shown in Fig. 2. The annual mean temperature is 26.1 °C (79.0 °F) and monthly mean temperatures are 18–29 °C (64–84 °F). Temperatures begin to rise in March and reach their peak in mid-May to mid-June before gradually declining till they reach their lowest point in mid-December to mid-January (SHUATS Prayagraj). During the monsoon period, the relative humidity in the study area ranges from 70% to 80% while it drops at 15% to 20% during the summer period. During the summer, wind speeds were generally high. From January to December, the wind speed ranged from 2.7 km/hr to 8.7 km/hr with mean yearly speed about 5.7 km/hr.

**Figure 2. Yearly rainfall in the study area.**

**Land use**

 The land of the study area has been divided into four categories *i.e.* gross sown area, fallow land, horticultural land, and grass land. Agriculture covered around 62% of the Prayagraj district and 66% of the study area. The main crops of study area are wheat, rice, and pearl millet.

**Data collection**

 Meteorological data from 1997 to 2021 (25 years) were collected from the College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS) Prayagraj. Cropping pattern was collected from statistical department of Prayagraj.

**Existing** c**ropping pattern**

In the study area, cropping practices revolve in two main seasons: *Kharif* (October to March) and *Rabi* (July to October). *Rabi* season crop sowing starts towards the end of October or the beginning of November, whereas *Kharif* season crop sowing starts in the middle of June. The main crop grown in *Rabi* and in *Kharif* season is wheat and rice, respectively.Study area existing cropping pattern is given in Table 1.

**Table 1. Existing cropping pattern of the study area.**

|  |  |  |  |
| --- | --- | --- | --- |
| **S. No.** | ***Rabi* season**  | **S. No.** | ***Kharif* season**  |
| **Crop** | **Area (ha)** | **Crop** | **Area (ha)** |
| **1** | Wheat | 25155 | **1** | Paddy | 15174 |
| **2** | Gram | 2003 | **2** | Millet | 4879 |
| **3** | Potato | 846 | **3** | *Arhar* | 3362 |
| **4** | Barley | 515 | **4** | Sorghum | 543 |
| **5** | Mustard | 488 | **5** | Black Gram (*Urad*) | 104 |
| **6** | Pea | 370 | **6** | *Til* | 11 |
| **7** | Sugarcane | 197 | **7** | Sugarcane | 197 |
| **Cultivated land** | **29574** | **Cultivated land** | **24270** |
| **Fallow land** | **25029** | **Fallow land** | **30333** |
| **Total land** | **54603** | **Total land** | **54603** |

**Source:** District statistical Dairy (2021) Prayagraj, U.P

**Estimation of the irrigation requirement of different crops**

Estimation of the irrigation needs of crops of various crops which is grown in the study area calculated by using reference evapotranspiration (ET0), coefficient of crop (Kc), crop water requirement or consumptive use (ETcrop), effective rainfall, water needed for net irrigation and gross irrigation water requirement.

**Reference evapotranspiration (ETo)**

 There are various methods of estimating the reference evapotranspiration. Water requirement for different crops was estimated in this study by utilizing the Penman Monteith Equation.

 $ETₒ = \left[\frac{0.408△\left(Rn-G\right)+γ\left(\frac{900}{T+273}\right)u\_{2}(VPD)}{∆+γ(1+0.34 u\_{2})}\right]$ …. (1)

Where,

ETo = reference evapotranspiration [mm day-1],

Rn = at crop surface, net radiation [MJm-2day-1],

G = heat flux density in soil [MJm-2day-1],

T = temperature of air at height of 2 metres [°C],

u2 = speed of wind at height of 2 metres [m s-1],

 es = vapour saturation pressure [kPa],

 ea = vapour actual pressure [kPa],

 es-ea = deficit vapour saturation pressure [kPa],

 Δ = Vapour pressure slope curve [kPa°C-1],

 Γ = psychrometric constant [kPa°C-1].

**Crop coefficient (Kc)**

The value of crop coefficient available for every crop growth stage, i.e. initial, crop development, mid-season and late-season stage, were taken from FAO, 56 (Allen *et al*., 2014). The Kc was estimated by using curve of crop coefficient methods as recommended by FAO 56.

**Crop evapotranspiration (ETcrop)**

Evapotranspirationof each cropwas estimated by multiply reference evapotranspiration (ETo) mm/day to coefficient of crop (Kc) (Babu *et al.*, 2016).

 ETcrop = ET0 × Kc …. (2)

**Effective rainfall**

 Effective rainfall was estimated on the basis of Soil Conservation Service Method (USDA) formula. The formulas utilized in analysis are as following:

 Peff **=** Pt (125-0.2 Pt) × (1/125**)** for Pt < 250 mm, and …. (3)

 Peff = 125 + 0.1× Pt for Pt > 250 mm …. (4)

Where,

 Peff = effective rainfall,

 Pt = total rainfall.

**Net irrigation water requirement** **(NIWR)**

 The water needed for net irrigation of each crop was calculated by utilizing field water balance. The formulas utilized in analysis are as following:

 NIWR = ET crop – (Pe + Ge + Wb) .... (5)

Where,

ETcrop = crop evapotranspiration,

Peff = effective rainfall,

Ge = groundwater contribution, and

Wb = stored soil water.

**RESULT AND DISCUSSION**

**Reference evapotranspiration (ETo)**

The FAO-56 Penman-Monteith method was used to estimate the daily reference evapotranspiration (ETo) values. On the basis of climatological data of 25 years, the computed average daily reference evapotranspiration values are graphically represented in Fig. 3. The estimated daily average reference evapotranspiration (ETo) ranged from 2.27 mm to 6.80 mm.

 **Figure 3. Variation of estimated** **average daily reference evapotranspiration, using FAO-56 Penman-Monteith method.**

**Crop evapotranspiration, ETcrop**

The method described in Chapter 3 with equation 3.50 was used to estimate the weekly crop evapotranspiration (ETc) values for the various crops grown in the study area. Based on the average ETo and Kc values for the last 25 years, the ETcrop values were calculated.

According to FAO-56 approach was used to develop the crop coefficient curves for various crops. The period of crop growth and the related Kc values for each stage is given in Table 2.

**Table 2. The number of days for each crop's growth period and each crop's stage-specific KC value.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Crop** | **Sowing** **time** | **Growth stage period (days)** | **Total** | **Kc** **Initial** | **Kc Mid** | **Kc** **End** |
| **Initial** | **Development** | **Mid** | **Last** |
| Wheat | November | 20 | 25 | 70 | 30 | 145 | 0.70 | 1.15 | 0.30 |
| Paddy | Mid June | 30 | 30 | 80 | 40 | 180 | 1.05 | 1.20 | 0.90 |
| Millet | Mid June | 15 | 25 | 40 | 25 | 105 | 0.70 | 1.00 | 0.30 |
| Barley | November | 15 | 25 | 50 | 30 | 120 | 0.30 | 1.15 | 0.25 |
| *Urad* | March | 20 | 30 | 30 | 30 | 110 | 0.40 | 1.05 | 0.50 |
| Pea | November | 15 | 25 | 35 | 15 | 90 | 0.50 | 1.15 | 0.30 |
| Gram | Mid October | 20 | 30 | 30 | 30 | 110 | 0.40 | 1.05 | 0.60 |
| Sorghum | April | 20 | 35 | 45 | 30 | 130 | 0.70 | 1.00 | 0.55 |
| Potato | Mid October | 25 | 30 | 30 | 30 | 115 | 0.50 | 1.15 | 0.75 |
| Sugarcane | October | 25 | 70 | 135 | 50 | 280 | 0.40 | 1.25 | 0.75 |
| Mustard | Mid October | 20 | 40 | 60 | 25 | 145 | 0.35 | 1.00 | 0.35 |
| *Arahar* | Mid June | 30 | 25 | 50 | 25 | 130 | 0.50 | 1.00 | 0.60 |
| *Til* | July | 20 | 30 | 40 | 10 | 100 | 0.35 | 1.10 | 0.25 |

**Crop water requirement**

 The weekly net irrigation requirements of different crops were estimated based on ETcrop and average effective rainfall values. Therefore, the monthly gross irrigation requirements (GIR) of different crops in study area are given in Table 3. It may be seen from Table 3 that the maximum monthly water requirement in the month of December was 82.26 cm, while the minimum value was zero in the months of July and August.

**CONCLUSION**

 This study established that millet could be grown conveniently during their growing season without supplemental irrigation in the study area. However, a crop water requirement of sugarcane in study area is very high. During the July and August months, there are no needs of irrigation water in the study area while, in April and December months, there are very much requirement of irrigation water in the study area.

**Table 3. Monthly gross irrigation water requirements for different crops grown in study area.**

|  |  |  |
| --- | --- | --- |
| **Month** | **Gross Irrigation Water Requirement (cm)** | **Total****(cm)** |
| **Wheat** | **Paddy** | **Barley** | **Millet** | ***Urad*** | **Pea** | **Sorghum** | **Potato** | **Sugarcane** | **Mustard** | ***Till*** | ***Arhar*** | **Gram** |
| Jan | 9.65 | 0.00 | 9.65 | 0.00 | 0.00 | 7.63 | 0.00 | 8.50 | 10.63 | 8.13 | 0.00 | 0.00 | 5.66 | **59.85** |
| Feb | 13.69 | 0.00 | 7.80 | 0.00 | 0.00 | 0.00 | 0.00 | 2.28 | 15.14 | 10.15 | 0.00 | 0.00 | 0.41 | **49.47** |
| Mar | 11.26 | 0.00 | 0.00 | 0.00 | 8.74 | 0.00 | 6.69 | 0.00 | 29.51 | 2.40 | 0.00 | 0.00 | 0.00 | **58.60** |
| Apr | 0.00 | 0.00 | 0.00 | 0.00 | 22.50 | 0.00 | 22.73 | 0.00 | 30.88 | 0.00 | 0.00 | 0.00 | 0.00 | **76.11** |
| May | 0.00 | 0.00 | 0.00 | 0.00 | 23.25 | 0.00 | 26.52 | 0.00 | 28.75 | 0.00 | 0.00 | 0.00 | 0.00 | **78.53** |
| Jun | 0.00 | 1.97 | 0.00 | 0.00 | 5.88 | 0.00 | 14.07 | 0.00 | 14.24 | 0.00 | 0.00 | 0.00 | 0.00 | **36.16** |
| Jul | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** |
| Aug | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** |
| Sep | 0.00 | 3.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.79 | 0.62 | 0.00 | **5.49** |
| Oct | 0.00 | 11.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.96 | 2.98 | 1.85 | 1.78 | 4.31 | 2.22 | **27.50** |
| Nov | 7.22 | 0.00 | 3.49 | 0.00 | 0.00 | 5.50 | 0.00 | 6.98 | 6.88 | 5.43 | 0.00 | 0.00 | 6.69 | **42.18** |
| Dec | 12.02 | 0.00 | 11.96 | 0.00 | 0.00 | 12.26 | 0.00 | 12.59 | 11.21 | 10.42 | 0.00 | 0.00 | 11.80 | **82.26** |
| **Total** | **53.84** | **16.43** | **32.88** | **0.00** | **60.38** | **25.39** | **70.02** | **33.31** | **150.23** | **38.38** | **3.57** | **4.94** | **26.79** | **516.15** |

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