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# REFERENCE EVAPOTRANSPIRATION ESTIMATION USING CROPWAT MODEL AT LUDHIANA DISTRICT (PUNJAB)

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**Abstract:** This paper estimate reference crop evapotranspiration in Ludhiana, Punjab (India) using CROPWAT model. Determination of Evapotranspiration (ET) is important in application such as irrigation design, irrigation scheduling, water resource management, hydrology and cropping systems modeling. The Penman–Montieth formulation is regarded as a good estimator for a wide variety of climatic conditions. The United Nations food agriculture organization (FAO) adopted the Penman–Montieth method as global standard to estimate reference crop ($ET_0$) from meteorological data. Based on the intensive study of this paper, daily basis meteorological weather data recorded from 1970 to 2012were used to obtain the result. The $ET_0$data were calculated for each parameter and the obtained results were compared. Reference crop Evapotranspiration ($ET_0$) and monthly effective rainfall was calculated using CROPWAT model. The study detects that Penman–Montieth method is the best method to estimate $ET_0$ because of its inclusion of parameters in calculation.

**Keywords:** Reference Evapotranspiration, CROPWAT, Penman–Montieth method.

## Introduction

CROPWAT is an irrigation management and planning model simulating the complex relationships of on-farm parameters the climate, crop and soil. The CROPWAT facilitate the estimate of the reference evapotranspiration, crop evapotranspiration, irrigation schedule and agricultural water requirements with different cropping patterns for irrigation planning (Nazeer2009).The estimate of reference evapotranspiration is an important in Crop water requirement and development of irrigation scheduling. The general knowledge of the spatial distribution of reference evapotranspiration ($ET_0$) is still sketchy despiteits importance for global ecosystem research. One reason is that $ET_0$ is difficult toobserve directly as it depends on several meteorological parameters which are observed only at major stations (Doorenbos and Pruitt1977). The first step in this paper consider the effect of climate by calculating the

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reference evapotranspiration ($ET_0$) which is define in FAO-24 as "the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall green grass cover of uniform height, activity growing, completely shading the ground and not short of water. To estimate reference crop evapotranspiration ($ET_0$) from meteorological data require daily maximum and minimum temperature, relative humidity, wind speed and solar radiation and sunshine duration (Admasu *et al* 2014).

## Materials and methods

### Study area

The study area comprises of Ludhiana district which is one of the centrally located district of Punjab with 3706 sq. kms geographical area. There are seven tehsils, 12 blocks, 12 towns and 969 villages in the district. The topography of the study area is a typical representation of an alluvial plain. According to survey of India, the latitude and longitude varies from $30^0$25'N to $31^0$55'N and $75^0$18'E to $76^0$20'E respectively, and it have an average elevation of 247 meters from mean sea level (Sharma *et al* 210). The location map of the study area with different blocks of Ludhiana is shown in Fig 1.

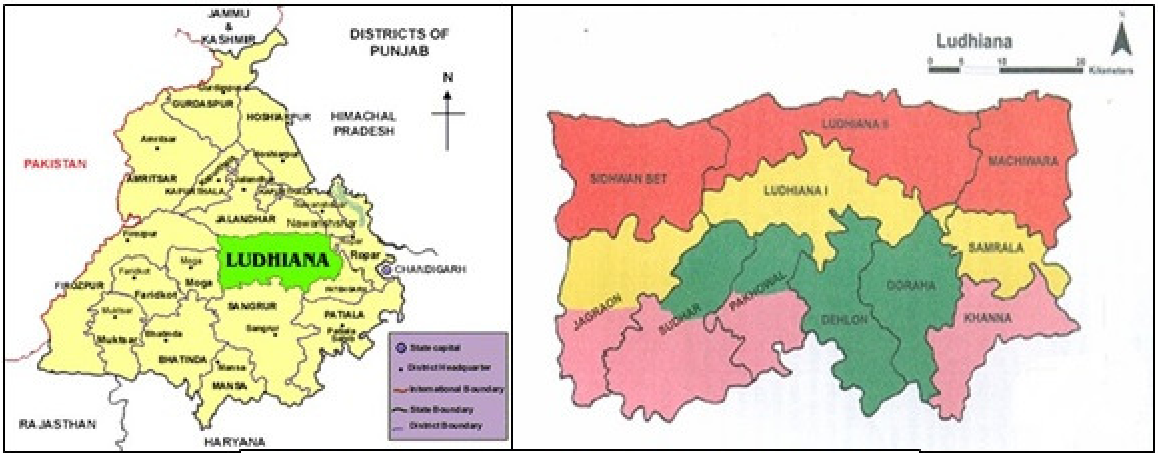


Fig. 1: Location map of Ludhiana district, Punjab

### Climatic data collection

In order to calculate $ET_0$, the respective daily climatic data collected from the School of Climate Change and Agro-meteorology, Punjab Agricultural University, Ludhiana of the periods 1970-2012 of the following parameters: Minimum and Maximum temperature, humidity, wind speed, sunshine hours and Rainfall, calculation were done using the mean value of each parameter. The module is primary for data input, requiring information on the meteorological station (country, station name, altitude, latitude and longitude) together with climatic data. CROPWAT 8.0 can calculate reference $ET_0$using temperature, humidity, sunshine and wind speed (Banik *et al* 2014). The Climate/$ET_0$ module includes calculations, producing radiation and $ET_0$ data using the FAO Penman-Montieth approach. A printout of climatic data inserted and calculated radiation and $ET_0$ is shown in Table 1.

**Table 1: Printout – Climate/ET0 Data**

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\2012.PEM

Country INDIA Station PAU

Altitude 247 m. Latitude 30.86 °N Longitude 75.96 °E

| Month | Min Temp | Max Temp | Humidity | Wind | Sun | Rad | ETo |
|---|---|---|---|---|---|---|---|
| | °C | °C | % | m/s | hours | MJ/m?/day | mm/day |
| January | 5.6 | 16.9 | 96 | 0.9 | 5.4 | 10.7 | 1.19 |
| February | 6.7 | 19.9 | 91 | 1.2 | 6.7 | 14.1 | 1.76 |
| March | 11.4 | 27.1 | 88 | 1.2 | 7.8 | 18.1 | 2.91 |
| April | 18.1 | 33.6 | 75 | 1.3 | 8.6 | 21.5 | 4.49 |
| May | 22.6 | 38.7 | 47 | 1.5 | 9.6 | 24.2 | 6.23 |
| June | 27.2 | 40.6 | 57 | 1.7 | 9.3 | 24.0 | 6.83 |
| July | 28.0 | 35.7 | 76 | 1.9 | 6.9 | 20.2 | 5.32 |
| August | 26.6 | 33.2 | 87 | 1.3 | 4.5 | 15.9 | 3.80 |
| September | 23.7 | 32.9 | 89 | 0.9 | 7.8 | 18.8 | 4.07 |
| October | 16.2 | 31.7 | 90 | 0.5 | 11.9 | 21.0 | 3.83 |
| November | 10.5 | 26.6 | 91 | 0.6 | 6.5 | 12.2 | 2.01 |
| December | 7.4 | 19.4 | 91 | 1.2 | 5.2 | 9.9 | 1.35 |
| **Average** | **17.0** | **29.7** | **81** | **1.2** | **7.5** | **17.6** | **3.65** |

**Reference evapotranspiration**

The Penman–Monteith equation for computation of daily reference evapotranspiration assumes the reference crop evapotranspiration as that from a hypothetical crop with assumed height of 0.12 m having a surface resistance of 70 s $m^{-1}$ and an albedo of 0.23, closely resembling the evaporation of an extension surface of green grass of uniform height, actively growing and adequately watered (Allen*et al* 1998). It is expressed as:

$$ET_0 = \frac{0.408\Delta(Rn - G) + \gamma * \frac{900}{(T+273)} * u_2 * (e_s - e_a)}{\Delta + \gamma * (1 + 0.34 * u_2)}$$

Where,$ET_0$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 mean daily air temperature at 2 m 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), ($e_s$- $e_a$) saturation vapour pressure deficit (kPa), Δ is slope vapour pressure curve (kPa °$C^{-1}$) and γ is psychrometric constant (kPa °$C^{-1}$)

So computing $ET_0$ by this method without using software is very difficult. Cropwat four windows is a program that uses FAO Penman- monteith for calculating $ET_0$. In addition, the FAO expert conclusion on revision of FAO methodologies for CWR recommended that empirical methods should be calibrated or validated using the Penman- monteith equation as reference (Smith *et al* 1991) (Gavilan *et al* 2006).

**Processing of rainfall data**

The rainfall contributes to a greater or lesser extent in satisfying CWR, depending on the location and time. During the rainy season in arid and semi-arid regions, a great part of the crop's water needs are covered by rainfall, while during the dry season, the major supply of water should come from irrigation. How much water is coming from rainfall and how much water should be covered by irrigation is unfortunately difficult to predict as rainfall varies greatly from season to season. Mathematically determined average values for a series of rainfall records, most commonly available. The dependable rainfall (65%) is used for the design of the irrigation system capacity. defined as the rainfall with a respectively 20, 50 and 80% probability of exceedance, representing a wet, normal and dry year. The three values are useful for the programming of irrigation supply and simulation of irrigation management conditions. The rainfall in normal years (50% probability) is, in general, well approached by the average rainfall (Smith 1993).

**Effective rainfall**

Not all rainfall is effective; some may be lost through surface runoff, deep percolation or evaporation. It is only a part of the rainfall that can be effectively used by the crop, depending on its root zone depth and the soil storage capacity. The effective rainfall is the rainfall ultimately used to determine the net irrigation requirements. To account for the losses due to runoff or percolation, a choice can be made of one of the four methods given in CROPWAT 8.0 (Fixed percentage, Dependable rain, Empirical formula, USDA Soil Conservation Service)is shown in Table 2. In general, the efficiency of rainfall will decrease with increasing rainfall. For most rainfall values below 100 mm/month, the efficiency will be approximately 80%.Unless more detailed information is available for local conditions, it is suggested to select the option "Fixed percentage" and give 65% as requested value (Pakhale *et al* 2010)

**Table 2: Printout of the average rainfall data**

Monthly rain - C:\ProgramData\CROPWAT\data\rain\2012.CRM

Station: PAU        Eff. rain method: Fixed percentage

| | Rain | Eff rain |
|---|---|---|
| | mm | mm |
| January | 51.7 | 33.6 |
| February | 4.6 | 3.0 |
| March | 0.0 | 0.0 |
| April | 37.6 | 24.4 |
| May | 1.6 | 1.0 |
| June | 3.5 | 2.3 |
| July | 76.9 | 50.0 |
| August | 161.2 | 104.8 |
| September | 123.5 | 80.3 |
| October | 0.0 | 0.0 |
| November | 0.0 | 0.0 |
| December | 17.4 | 11.3 |
| Total | 478.0 | 310.7 |

## Results and discussion

Daily weather data and reference evapotranspiration are shown in Table 1forexample year 2012. And also we show rainfall and effective rainfall in the same year. Reference crop evapotranspiration ($ET_0$) and monthly effective rainfall calculated using CROPWAT model. The $ET_0$ was low in January and February months, increased during the March-October, reached maximum value of 205.2 mm/month at June and declined during November and December months. The difference in $ET_0$ is attributed to combined effects of temperature, sunshine hours, radiation, wind speed and humidity. The increased in $ET_0$ during the March-October can be explained by change in temperature because in this period we obtained the highest temperature. The $ET_0$decreases in late months because temperature was low.

Figure 2: Shows evapotranspiration due to minimum and maximum temperature the value of $ET_0$ was so high especially between March to October.

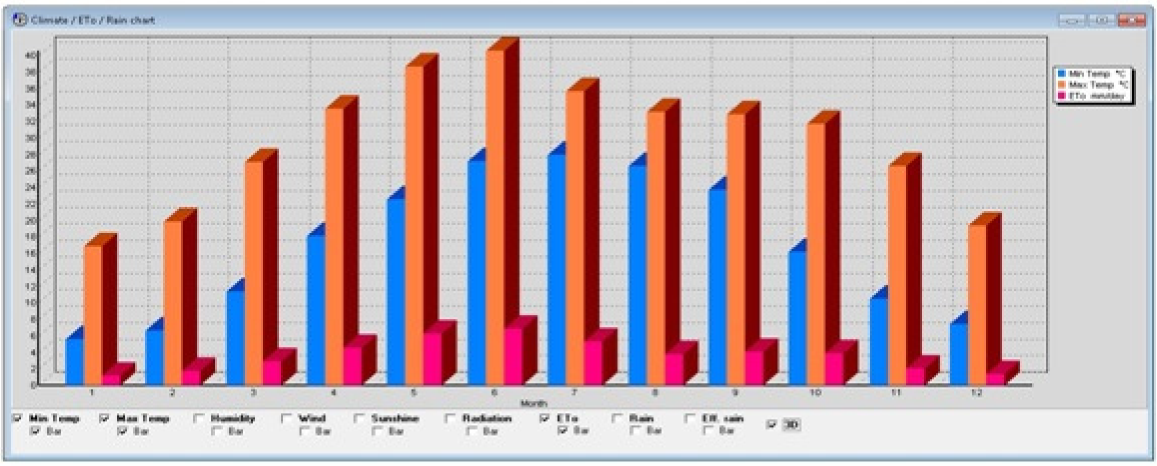


**Fig. 2: Monthly minimum and maximum temperature and $ET_0$**

Figure 3: Shows evapotranspiration is so less due to average humidity is high especially between November to January. So inversely relation between humidity and $ET_0$.

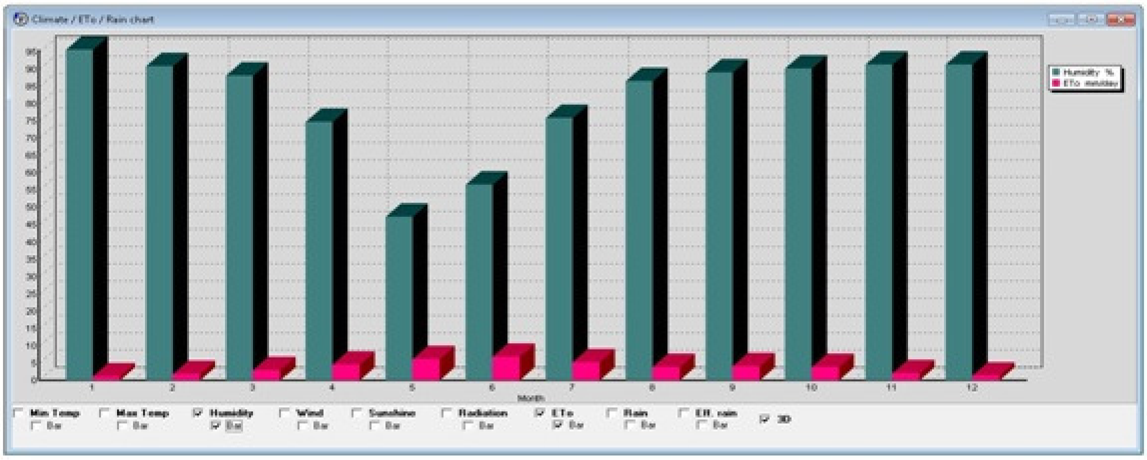


**Fig. 3: Monthly humidity and $ET_0$**

Figure 4: shows the relationship between sunshine and $ET_0$. From the graph, we noticed the strong relations between sunshine and evapotranspiration. This is evident that when sunshine hours increase, $ET_0$ also increases. There is a direct relationship between these two parameters.

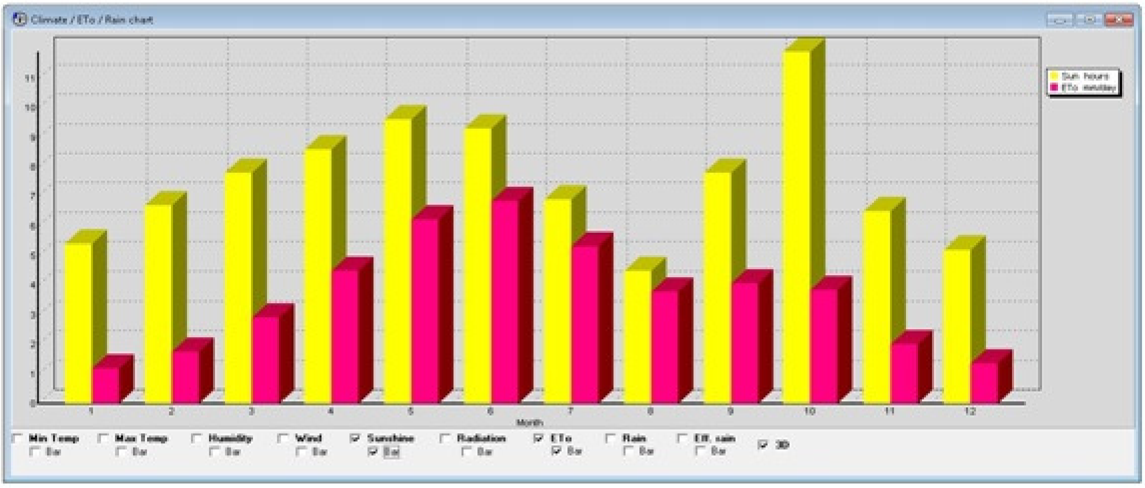


**Fig. 4: Monthly sunshine hours and $ET_0$**

Figure 5: shows the relationship of evapotranspiration with wind speed. The plot indicates that wind speed has very less effect on $ET_0$. Despite changes in wind speed, $ET_0$ remains constant in the studying findings.

Figure 6: Shows relationship between monthly radiation and $ET_0$. It can be observe that, there are fluctuations between the radiation and $ET_0$. As long as radiation increases, $ET_0$ also makes a slight increase.

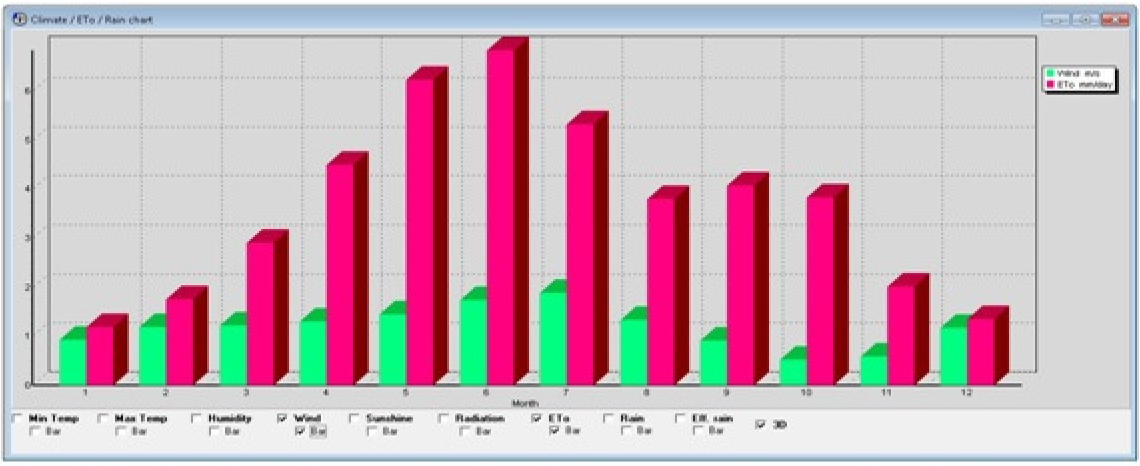


**Fig 5: Monthly wind speed and $ET_0$**

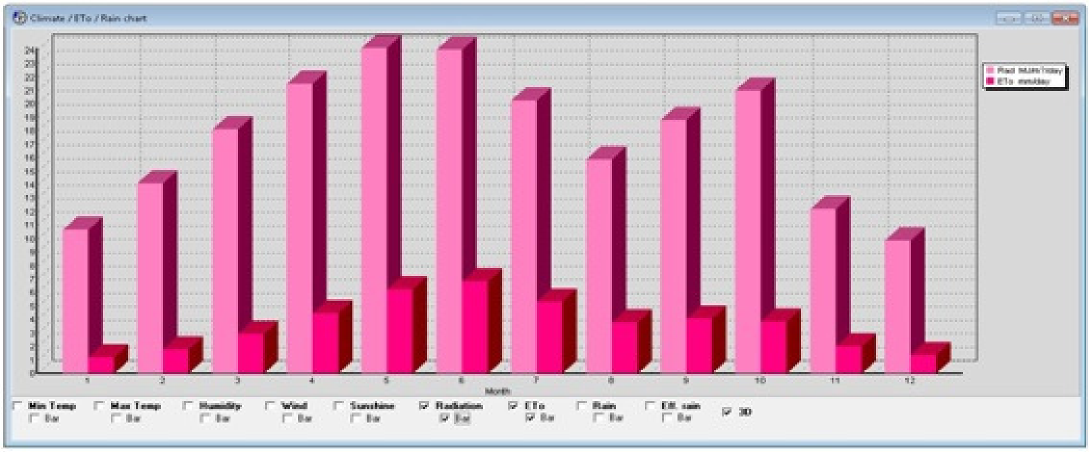


**Fig. 6: Monthly radiations and ET0**

Figure 7: Monthly Rainfall and effective rainfall and $ET_0$, not all rain which falls is used by the crop. The intensity of rain may be such that part of the rainfall is lost due to interception, surface runoff and deep percolation below the root zone.

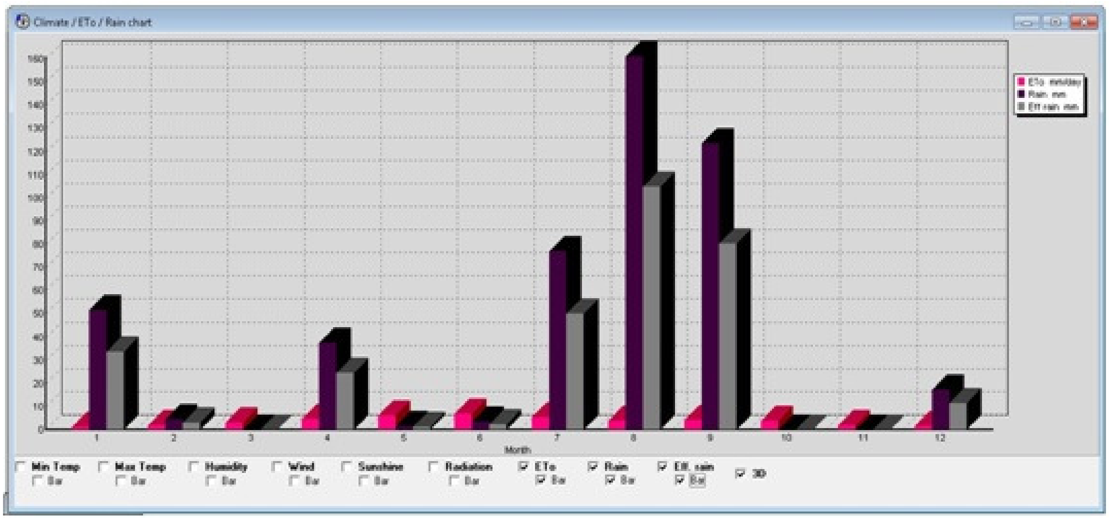


**Fig 7: Monthly rainfalls and effective rainfall and $ET_0$**

Figure 8: All monthly basis climate parameters have combined effect on $ET_0$.

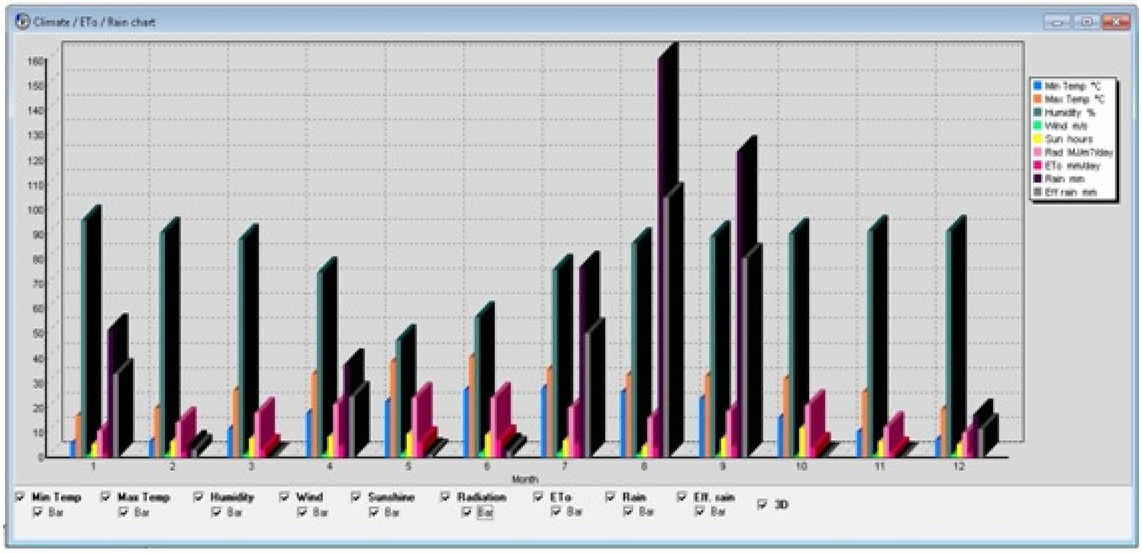


**Fig 8: All climate parameters have combined effect on $ET_0$**

Figure 9: shows $ET_0$ in previous 42 years also rainfall and effective rainfall. This may be help to done forecasting for next years.

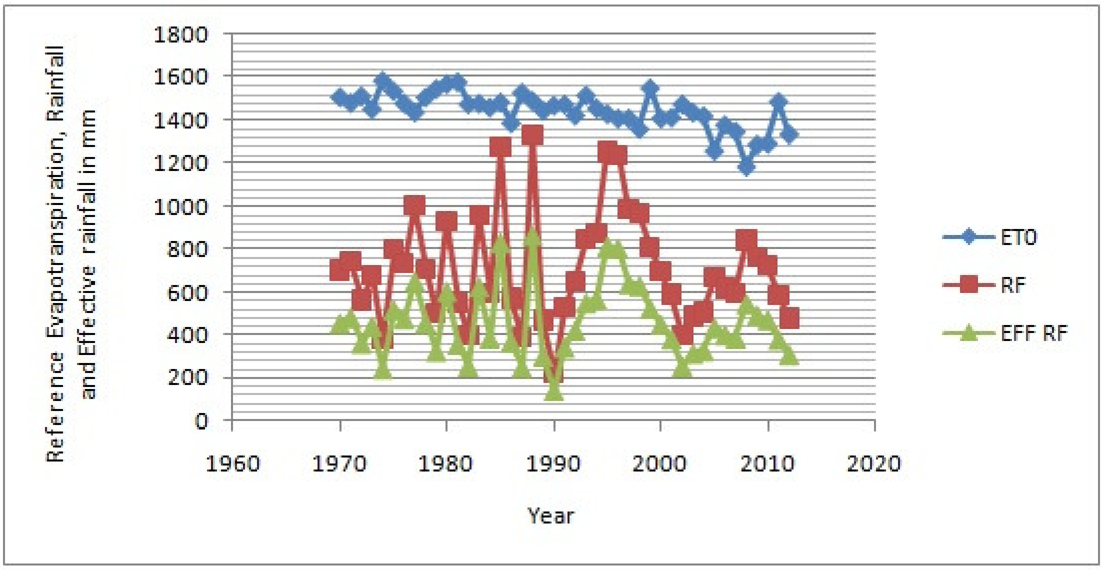


**Fig. 9: Reference evapotranspiration, rainfall effective rainfall with time**

## Conclusion

The FAO-Penman-Montieth equation is recommended as the standard method for estimating reference evapotranspiration. The new method has been proved to have a global validity as a standardized reference for grass evapotranspiration and has found recognition both by the International Commission for Irrigation and Drainage and by the World Meteorological Organization. Procedures have been established to estimate missing climatic data which allow the FAO Penman-Montieth method to be used under all conditions. This eliminates the use of any other method and will increase the transparency and consistency of reference and crop water requirement studies. There are two main conclusions from this study first we obtained meteorological data for 42 years and calculated $ET_0$ due to any parameter and compare the results. For all this diagrams all parameter effects in $ET_0$ estimation specially temperature, sunshine hours and radiation. This means Penman-Montieth is the best method to estimate$ET_0$ because its take all parameter in calculation. Second CROPWAT model appropriately estimate the $ET_0$, which makes this model as a best tool for irrigation planning and management.

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