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# POTENTIAL EVAPOTRANSPIRATION TREND ANALYSIS FOR DIFFERENT CLIMATIC ZONES IN KHYBER PAKHTUNKHWA, PAKISTAN

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Estimation of potential evapotranspiration (ETo) plays a significant role in the study of water resources management. The study was conducted to investigate the change in potential evapotranspiration value during the past three decade in three diverse climatic zones of Khyber Pakhtunkhwa, Pakistan. Three Districts of Khyber Pakhtunkhwa, Pakistan (Chitral, Peshawar and D. I. Khan) were selected based on their climatic diversity. Thirty years climatic data (1981-2010) obtained from Pakistan Metrological Department, Islamabad and Agriculture Research Institute, Peshawar was used. Potential evapotranspiration was determined for three decades separately, as well as on mean monthly basis. World Meteorological Organization (WMO) technique was used for trend analysis. Results revealed highest ETo in D.I Khan followed by Peshawar and Chitral. However, in the summer months ETo value was found highest in Chitral as compared to other selected Districts. Trend analysis results showed that decrease in ETo trend was observed in all the selected Districts with the passage of time. It can be concluded that ETo values decreased as compared to past in all the selected Districts without any discrimination of physical geography and location.

**Keywords:** Evapotranspiration, Geography, Trend analysis, Climatic, Khyber Pakhtunkhwa

## 1. Introduction

Potential evapotranspiration (ETo) is the amount of water that evaporate and transpire under adequate water supply conditions. ETo is the amount of water transpired from disease-free, well-fertilized crops, grown in large fields, under optimum soil water condition [1]. It is normally greater in the summer or sunny days and at latitudes near to the equator. One of the major components of the hydrological cycle is evapotranspiration. Potential evapotranspiration (ETo ) is an important index of hydrologic budgets at different spatial scales and a critical variable for understanding regional natural processes [2]. Over the entire land surface of the globe rainfall averages around 750 mm per year of which some two thirds are returned to the atmosphere as evapotranspiration thus making evapotranspiration the largest single component of the terrestrial hydrological cycle [3]. Evapotranspiration is not only an important component of water cycle but also an indicator of irrigation planning. Its accurate estimation is of crucial importance for proper irrigation planning schemes. A process - based understanding of evapotranspiration is needed to quantify possible shift in the processes due to climatic and land surface changes [4,5].

Numerous methods have been introduced for computing $ET_o$ by different scientists in different eras. However, FAO Penman-Monteith method is commonly used all over the world for the calculation of ETo [6-9] due to its worldwide applicability and recognition by the FAO. Its applicability in real terms is little difficult to an enormous numbers of climatic parameters that are essential to calculate ETo. However, for ease FAO has developed several software (ETo Calculator, CropWat and AquaCrop etc.) which automatically determine ETo from four climatic parameters including temperature, windspeed, humidity and sunshine hours.

The climatic parameters (temperature, sunshine hours, windspeed and relative humidity) as well as the physical geography of a location can affect the rate of evapotranspiration [10-13]. Several scientists [14-16] conducted studies on ETo for different region and scenario and reported various results. The main aim of this study is to find out the changes in ETo value as compared to past in three selected climatologically diverse locations.

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## 2. Materials and Methods

### *2.1 Study Areas and Climatic Data Sources*

The study was carried out in different climatic regions of Khyber Pakhtunkhwa, Pakistan. The detailed description including altitude, longitude and latitude is presented in Table 1. Thirty year data (1981-2010) was used in the study, obtained from Pakistan Metrological Department, Islamabad for Chitral and Dera Ismail Khan (D.I. Khan) and from Agriculture Research Institute, Tarnab for Peshawar. The data include mean monthly temperature, relative humidity, windspeed and sunshine hours.

Table 1. Description of selected climatologically zones.

| Name | Description | Altitude (m) | Latitude (°N) | Longitude (°E) |
|---|---|---|---|---|
| Chitral | Humid (Dense Forest) | 1500 | 35.51 | 71.50 |
| Peshawar | Central valley (Semi Arid) | 352 | 34.32 | 71.35 |
| D. I. Khan | Arid (Desert Type) | 174 | 31.49 | 70.55 |

The selected Districts based on diverse climate including dry to humid are shown in Figure 1. It is evident that Chitral and D.I. Khan are on the two extremes representing humid and dry climate, respectively. While the district Peshawar is the central district of the province.

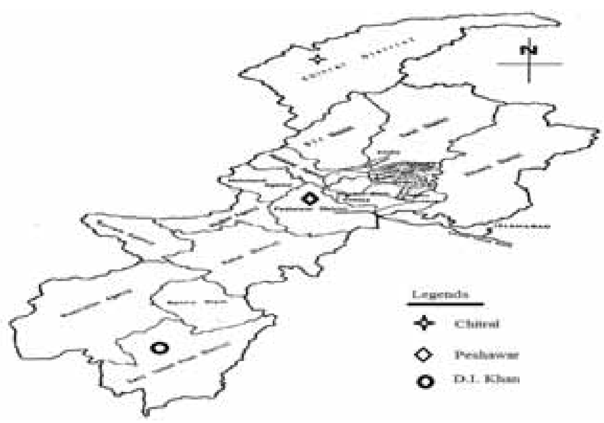


Figure 1. Map of Khyber Pakhtunkhwa showing the selected zones (Source: www.unodc.org).

### *2.2 Determination of Potential Evapo-transpiration (ETo)*

In 1948, Penman [17] combined the energy balance with the mass transfer method and derived an equation to compute the evaporation from an open water surface from standard climatologically records of sunshine, temperature, humidity and wind speed. Monteith (1965) modified Penman equation by incorporating a canopy resistance. In this equation, several parameters are either directly or indirectly calculated from climatic data. The equation is:

$$ET_0 = \frac{0.408\,\Delta\left(R_n - G\right) + \gamma \dfrac{900}{T + 273}\mu_2\left(e_s - e_a\right)}{\Delta + \gamma\left(1 + 0.34\mu_2\right)} \quad (1)$$

Where

ETo = references 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]

$U_2$ = windspeed at 2 m height [m $s^{-1}$]

$e_s$ = saturation vapour pressure [kPa]

$e_a$ = actual vapour pressure [kPa]

$e_s – e_a$ = saturation vapour pressure deficit [kPa]

$\Delta$ = slope vapour pressure curve [kPa $°C^{-1}$] and

$\gamma$ = psychrometric constant [kPa $°C^{-1}$].

Change in ETo was calculated for three selected zones of Khyber Pakhtunkhwa, for three decades. Mean monthly ETo was also determined (1981-2010). ETo Calculator computer model was used to determine ETo based on FAO Penman-Monteith equation.

### *2.3 Trend Analysis*

WMO (1966) technique was used for decade verses 30 years mean comparison. The whole data set for each climatic parameter was divided into three set for three decades. ETo of each decade was compared with the mean of whole period in order to identify the trend. Following equation was used for this phenomenon;

$$T = \frac{\overline{X}_D - \overline{X}}{SD} \qquad (2)$$

Where

$\overline{X}_D$ is the decade mean

$\overline{X}$ is the mean of whole period and

SD is the standard deviation of the whole period

## 3. Results and Discussion

### *3.1 Climatic Variability of the Selected Zones*

### *3.1.1 Mean Monthly Temperature*

D.I. Khan had highest mean monthly temperature (33.5°C) followed by Districts Peshawar (30.9°C) and Chitral (27.7°C) respectively, in the month of June as shown in Figure 2. While lowest mean monthly temperature of values 4.6, 10.5 and 12.3°C was recorded for Chitral, Peshawar and D.I. Khan, respectively, in the month of January. The variation in mean monthly temperature values may be due to altitude and physical geography of the Districts. The plain ground can absorb the heat from the sun, the air above such ground conducts the warmth and that is how the air gets it heat. So there must be a difference in the temperature between high and low altitude places.The temperature of D.I. Khan was found highest followed by Peshawar and Chitral.

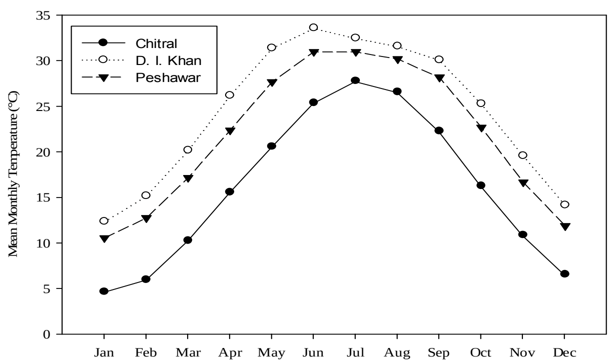


Figure 2. Mean monthly temperature of the selected Districts of Khyber Pakhtunkhwa

### *3.1.2 Mean Monthly Windspeed*

From Figure 3, it is clear that the mean monthly windspeed was recorded maximum (2.3m/s) and minimum (1.4m/s) in the months of August and November, respectively, in District Chitral. Maximum windspeed values of 1.1m/s and 1.0 m/s were observed in July for District D.I. Khan and Peshawar, respectively. Windspeed is highly sensitive to the height and topographic features. The plain areas are in continuous contact with air motion, which cause resistance to its movement, while this resistant decreases with height. The lower values of windspeed in Districts D.I. Khan and Peshawar may be due to its lower altitude.

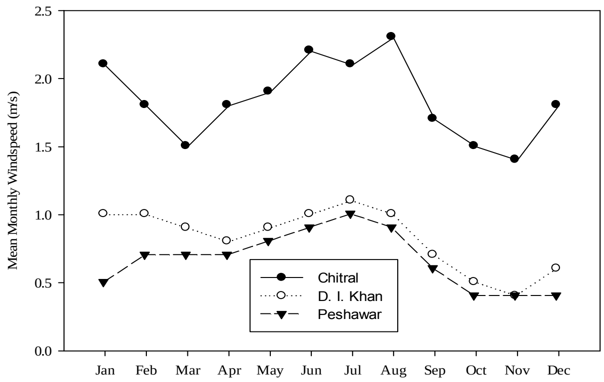


Figure 3. Mean monthly windspeed of the selected Districts of Khyber Pakhtunkhwa.

### *3.1.3 Mean Monthly Relative Humidity*

Figure 4 indicates the mean monthly relative humidity for the three Districts. D.I. Khan showed maximum relative humidity value (71.2%) followed by Peshawar (61.9%) in August, while in Chitral it maximum value (65.1%) was recorded in September. Minimum values of relative humidity were observed in June with 35.3, 47 and 41.3% for Districts Chitral, D. I. Khan and Peshawar,

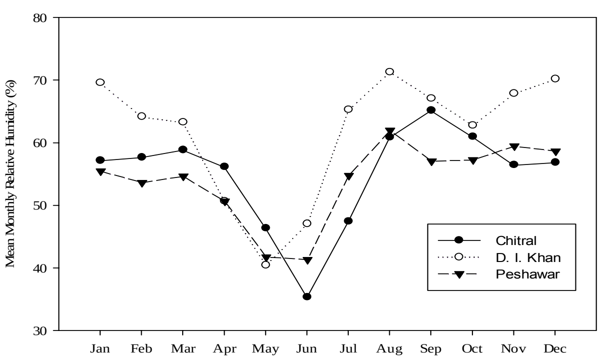


Figure 4. Mean monthly relative humidity of the selected Districts of Khyber Paktunkhwa.

respectively. Furthermore, temperature decreases with altitude which reduces the moisture carrying capacity of the air. Hence, colder air can hold less water than warm air [14].

### *3.1.4 Mean Monthly Sunshine Hours*

The variation in mean monthly sunshine hours of the selected Districts during the period 1981-2010 is shown in Figure 5. The lowest sunshine hours values of 3.9 and 5.3 were recorded in December for District Chitral and Peshawar. However, it was found lowest (6.8) in January for D.I. Khan. While maximum sunshine hours were observed in D.I. Khan (9.4) in May, followed by Chitral (9.0) in July and Peshawar (8.8) in June. The increase of sunshine hours in the months of July and August in District Chitral may be due to lack of monsoon, while the decrease in sunshine hours values in District D.I. Khan and Peshawar in the said months are the lower latitude in the plain area of Khyber Pakhtunkhwa

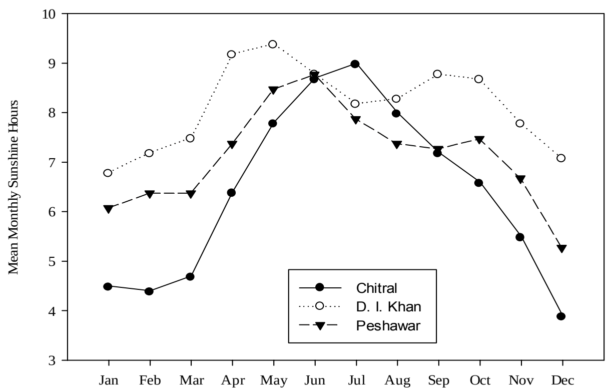


Figure 5. Mean monthly sunshine hours in selected Districts of Khyber Pakhtunkhwa.

## *3.2. ETo and Trend Analysis*

Mean monthly evapotranspiration (1981-2010) values determined through FAO Penman-Monteith equation for three selected locations are shown in Figure 4 Results indicated maximum ETo for the month of June with 6.3, 5.6 and 5.9 mmday$^{-1}$ for Districts Chitral, Peshawar and D.I. Khan, respectively. Districts Peshawar and D.I. Khan showed the similar pattern for ETo, however the trend of Peshawar was slight lower than D.I. Khan throughout the year. The ETo of Chitral was quite lower than that of D.I. Khan except in the three months (June, July and August) of summer season. The main reason for this may be due to the lack of Monsoon rainfall in District Chitral. The variation in the ETo pattern in the three Districts may be due its climatic variability (temperature, sunshine duration, humidity and windspeed). Furthermore, physical geography and altitude and latitude can also have effect on regional evapotranspiration values.

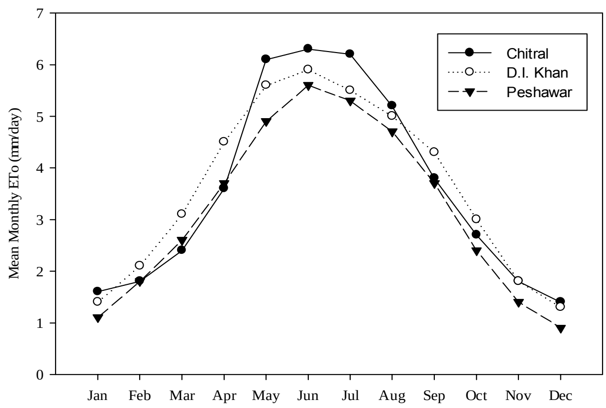


Figure 6. Mean monthly ETo of the selected Districts of Khyber Pakhtunkhwa.

Change in ETo during the past three decades (1980-2010) in Chitral is shown in Table 2. It was found that ETo trend was decreased (negative value indicate decrement) in the first decade through out the year. The trend showed increment in the second decade (1991-2000) except in the months of March, May and November. However, it adopted again a decrement during the last decade (2001-2010).

Table 2. Trend Analysis of ETo During the Past Three Decades (Chitral).

| Months | Decade I (1981-1990) | Decade II (1991-2000) | Decade III (2001-2010) |
|---|---|---|---|
| Jan | -0.16 | 0.00 | -0.16 |
| Feb | -0.10 | 0.05 | -0.16 |
| Mar | -0.16 | -0.11 | 0.05 |
| Apr | -0.11 | 0.00 | -0.11 |
| May | -0.53 | -0.68 | -0.63 |
| Jun | 0.00 | 0.05 | -0.11 |
| Jul | -0.47 | 0.32 | 0.16 |
| Aug | -0.42 | 0.37 | 0.16 |
| Sep | -0.26 | 0.21 | 0.11 |
| Oct | -0.26 | 0.00 | -0.11 |
| Nov | -0.05 | -0.05 | -0.16 |
| Dec | -0.16 | 0.16 | -0.16 |

Trend analysis for D.I. Khan is shown in Table 3. Results revealed that during the first decade increase in trend was observed except in some months. ETo shows a raising trend during the second decade throughout the year. However, a falling trend was observed in the last decade.

Table 3. Trend Analysis of ETo During the Past Three Decades (D. I. Khan).

| Months | Decade I (1981-1990) | Decade II (1991-2000) | Decade III (2001-2010) |
|---|---|---|---|
| January | 0.06 | 0.12 | -0.12 |
| February | 0.00 | 0.18 | -0.18 |
| March | -0.12 | 0.06 | 0.00 |
| April | 0.06 | 0.12 | 0.06 |
| May | 0.18 | 0.12 | -0.18 |
| June | 0.24 | 0.18 | -0.24 |
| July | 0.00 | 0.18 | -0.29 |
| August | -0.06 | 0.24 | -0.12 |
| September | 0.12 | 0.06 | -0.18 |
| October | 0.00 | 0.06 | -0.18 |
| November | 0.00 | 0.00 | -0.12 |
| December | 0.00 | 0.06 | -0.18 |

From Table 4 it is clear that a gradual falling and persistence in trend occurs during the three decade in Peshawar. The results are found in agreement with Roderick and Farquhar (2002) [14], who reported that ETo trend, has been decreased with the passage of time. Furthermore, the raise in trend during the second decade in Chitral and D.I. Khan may be also due to severe drought condition prevailed in Pakistan during the second decade.

Table 4. Trend Analysis of ETo During the Past Three Decades (Peshawar).

| Months | Decade I (1981-1990) | Decade II (1991-2000) | Decade III (2001-2010) |
|---|---|---|---|
| January | 0 | 0.06 | -0.06 |
| February | -0.06 | 0.00 | -0.06 |
| March | -0.12 | 0.00 | 0.00 |
| April | 0.00 | -0.06 | 0.00 |
| May | 0.12 | -0.06 | 0.06 |
| June | 0.18 | -0.06 | -0.12 |
| July | 0.12 | -0.06 | -0.06 |
| August | 0.06 | -0.06 | -0.06 |
| September | 0.18 | -0.06 | -0.06 |
| October | 0.12 | 0.00 | -0.06 |
| November | -0.12 | 0.00 | -0.12 |
| December | 0 | 0.00 | 0.00 |

## 4. Conclusion

The study revealed that ETo decreased as compared to past in all the selected Districts without any discrimination in location diversity. It is suggested that climatic change studies should not be focused solely on climatic parameters (temperature, sunshine, wind speed and relative humidity) but ETo should also be used as climatic change indicator.

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