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Comparative Crop Water Assessment Using CROPWAT

Crop Water Assessment of Plain and Hilly Region Using CROPWAT Model

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***Abstract*—This paper investigates the potential of CROPWAT to model the crop water assessment using field data. A dataset consisting of 2007 to 2011 each for maximum temperature, minimum temperature, relative humidity, sunshine hour, wind speed and rainfall data taken from CSSRI (Central Soil Salinity Research Institute), Karnal, Haryana and MC (Meteorological Centre), Dehradun, Uttarakhand for the plain and hilly region were used for this analysis. Besides, information on crop and soil were collected from different literature review. Results obtained by CROPWAT model were compared between plain and hilly region for rice and wheat crop to meet the irrigation demand of crops. Results were found that reference evapotranspiration of rice and wheat crop is more for the plain region as compared to the hilly region while crop evapotranspiration of rice crop is more for the hilly region as compared to plain region and for wheat crop it is more for the plain region as compared to the hilly region. Irrigation requirement of rice and wheat crop is more for the plain region as compared to the hilly region.**

***Keywords*—CROPWAT model, reference and crop evapotranspiration, irrigation requirement.**

I. Introduction

Since agriculture is the major user of water, improving agricultural water management is essential. Efficient agricultural water management requires reliable estimation of crop water requirement. Crop water requirements are normally expressed by the rate of evapotranspiration (ET) in mm day^{-1}. From an agricultural point of view, ET determines the amount of water to be applied through artificial means. The global consumption of water is doubling every 20 years, more than twice the rate of human population growth. A Food and Agriculture organization (Food and Agriculture Organization) estimate puts that 70-80 per cent of the increase in food demand between 2000 and 2030 will have to be met by irrigation. Irrigated agriculture is practiced on about 300 million hectares only or 20 per cent of the cultivable area (Food and Agriculture Organization, 2010), but contributing substantially with more than 40 per cent of world's food production. Irrigation can reduce the risks associated with the unpredictable nature of rain fed agriculture in dry regions. Irrigated agriculture offers great potential for economic growth and poverty reduction. Evaporation demand is projected to increase almost everywhere in the world in future climate scenarios. Thus, the process of evapotranspiration (ET) is of great importance in present and future climates. The measurement of ET from a crop surface is a very difficult and time consuming task. A large number of more or less empirical methods have been developed over the last 50 years by numerous scientists and specialists worldwide to estimate evapotranspiration from different climatic variables like Thornthwaite method, Hargreaves method, Turc method, Blaney Criddle method, Modified Penman method, Penman-Monteith method etc. To evaluate the performance of these methods under different climatological conditions, a major study was undertaken under the auspices of the Committee on Irrigation Water Requirements of the American Society of Civil Engineers (ASCE). They said that these methods either underestimate or overestimate the evapotranspiration except Penman-Monteith method. They recommended the FAO Penman-Monteith method as the sole standard method for computation of evapotranspiration. India have different topographical region. Different region will have different crop water requirement. In this study, comparison of crop water requirement is made between plain and hilly region. Karnal and Dehradun region have been considered for the study as plain and hilly region respectively. It is necessary to know the crop water requirements for different regions to meet the irrigation demand and for sustainable development of agriculture. 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 model is used which was developed by the FAO Land and Water Development Division. Based on FAO Penman-Monteith method CROPWAT model has been developed. It requires some input meteorological parameter like maximum temperature, minimum temperature, relative humidity, sunshine hour, wind speed. After putting all the input parameters it calculates reference evapotranspiration, effective rainfall, crop evapotranspiration and irrigation requirement for the plain and hilly region.

II. Materials and Methods

A. *Selection of a model*

In this study, CROPWAT model is selected for the computation of crop water requirement and irrigation requirement of plain and hilly region for rice and wheat crop. CROPWAT 8.0 can calculate reference evapotranspiration using only maximum and minimum temperature, sunshine hour, rainfall, relative humidity, wind speed et

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B. CROPWAT Model

Computer model simulation is an emerging trend in the field of water management. CROPWAT is a powerful simulation tool which analyzes complex relationships of on-farm parameters such as the crop, climate, and soil, for assisting in irrigation management and planning. CROPWAT is one of the models extensively used in the field of water management throughout the world. CROPWAT facilitates the estimation of the crop evapotranspiration, irrigation scheduling and agricultural water requirements with different cropping patterns for irrigation planning.

C. Advantage of CROPWAT Model

The advantage of using the CROPWAT model as a tool for assessing crop water use is that it is simple and easy to use, and linked to less intense data requirements than other dynamic models such as ARCU, WOFORST and DSSAT. CROPWAT requires only monthly or daily inputs of climate and rain data, coupled with crop parameters and soils data, to calculate water and irrigation requirements.

D. CROPWAT Model Input Data

The basic input data for CROPWAT model are the climatic parameters which are required for calculating Reference Evapotranspiration. Researchers proposed several methods to determine evapotranspiration out of which the Penman-Monteith Method (FAO 1998) has been recommended as the appropriate combination method to determine the crop water requirements from climatic data on temperature, humidity, sunshine and wind speed.

III. Reference Evapotranspiration (ET_o) Calculation Methodology

A. ET_O /Climate Data Input and Output

The climate module can be selected by clicking on the "Climate/ET_o" icon in the module bar located on the left of the main CROPWAT window. The data window will open with the default data type (monthly / decade / daily values); it is possible to quickly change to another data type by using the drop down menu from the "New" button on the toolbar. In alternative, use the "New" button in the "File" drop down menu. The module is primary for data input, requiring information on the meteorological station (country name, altitude, latitude and longitude) together with climatic data.

B. ET_o /Climate Data Saving

After checking the data for possible errors, climate/ET_o data can be saved selecting the "Save" button on the Toolbar or the "File" > "Save" menu item. It is important to give an appropriate name to the data set which can easily be recognized later. In this study, the name KARNAL and DEHRADUN, referring to the climate station of plain region and hilly region from which data has been taken, were used.

C. Rainfall Data Input and Output

The Rain module can be selected by clicking on the "Rain" icon in the module bar located on the left of the main CROPWAT window. The data window will open with the default data type (daily / decade / monthly values); it is possible to quickly change to another data type by using the drop down menu from the "New" button on the toolbar. In alternative, use the "New" button in the "File" drop down menu. Once the window is open with the suitable data type, type rainfall data and check the input. The rain module includes calculations producing effective rainfall.

D. Saving Rainfall Data

Rainfall data should be saved after input of one set of data is completed. To do so, select the "Save" button on the toolbar or the "File" > "Save" menu item.

E. Crop Data Input and Output

The crop module can be selected by clicking on the "Crop" icon in the module bar located on the left of the main CROPWAT window. The data window will open with the default data type (non-rice / rice crop); it is possible to quickly change to the other data type by using the drop down menu from the "New" button on the toolbar. In alternative, use the "New" button in the "File" drop down menu. Data required differ in case of non-rice or a rice crop. In case of non-rice crop, crop name, planting date, crop coefficient (K_c), stages length, rooting depth, critical depletion fraction (p), yield response factor (K_y) are necessary.

F. Soil Data Input and Output

The soil module is selected by clicking on the "Soil" icon in the module bar located on the left of the main CROPWAT window. In alternative, it can be opened by using the drop down menu from the "New" button on the toolbar or using the "New" button in the "File" drop down menu. The Soil module is essentially data input, requiring the general soil data like Total Available Water (TAW), maximum infiltration rate, maximum rooting depth, initial soil moisture depletion. In case of rice calculation, additional soil data are required like drainable porosity, critical depletion for puddle cracking, water availability at planting, maximum water depth.

G. *Soil Data Saving*

Soil data should be saved after input of one set of data is completed. To do so, select the "Save" button on the toolbar or the "File" > "Save" menu item.

H. *Crop Water Requirement (CWR) Calculations*

Calculation of the CWR can be carried out by calling up successively the appropriate climate and rainfall data sets, together with the crop files and the corresponding planting dates. In case of CWR calculation of rice, soil data are also required.

I. *CWR Data Input and Output*

The CWR module can be selected by clicking on the "CWR" icon in the module bar located on the left of the main CROPWAT window. Data on climate/ET_o, rainfall, crop and soil are required. If not all data are available, CROPWAT will produce a warning and close the CWR module. The CWR module includes calculations, producing the irrigation water requirement of the crop on a decadal basis.

IV. Results and Discussion

The results obtained by CROPWAT 8.0 software are tabulated below:

TABLE 1. ET_o, ET_c and IR Values of Rice Crop for Plain Region[1]

Year	Values of Reference Evapotranspiration, Crop Evapotranspiration and Irrigation Requirement		
	Reference Evapotranspiration (ET_o) (mm/day)	*Crop Evapotranspiration (ET_c) (mm/decade)*	*Irrigation Requirement (IR) (mm/decade)*
2007	4.59	698	693.3
2008	4.02	628.6	550.3
2009	4.86	750.6	882.5
2010	4.12	632.7	453
2011	4.17	637.8	682.2

TABLE 2. ET_o, ET_c and IR Values of Rice Crop for Hilly Region[1]

Year	Values of Reference Evapotranspiration, Crop Evapotranspiration and Irrigation Requirement		
	Reference Evapotranspiration (ET_o) (mm/day)	*Crop Evapotranspiration (ET_c) (mm/decade)*	*Irrigation Requirement (IR) (mm/decade)*
2007	4.06	756.5	427.7
2008	3.31	650.4	263.2
2009	3.95	741.9	377.6
2010	3.57	659.2	367.4
2011	3.48	665.3	250.4

TABLE 3. ET_o, ET_c and IR Values of Wheat Crop for Plain Region[1]

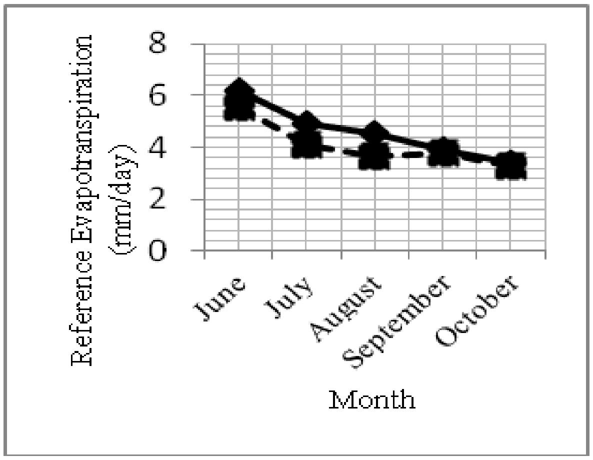
Year	Values of Reference Evapotranspiration, Crop Evapotranspiration and Irrigation Requirement		
	Reference Evapotranspiration (ET_o) (mm/day)	*Crop Evapotranspiration (ET_c) (mm/decade)*	*Irrigation Requirement (IR) (mm/decade)*
2007	2.85	309.5	211.6
2008	2.71	305.2	296.5
2009	2.86	311.6	287.2
2010	2.78	292.5	267.8
2011	2.60	284	231

TABLE 4. ET_o, ET_c and IR Values of Wheat Crop for Hilly Region[1]

Year	Values of Reference Evapotranspiration, Crop Evapotranspiration and Irrigation Requirement		
	Reference Evapotranspiration (ET_o) (mm/day)	*Crop Evapotranspiration (ET_c) (mm/decade)*	*Irrigation Requirement (IR) (mm/decade)*
2007	3.30	278	164.2
2008	2.59	223.5	183.5
2009	2.72	240.8	194.1
2010	2.71	231.3	175
2011	2.49	215.6	145.9

Now comparison is made between reference evapotranspiration, crop evapotranspiratopn and irrigation requirement of rice and wheat crop for the plain and hilly region.

A. *Comparison of Reference Evapotranspiration of Rice Crop*



[1] In Table 1, 2 ,3 and 4 ET_0, ET_c and IR represents Reference Evapotranspiration, Crop Evapotranspiration and Irrigation Requirement respectively.

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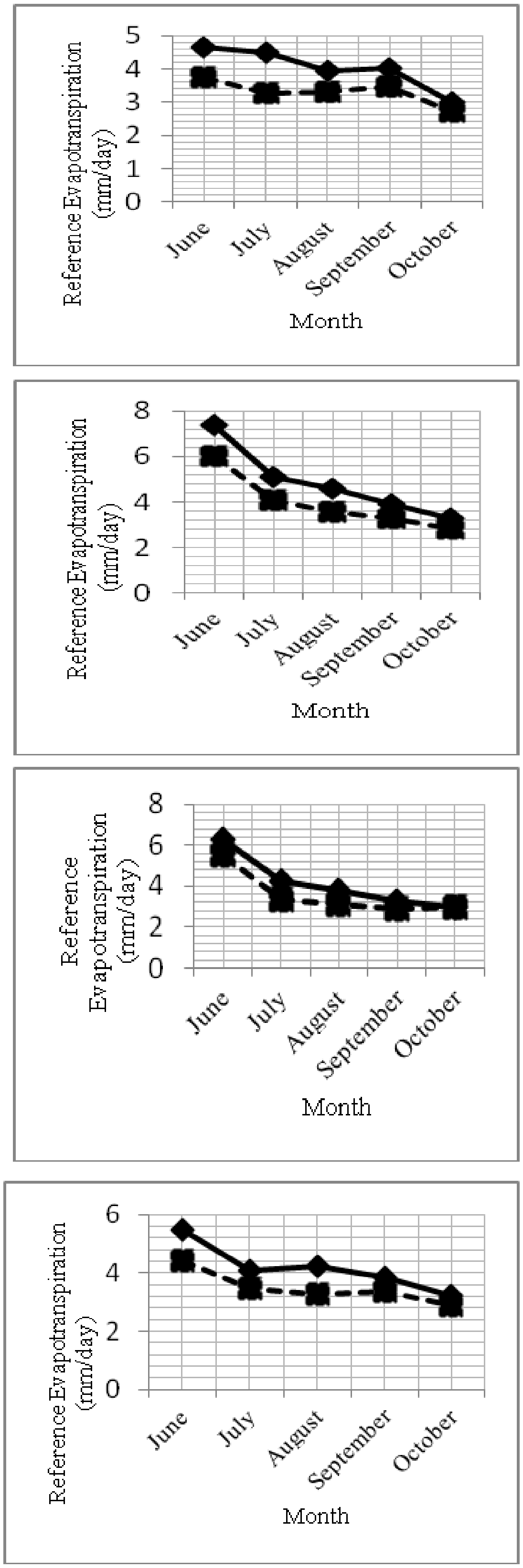
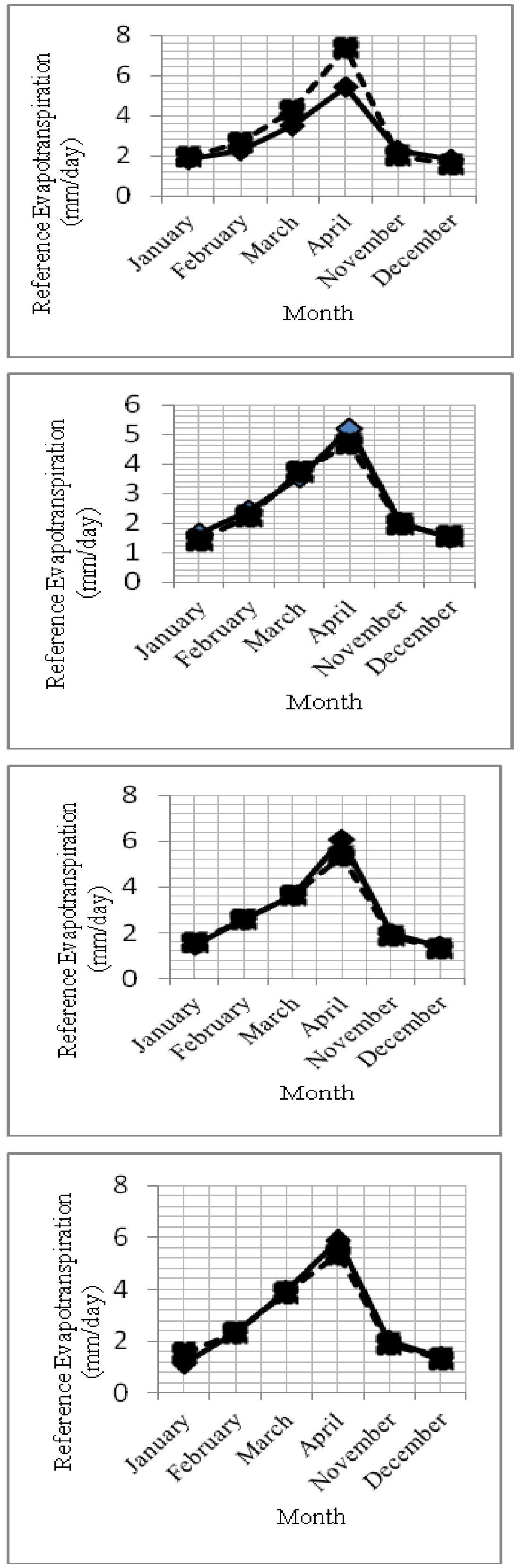


Figure 1. Reference evapotranspiration comparison of plain and hilly region of the year 2007, 2008, 2009, 2010 and 2011 respectively[2]

[2] In Fig. 1 and Fig. 2 black line and dotted line represents the reference evapotranspiration of plain and hilly region respectively.

B. *Comparison of Reference Evapotranspiration of Wheat Crop*



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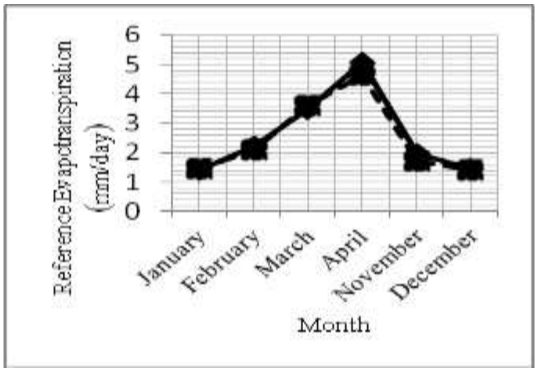
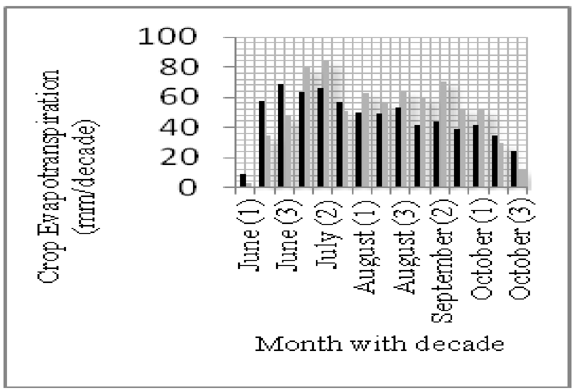
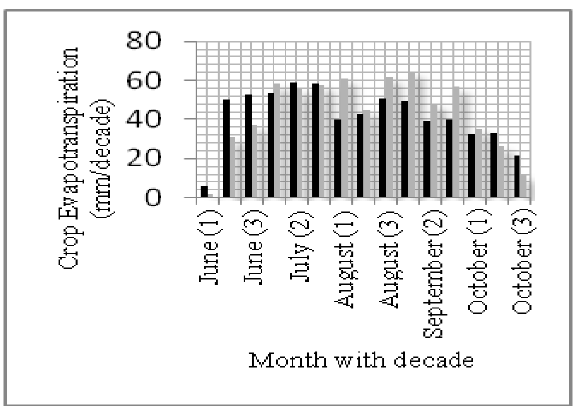
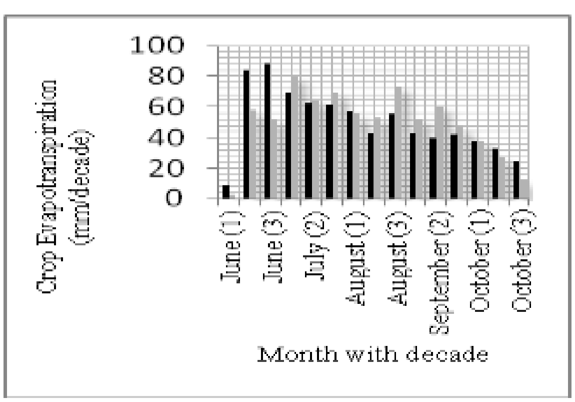


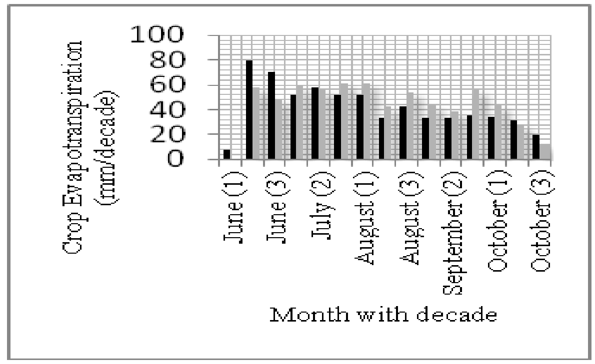
Figure 2. Reference evapotranspiration comparison of plain and hilly region of the year 2007, 2008, 2009, 2010 and 2011 respectively[2]

C. Comparison of Crop Evapotranspiration of Rice Crop









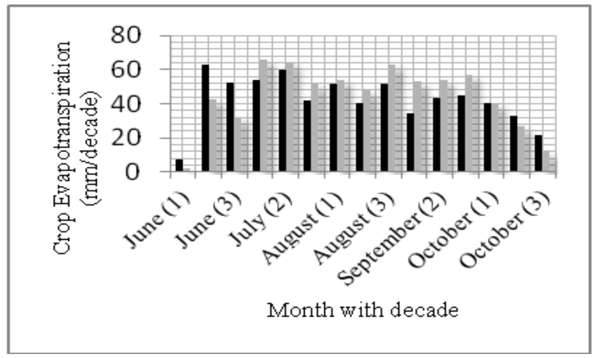
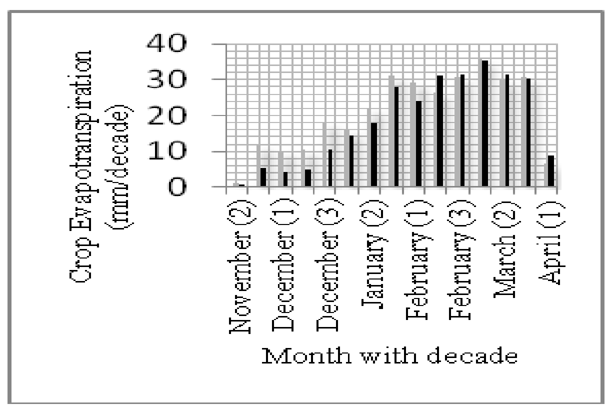
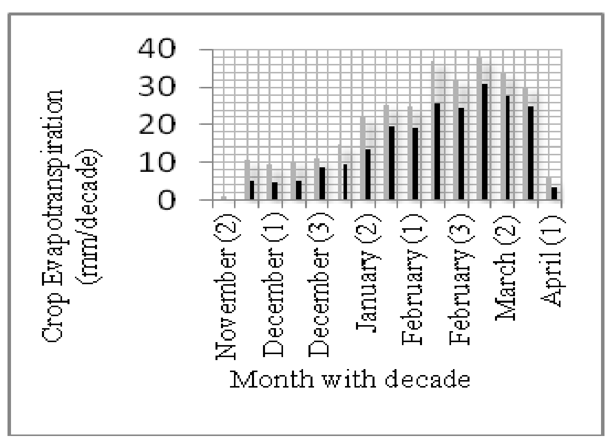


Figure 3. Crop evapotranspiration comparison of plain and hilly region of the year 2007, 2008, 2009, 2010 and 2011 respectively[3]

D. Comparison of Crop Evapotranspiration of Wheat Crop





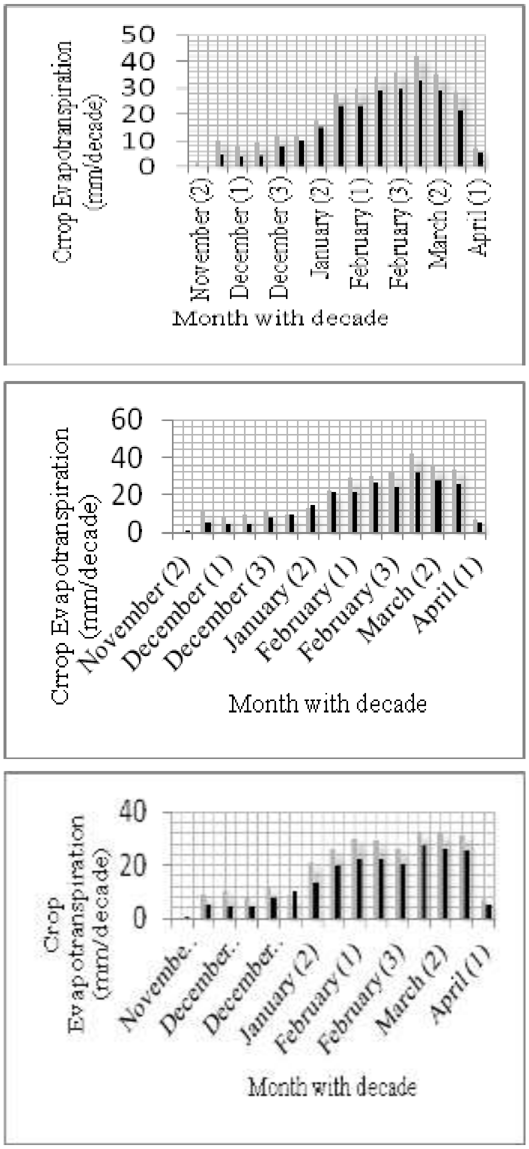
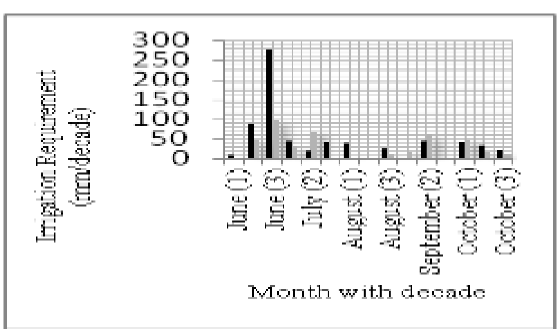


Figure 4. Crop evapotranspiration comparison of plain and hilly region of the year 2007, 2008, 2009, 2010 and 2011 respectively[3]

E. Comparison of Irrigation Requirement of Rice Crop



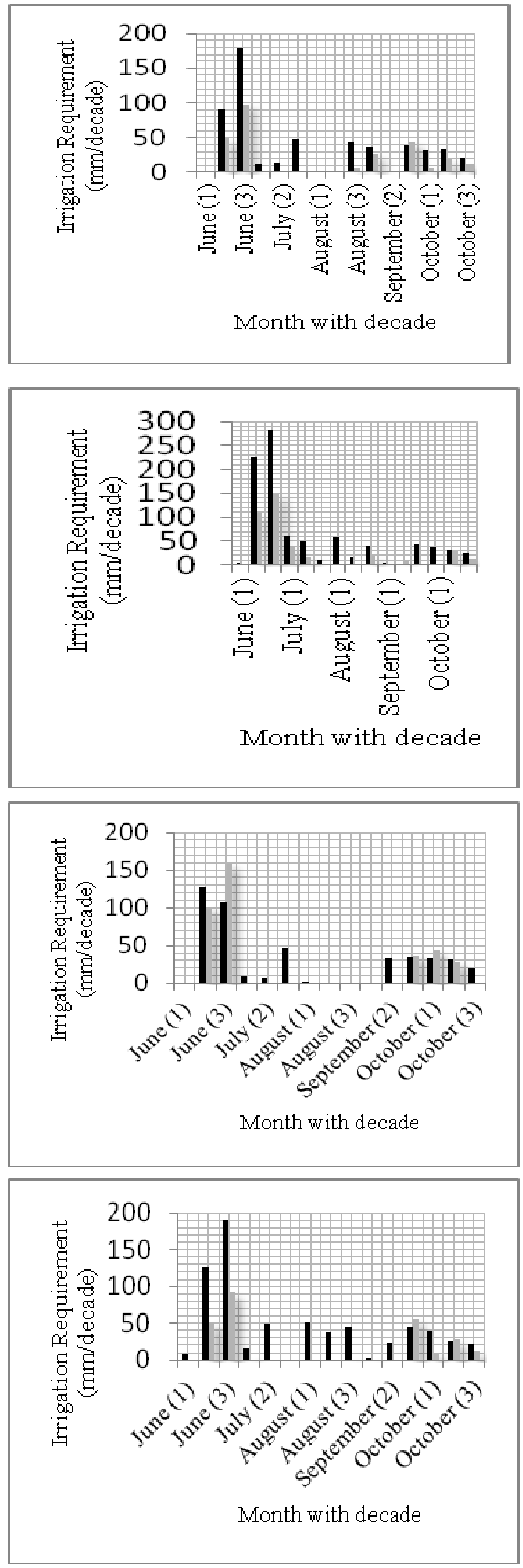


Figure 5. Irrigation requirement comparison of plain and hilly region of the year 2007, 2008, 2009, 2010 and 2011 respectively[4]

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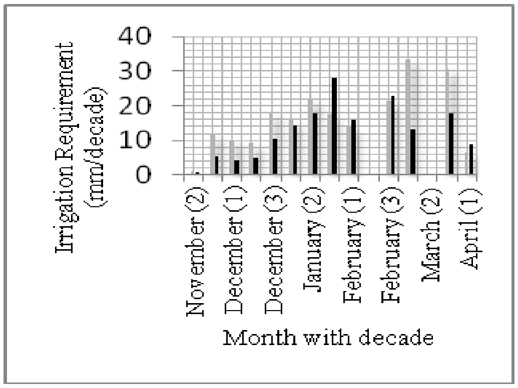
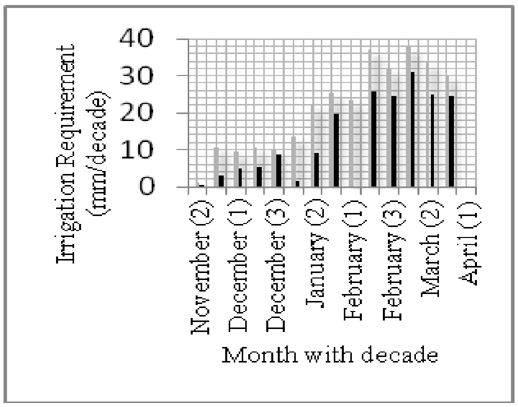
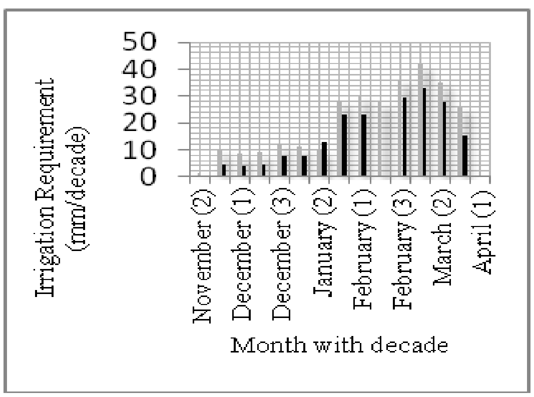
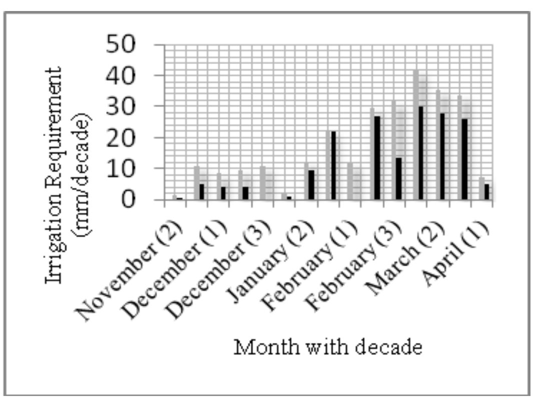
[3] In Fig. 3 black and grey colour represents the ET_c of rice crop for plain region and hilly region respectively. In Fig. 4 grey and black colour represents the ET_c of plain and hilly region respectively for wheat crop.

F. Comparison of Crop Irrigation Requirement of Wheat Crop









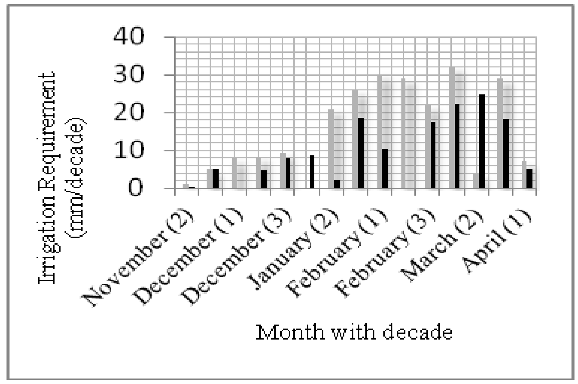


Figure 6. Irrigation requirement comparison of plain and hilly region of the year 2007, 2008, 2009, 2010 and 2011 respectively[4]

From the above graphs (Figure 1) it has been observed that reference evapotranspiration of rice crop is more for the plain region as compared to the hilly region. Because temperature and sunshine hour was maximum during these periods for the plane region as compared to the hilly region. From Figure 2 it is again observed that reference evapotranspiration of wheat crop is also more for the plane region as compared to the hilly region due to the maximum temperature and sunshine hour during the period of 2007 to 2011.

Then again from Figure 3 it is observed that crop evapotranspiration of rice crop is more for the hilly region as compared to the plain region. It was observed that temperature and sunshine hour was maximum for the Karnal region during the period of 2007-2011 as compared to the Dehradun region. It was also observed that effective rainfall was less for the Karnal region during that period as compared to Dehradun region. From Fig.4 it is observed that crop evapotranspiration (ET_c) of wheat crop is more for the plane region as compared to the Dehradun region during the period of 2007 to 2011. It was observed that temperature and sunshine hour was minimum in Karnal region during Rabi season as compared to Dehradun region. It was also observed that effective rainfall was less in Karnal region as compared to Dehradun region during Rabi season.

From Figure 5 and Figure 6 it is observed that irrigation requirement of rice and wheat crop is more for the plain region as compared to the hilly region. It was observed that there was less effective rainfall in Karnal region as compared to the Dehradun region during Kharif season. So irrigation requirement for Karnal region was more as compared to Dehradun region.

[4] In Fig. 5 black and grey colour represents the IR of plain and hilly region respectively for rice crop. In Fig. 6 grey and black colour represents the IR of plain and hilly region respectively for wheat crop.

Conclusions

It was found that reference evapotranspiration of rice and wheat crop is more for the plain region as compared to the hilly region. Crop evapotranspiration of rice crop is found more for the hilly region as compared to plain region whereas for wheat crop it was more for plain region as compared to hilly region. Irrigation requirement of rice and wheat crop is more for the plain region as compared to the hilly region.

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