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# Study on Water Requirement of Rice using CROPWAT Model for Lucknow Division of Uttar Pradesh

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## ABSTRACT

Due to the overuse of available water resources, it has become very important to define appropriate strategies for planning and management of irrigated farmland one of the major practices adopted by the researchers for estimating water requirement of the crop is modeling. For determination of crop evapotranspiration and yield responses to water in agro-ecological units (AEUs) of Lakhimpur Kheri, Sitapur, Lucknow, Unnao, Hardoi, Rai Bareilly district of Uttar Pradesh, CROPWAT 8.0 model is used, which includes a simple water balance model that allows the simulation of crop water stress conditions and estimation of yield reductions based on well-established methodologies. This paper is been focused on the study of water requirement for rice crop in Lucknow division of Uttar Pradesh.

*KEYWORD*

CROPWAT model, Crop water requirement, Effective Rainfall, Irrigation demand, Rice

## INTRODUCTION

Water is an essential input for crop production and it is becoming increasingly scarce worldwide. Serious water shortages are developing in many countries particularly in India and water for agriculture is becoming increasingly scarce in the light of growing water demands from different sectors. Agriculture is the largest (81 per cent) consumer of water in India and hence the most efficient use of water in agriculture needs to be top most priority. Aridity and drought are natural causes of scarcity. However man-made desertification and water shortages have aggravated natural scarcity while at the same time population is increasing and there is increased competition for water among water user sectors and regions. In addition, the quality of water is often degraded, so that water resources become less and less available. Thus, improved management and planning of the water resources are needed to ensure proper use and distribution of the water among competing users. For the accurate planning and delivery of the necessary amount of the water in the time and space can conserve water. A scarce water resources and growing competitions for water will reduce its availability for irrigation. Achieving greater efficiency of water use will be a primary challenge for the near future and will include the employment of techniques and practices that deliver a more accurate supply of water to crops. Prediction of the crop water requirement is of vital importance in water resources management. Crop water requirements are normally expressed by the rate of evapotranspiration (ET) in mm day$^{-1}$ or mm period$^{-1}$. One of the major practices adopted by the researchers for water requirement of crops is modeling. For determination of crop evapotranspiration and yield responses to water, CROPWAT 8.0 model is used which was developed by the FAO Land and Water Development Division (FAO, 1992). It also includes a simple water balance model that allows the simulation of crop water stress conditions and estimation of yield reductions based on well-established methodologies. Several researchers have used the CROPWAT 8.0 model for analyzing crop water and requirements in different parts of the world (Kar and Verma, 2005; Martyniak *et al.*, 2006; Dechmi *et al.*, 2003 and Gangwar *et al.*, 2017). The irrigation schedule recommendations for various crops should be location-specific, considering the soil types and agro-ecological conditions. The scientific crop water requirements are required for efficient irrigation scheduling, water balance, canal design capacities, regional drainage, water resources planning, reservoir operation studies, and to assess the potential for crop production.

## MATERIALS AND METHODS

### Study location

Lucknow Division consists of Lakhimpur Kheri, Sitapur, Lucknow, Unnao, Hardoi, Rai Bareilly district of Uttar Pradesh, which is situated at northern India and located between 80.30º E to 81.16º E longitudes and 26.14º N to 27.57º N latitudes. The study area receives an average annual rainfall of 1025 mm and the elevation ranges from 22 to 222 m. The study area characterized by hot summer (41.7 $^0$C) and mild winter (8.5 $^0$C) and it contain very vast range of soil i.e. deep loamy soil, deep loamy with sodicity, deep silty soils, deep fine soils with loamy soils and deep fine soils.

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### Land use and land cover

From the result, it has been depicted that the land use and land cover classified into thirteen different classes, which is presented with the area covered in Table 1 and prepared map of land use and land cover is shown in Fig. 1. The maximum part of the study area is covered by the irrigated, conjunctive use, double crop (21613.43 $Km^2$) while minimum by water bodies (7.49 $Km^2$). The major crop grown in the area is rice, wheat, cotton, sugarcane, lentil, gram and groundnut.

Table 1: Area covered by different land use and land cover classes

| Classes | Area ($Km^2$) |
|---|---|
| Water bodies | 7.49 |
| Wetlands | 14.37 |
| Barren/desert/wastelands/builtup | 100.23 |
| Rangelands: grassland, shrublands, woodlands | 358.02 |
| Rainfed crop lands | 44.95 |
| Irrigated, surface water, single crop | 11.54 |
| Irrigated, surface water, double crop | 6970.25 |
| Irrigated, surface water, continuous crop | 137.49 |
| Irrigated, ground water, single crop | 82.62 |
| Irrigated, ground water, double crop | 197.03 |
| Irrigated, conjunctive use, single crop | 161.59 |
| Irrigated, conjunctive use, double crop | 21613.43 |
| Forest | 1552.97 |

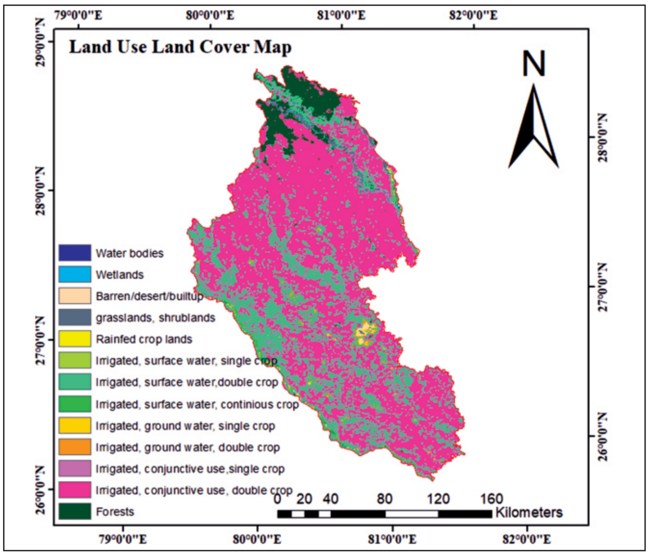



Fig. 1: Land Use Land Cover Map of the Study Area

### Crop data

The major cultivated crops in study area are Wheat, rice, sugar cane, apples, mango, pulses, oil seeds and potato are the main crops. The salient details (i.e. crop coefficient, length of growing stages, yield response factor and crop height etc.) of crops considered for the study are as per guide for estimating irrigation water requirement, Ministry of Irrigation, Govt. of India and FAO - Irrigation and Drainage paper, 24 & 56.

### CROPWAT 8.0 Model

CROPWAT for Windows is a decision support system developed by the Land and Water Development Division of FAO, Italy with the assistance of the Institute of Irrigation and Development Studies of Southampton, UK and National Water Research Center, Egypt. The model carries out calculations for reference evapotranspiration, crop water requirements and irrigation requirements in order to develop irrigation schedules under various management conditions. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules and the assessment of production under rainfed conditions or deficit irrigation (Adriana and Cuculeanu, 1999).

### Reference evapotranspiration

This parameter was calculated in CROPWAT8.0 Model which uses the FAO Penman-Monteith method (Allen *et al.*, 1998). In this model, most of the equation parameters are directly measured or can be readily calculated from weather data.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where, $ET_o$ is reference evapotranspiration (mm $day^{-1}$), $R_n$ is net radiation at the crop surface (MJ $m^{-2}$ $day^{-1}$), G is soil heat flux density (MJ $m^{-2}$ $day^{-1}$), T is air temperature at 2m height (°C), $u_2$ is wind speed at 2 m height (m $s^{-1}$), $e_s$ is saturation vapour pressure (kPa), $e_a$ is actual vapour pressure (kPa), $e_s$ - $e_a$ is saturation vapour pressure deficit (kPa), Δ is slope vapour pressure curve (kPa $°C^{-1}$), ϒ is psychrometric constant (kPa $°C^{-1}$).

### Effective rainfall

It is the part of rainfall which is stored in the soil profile and helps in the growing of crops. Rainfall of Lakhimpur Kheri, Sitapur, Lucknow, Unnao, Hardoi, Rai Bareilly district of Uttar Pradesh in Table 2. USDA Soil Conservation Service method was used to calculate the effective rainfall (Smith, 1991).

Table 2: Rainfall pattern of Lucknow division of Uttar Pradesh

| District | Rainfall (mm) | | | | |
|---|---|---|---|---|---|
| | SW monsoon (June-Sep) | Post Monsoon (Oct-Dec) | Winter (Jan-Mar) | Pre (Apr-May) | Annual |
| Lakhimpur Kheri | 921.8 | 55.5 | 57.4 | 34.0 | 1068.7 |
| Sitapur | 849.8 | 52.3 | 47.6 | 24.3 | 974.3 |
| Lucknow | 848.4 | 46.1 | 43.1 | 21.6 | 959.2 |
| Unnao | 742.3 | 41.0 | 41.2 | 16.3 | 840.8 |
| Hardoi | 767.9 | 45.8 | 41.6 | 19.5 | 874.8 |
| Rai Bareilly | 825.1 | 43.5 | 43.8 | 15.2 | 927.6 |

$P_{eff} = P_{tot} \times (125 - 0.2P_{tot})/125$ for $P_{tot} < 250$mm

$P_{eff} = 125 + 0.1 \times P_{tot}$ for $P_{tot} > 250$mm

Where, $P_{eff}$ represents effective rainfall (mm) and $P_{tot}$ represents total rainfall (mm)

### Crop Evapotranspiration

For calculation of crop evapotranspiration CROPWAT 8.0

model uses crop coefficient approach and crop water requirements of different crops have been estimated by summing up the crop evapotranspiration in all growth stages.

$$ET_{crop} = K_c \times ET_o$$

where, $ET_c$ represents crop evapotranspiration, $K_c$ represents crop coefficient and $ET_o$ represents reference evapotranspiration.

## RESULTS AND DISCUSSION

### Reference evapotranspiration

The simulated values of reference evapotranspiration (ETo) through CROPWAT 8.0 model using FAO Penman-Monteith equation, for the Lakhimpur Kheri, Sitapur, Lucknow, Unnao, Hardoi, Rai Bareilly district along with the meteorological parameters is presented in the Table 3 and monthly distribution of reference evapotranspiration is shown in the Fig. 3. From the result, it is revealed that the maximum $ET_o$ was found in Unnao district (2.1 mm/day), which was mainly due to high temperature and wind velocity, whereas it was minimum in Sitapur district (1.8 mm/day). The reference evapotranspiration also affected by relative humidity which is the function of temperature.

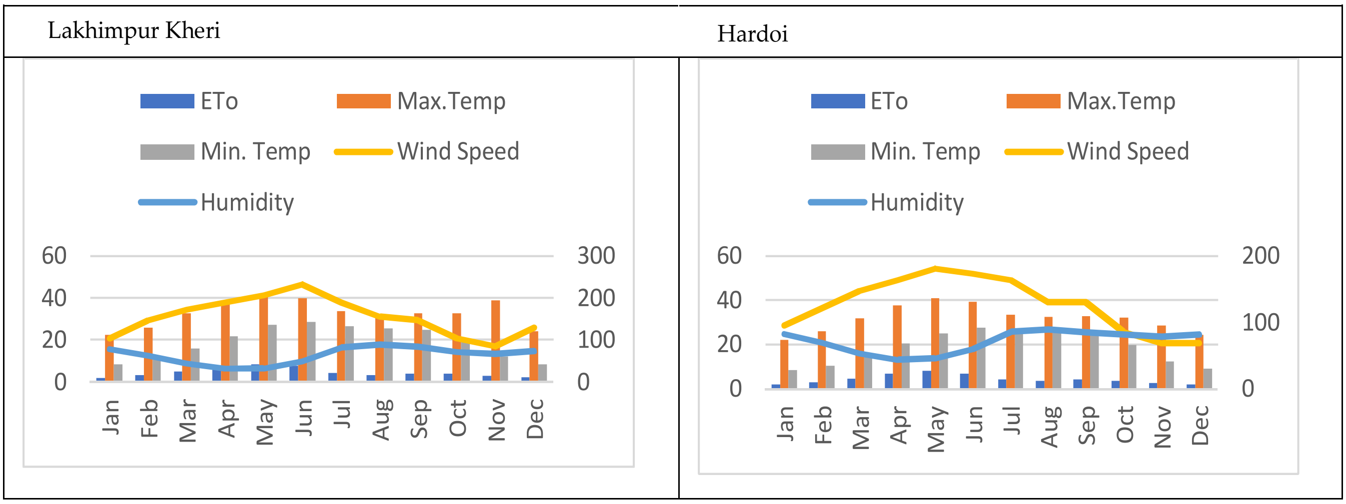
**Table 3:** Reference evapotranspiration along with meteorological parameters of the study area

| Districts | Temperature ($^0$C) | | Wind Speed (Km/h) | | Humidity (%) | | Rainfall (mm) | | ETo (mm day$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| Lakhimpur Kheri | 38.5 (May) | 9.1 (Jan) | 147 (April, May) | 69 (Nov, Dec) | 88 (Aug, Sept) | 49 (April) | 336 (Aug) | 1 (Nov) | 6.53 (May) | 1.85 (Dec) |
| Sitapur | 38.5 (May) | 9.1 (Jan) | 181 (May) | 69 (Nov, Dec) | 93 (Jul, Aug) | 44 (April) | 300 (Aug) | 1 (Nov) | 6.9 (May) | 1.8 (Dec) |
| Lucknow | 41.2 (May) | 8.8 (Jan) | 104 (June) | 26 (Jan, Oct, Nov, Dec) | 90 (Aug) | 38 (April) | 302 (Aug) | 1 (Nov) | 6.15 (May) | 1.83 (Jan) |
| Unnao | 41.7 (May) | 8.5 (Dec) | 233 (June) | 86 (Nov) | 89 (Aug) | 33april (May) | 293 (Aug) | 1 (Nov) | 8.48 (May) | 2.1 (Jan) |
| Hardoi | 41 (May) | 8.5 (Jan) | 181 (May) | 69 (Nov, Dec) | 89 (Aug) | 44 (April) | 333 (Aug) | 2 (Nov) | 8.28 (May) | 1.88 (Jan) |
| Rai Bareilly | 42.2 (May) | 8.8 (Jan) | 112 (Jun) | 35 (Oct, Nov, Dec) | 89 (Sep) | 41 (May) | 278 (Aug) | 2 (Nov) | 6.72 (May) | 1.93 (Jan) |

### Effect of weather parameters on reference evapotranspiration

Relative Humidity is a function of air temperature which means higher the temperature more is the amount of water vapor that can be hold by the atmosphere; however the relative humidity decreases with increasing temperature due to increasing saturation point.

The extent of evaporation and transpiration depend on the amount of moisture present in the atmosphere. From the analysis, it is depicted that the reference evapotranspiration was higher in the sunny period (Mar-June) for all the considered districts whereas it was found minimum in monsoon season (June-Sep) and cooler period (Nov-Feb). It has been observed from the result that, the reference evapotranspiration is greatly influenced throughout the sunny periods because it possesses a high temperature as well as high wind velocity and encounter low relative humidity. The effect of different parameters on reference evapotranspiration is shown in the Fig.2.



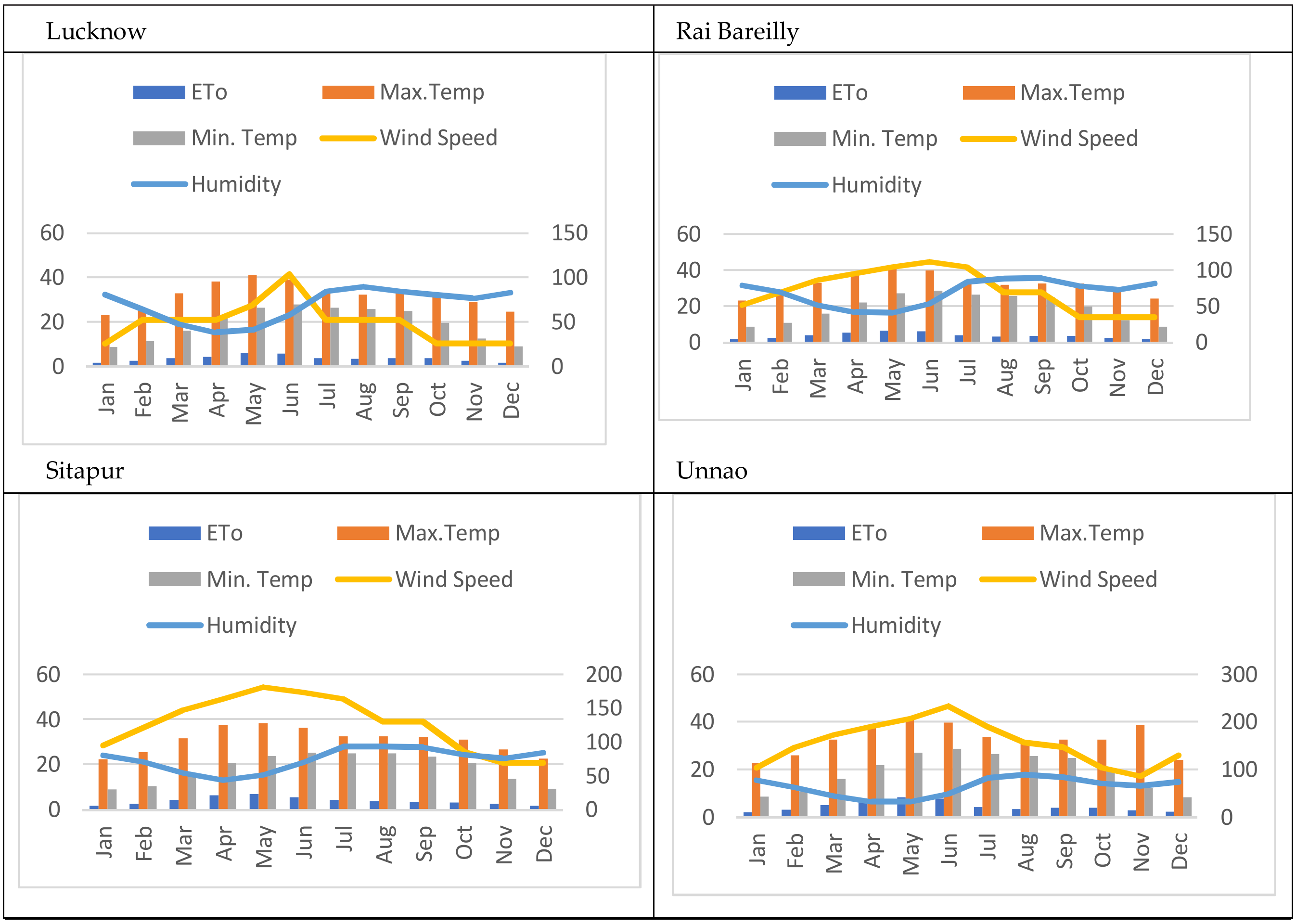



**Fig. 2 :** Effect of weather parameters on reference evapotranspiration (ETo)

**Crop water requirement**

The difference in the evapotranspiration and evaporation was considered as the water consumed by the rice plant and termed as crop water requirement. Estimated Crop water requirement of rice crops for Lucknow division has been presented in Table 5. The results show that the crop water requirement of rice crop is more in the month of June followed by May month for all the districts which falls under the study area. This was happened due to high reference evapotranspiration in the same months. Also, during the growing and developing period crops also need large quantity of water for various physiological functions. The crop water requirement was calculated for six districts of Lucknow division and it was found the maximum in Unnao district (639.6 mm), whereas minimum in Sitapur district (403.8 mm). From the result, it is revealed that the other districts i.e. Hardoi and Rai Bareilly have almost equal crop water requirement which was 487.4 mm and 482.2 mm, respectively. A certain crop grown in a sunny and hot climate needs more water per day when contrasted with a crop grown in a cool and cloudy climate. Apart from sunshine and temperature, other climatic factors like wind velocity and

**Table 4:** District-wise effective rainfall of Lucknow division

| | Months | Effective Rainfall (mm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) |
| Districts | Lakhimpur Kheri | 31.3 | 12.7 | 15.6 | 5 | 20.3 | 97.6 | 156 | 158.6 | 130.2 | 63.7 | 1 | 4 | 696 |
| | Hardoi | 24.9 | 12.7 | 16.5 | 3 | 10.8 | 79.2 | 156 | 158.3 | 141 | 62.2 | 2 | 5.9 | 672.5 |
| | Lucknow | 23.1 | 16.5 | 8.9 | 5.9 | 11.8 | 79.9 | 154.9 | 155.2 | 129 | 37.4 | 1 | 5.9 | 629.5 |
| | Rai Bareilly | 19.4 | 13.7 | 6.9 | 5 | 5.9 | 56.6 | 152.6 | 152.8 | 124.7 | 37.4 | 2 | 7.9 | 584.9 |
| | Sitapur | 24 | 9.8 | 17.5 | 5 | 7.9 | 91.9 | 151.2 | 155 | 130.2 | 69 | 1 | 4 | 666.5 |
| | Unnao | 21.2 | 12.7 | 7.9 | 3 | 7.9 | 50.2 | 143.4 | 154.3 | 115 | 46 | 1 | 7.9 | 570.5 |

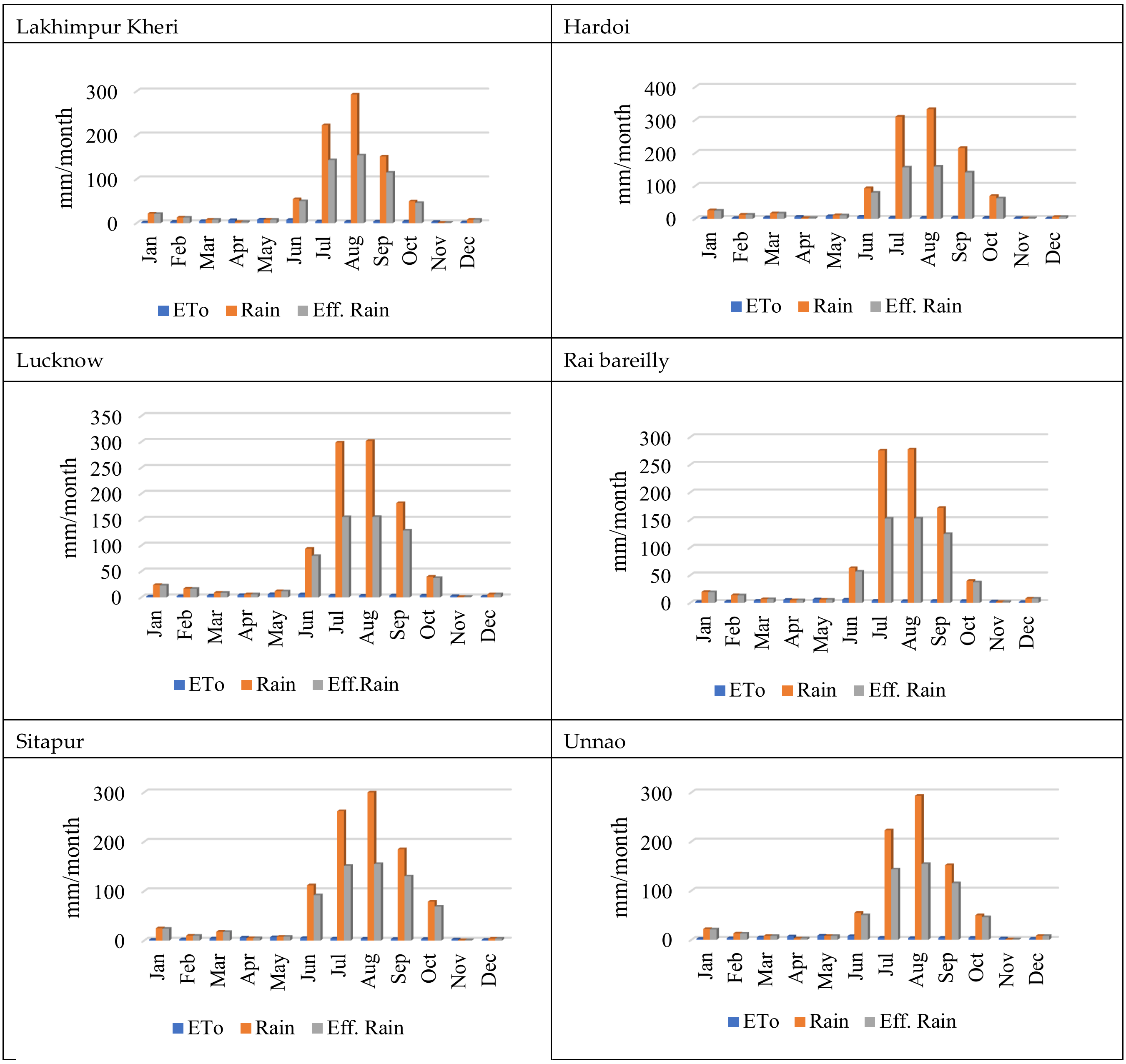



**Fig. 3**: Reference evapotranspiration ($ET_o$), rainfall and effective rainfall at six districts of Lucknow Division.

humidity also influence the crop water need. By using the crop water requirement of rice crops, water demand has been calculated for all six districts of Lucknow division, which is shown in Fig. 4. This water demand for rice crop will help in water management in the study area also assist in the scheduling of irrigation.

**Table 5**: District-wise crop water requirement of Rice crops in Lucknow division

| | Months | Crop Water Requirement (mm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total (mm) |
| Districts | Lakhimpur Kheri | 0 | 0 | 0 | 0 | 143.2 | 232.6 | 6.2 | 0 | 1.3 | 0 | 0 | 0 | 383.3 |
| | Hardoi | 0 | 0 | 0 | 0 | 174.8 | 297.5 | 10.1 | 0 | 5 | 0 | 0 | 0 | 487.4 |
| | Lucknow | 0 | 0 | 0 | 0 | 148.6 | 266.2 | 2.6 | 0 | 6.2 | 6.8 | 0 | 0 | 430.4 |
| | Rai bareilly | 0 | 0 | 0 | 0 | 161 | 295.9 | 10.6 | 0 | 7.8 | 6.9 | 0 | 0 | 482.2 |
| | Sitapur | 0 | 0 | 0 | 0 | 157.6 | 238.5 | 7.5 | 0 | 0.2 | 0 | 0 | 0 | 403.8 |
| | Unnao | 0 | 0 | 0 | 0 | 182.2 | 408 | 18.7 | 0 | 22.3 | 8.4 | 0 | 0 | 639.6 |

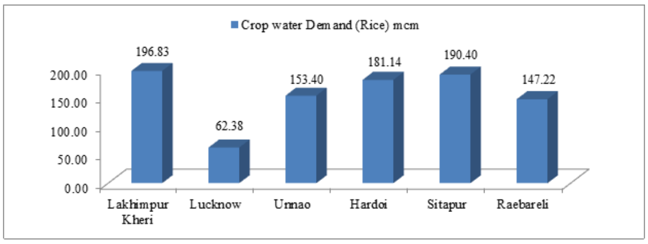



**Fig.4:** Crop water demand for Rice crop in Lucknow division

## CONCLUSIONS

The present study indicated that the maximum crop water requirement was 639.6 mm in Unnao district while maximum crop water demand was 196.83 MCM in Lakhimpur Kheri district. This study will help in the calculation of net irrigation water requirement of rice crop as well as in scheduling of irrigation, and aids for understanding the behavior of weather parameter on reference evapotranspiration. The results clearly show that the crop water requirement during the sunny period is very high as compared to another season. The consequences of this study may help in judicious utilization of available water and may reduce the over utilization of ground water source and eventually helps in improving the water use efficiency.

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