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Trends in Reference Evapotranspiration of Dikhow Catchment, North East India

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ABSTRACT: *In this study, the trend analysis has been carried out for annual and seasonal ETo values for six meteorological stations located in the Dikhow catchment in North East India. The magnitude of trends has been calculated using Sen's slope estimator. All the stations showed the significant increasing trend in ETo values for both annual and seasonal time scale at a significance level of 0.05. The significant increasing trends were found in summer ETo values during the period of analysis. Reference evapotranspiration showed increasing trend for both annual and seasonal time scale especially during summer season.. The magnitude of increase for annual was 0.303mm/year, for winter was 0.071mm/year, for summer was 0.186mm/year and for Monsoon was 0.078mm/year. Further, spatial analysis was performed on annual and seasonal scale for the time period 1901-2002. The percentage changes from 1901-2002 showed increase in reference evapotranspiration. The maximum increase in reference evapotranspiration in summer(20.02%) followed by annual (6.057%), Monsoon(4.56%) and winter(2.56%). It can be concluded that increase in reference evapotranspiration was detected during the entire historical time period (1901-2002).*

Key word: *Reference evapotranspiration, Non-parametric test, Mann-Kendall test, Sen's Slope estimator.*

INTRODUCTION

Evapotranspiration is one of the important parameter for irrigation scheduling and regional water allocation. Any change in meteorological variables due to climate change will affect evapotranspiration or crop water requirement. In recent years, numerous studies have been conducted to examine the trend in Pan Evaporation (Epan) and in reference evapotranspiration.

(ETo) for many regions resulting in different conclusions. [11] reported 1-6% decreases in Epan over most of theUnited States and the former Soviet Union national during the period of 1951-1990. In Australia, the decrease in Epan was 6.8 % [19] over the last 33 years (1970-2002 [32] found 1 and 4% decreases in Epan and ETo respectively across the Tibetan Plateau during the period 1966-2001. [12] found decreasing trends in Epan at 64 % of pans in the conterminousU. S. over the period of 1950-2002. [16] observed decrease in Epan ranged between 3 and 24% in China from 1955 to 2000. Decreasing trends in annual potential and actual evapotranspiration were found in most parts of the Haihe River Basin during1960-2002[10] The decrement of 5.04% in annual ETo compared to 48 years (1961-2008) average [28] over entire China. The ETo decrease in North China Plain was 5% [22] during 1961-2006. [27] reported decrease in both Epan (11%) and ETo (5.6%) for the whole Changjiang (Yangtze River) catchment, China during 1960-2000. [25] observed decreasing trend in Epan in the Chao Phraya River basin, Thailand over a period of 19 years (1982-2000). On the other hand, several researchers also reported increases in ETo trend across the world. [29] observed increasing trend in ETo at Kao-Hsiung, south Taiwan, using 48 years of data (1950-1997). [2] established both increasing and decreasing trends in lake evaporation calculated at 48 stations of the Canadian Prairies for 1971-2000. Further, this study concluded that increasing trends were more in northern regions and decreasing trends were more in the southern regions. [8] reported maximum increase was 28 % and maximum decreasing was 18 % in annual ETo over Iran during the period 1965-2005. Analysis of Epan (from 1964 to 1998) in the central coastal plains of Israel showed a significant increase of 7% [4]. [23] found ETo significant increasing trends in 75% of the stations in the western half of Iran in past 50 years (1955-2001). The significant increase was 8% in annual ETo during the 45 years (1960-2005) in

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Southern Spain [9]. [6] reported maximum increase was 42 and 25.2% in Epan and ETo respectively in Northeast Brazil using the 30 years data (1961–1990) for different stations. There is very few studies in literature related to ETo in India which shows decrease in recent decades. [1] reported maximum decrease in ETo were 0.03 mm/day/year all over India during 1971-2002[14] indicated annual significant decrease in ETo at the rate of 7.7% in north east India during 1979-2000. The meteorological variables which can have influence on ETo are: air temperature, sunshine duration, relative humidity, wind speed and solar radiation. However, as reported by various researchers important meteorological parameters controlling ETo are sunshine duration or solar radiation in Russia and United States, in [10];[16]; in southwest England [13]. and in Israel [4] while others have mainly attributed it to wind speed in Australia [18]; [20] Tibetan Plateau [32] Canadian Prairies [2] Iran [8] and North East India [14], to relative humidity in India [3], as well as to maximum temperature in China [5] and in western half of Iran [23]. Evapotranspiration (ET) affects crop water requirement and future planning and management of water resources. Therefore, for future crop planning and management of water resources, expected change in Evapotranspiration will be a prerequisite. Quantitative estimation of the ETo trend using long term data may provide insight into the possible impacts of climate change on the future water balance and water resource planning in the Dikhow catchment. The present study has been undertaken with the following specific objectives: (1) to detect the Monotonic linear trends in annual and seasonal ETo series using the non-parametric Mann-[15] test; (2) to estimate the magnitude of trend in ETo times series using the Theil-Sen's estimator method.

MATERIALS AND METHODS

Study area

The Dikhow catchment comprises of part of Assam, Arunachal Pradesh and Nagaland states, part of North

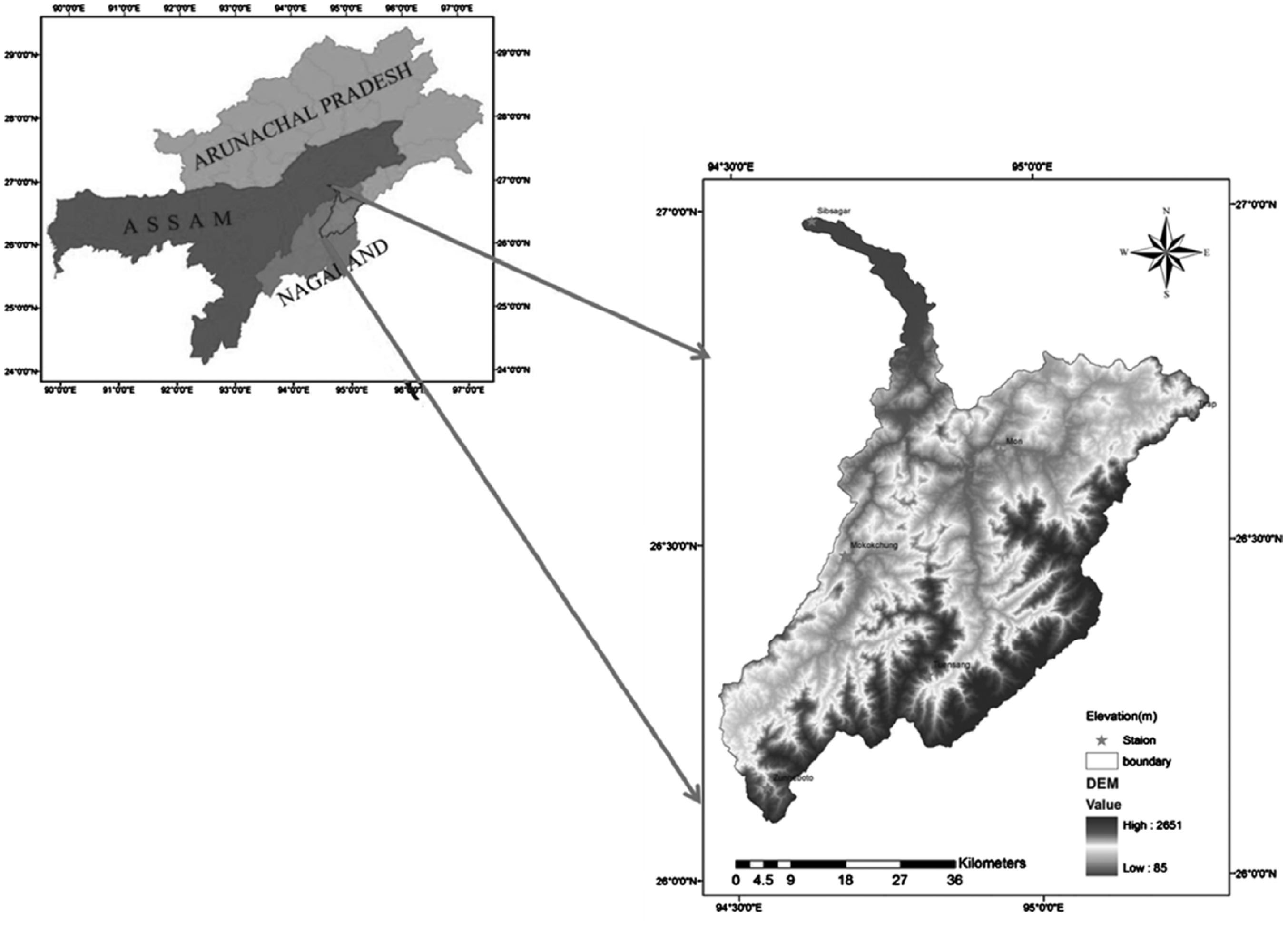

Figure 1: Map of the Dikhow Catchment with Location of the stations

East India has chosen for this study presented in Fig. 1. Dikhow River is originated from the hills of the state Nagaland. It is the lifeline of Assamese people of Upper Assam. Dikhow is the south bank river of River Brahmaputra contributing 0.7% runoff.

The Dikhow catchment is located between 94028′49.85" E to 95009′52.23" E longitude and 26052′20.03" N to 260 03′50.72" N latitude and covers an area of 3100.17 Km2. The lat/ long, altitude, area and stations under different states were presented in Table 1. Different districts covers the catchment were depicted in Fig 2a. Fig.2b presented the elevation classes, showed that only Sibsagar (Assam) located on Plaines, remaining all stations occupied moderate to hilly region. The year is divided into four seasons: cold winter sea-son (December – February), hot summer season (March to May), the Monsoon season (June to September) and the post Monsoon season (October and November). The watershed receives an average annual rainfall of 2323.5 mm, July Month alone accounts for nearly 19.8% and November to January Months together account for only 3.0% of annual rainfall at Sibsagar. August is the hottest Month and January is the coldest Month with Monthly mean maximum and minimum daily temperatures of nearly 32.00C and 25.40C, and 23.00C and 10.20C, respectively. Mean relative humidity is highest in August and lowest in April. The prevailing winds at 8:30 and 17:30 hours generally blow from N-NE sector towards S-SW sector throughout the year. Annual average wind speed is 3.8 km/h with April and July having the highest mean wind speed of 5.4 km/h and December having the lowest mean wind speed of 1.7 km/h.

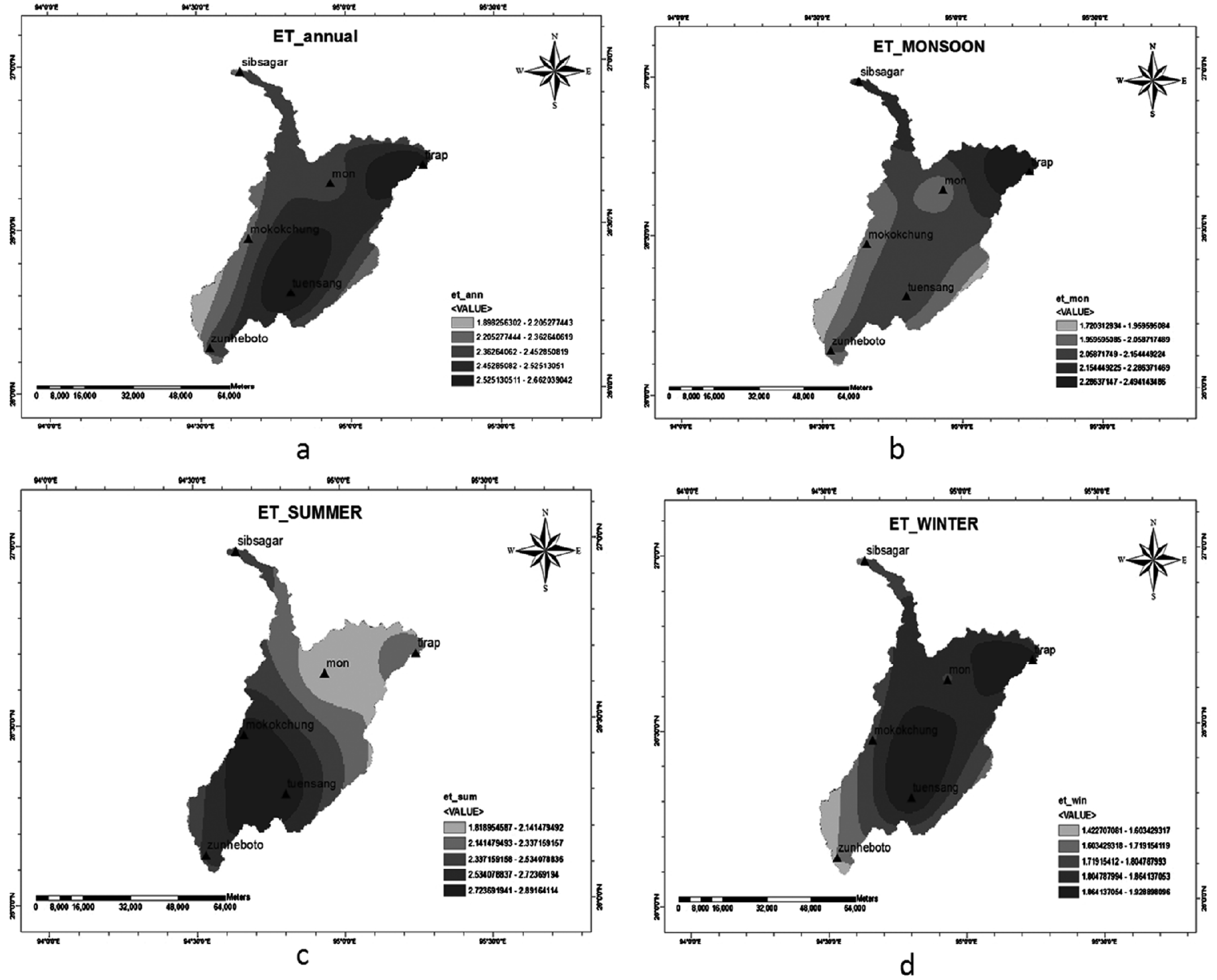

Figure 2: Spatial variation of percentage change of Reference evapotranspiration for (a) annual, (b) monsoon, (c) summer and (d) winter

Table 1
Description of the stations of study area.

S.N.	*State*	*Station*	*Latitude (° ′N)*	*Longitude (° ′E)*	*Altitude (m)*
1	Assam	**Sibsagar**	26°58′59"N	94°37′59"E	98
2	Nagaland	**Mokokchung**	26°28′54"N	94°40′37"E	1045
3	Nagaland	**Mon**	26°38′9 "N	94°56′32"E	776
4	Arunachal Pradesh	**Tirap**	26°41′9"N	95°15′29"E	1500
5	Nagaland	**Tuensang**	26°18′13"N	94°48′59"E	1369
6	Nagaland	**Zunheboto**	26°8′14"N	94°32′53"E	1302

Data Description

Monthly measured reference evapotranspiration data of six stations, namely, Sibsagar, Mokokchung, Mon, Tirap, Tuensang and Zunheboto,were procured from the meterological department.

MATERIALS AND METHODS

Trend analysis using Mann-Kendall(MK) and Sen slope estimator tests

There are various parametric and nonparametric tests, for identifying trends; however, nonparametric MK [15]; [17] test has been widely used in trend detection studies in temperature series [7]. Therefore, in the present study, MK test and Sen slope estimator test [21] are applied to detect the direction and magnitude of trends in annual and seasonal (i.e., Winter (Nov-Feb), Summer (Mar-May) and Monsoon (June-Oct) scale for historical and future time series .The details of MK test and Sen slope estimator test can be found in the previous research papers [7] .In this study, before applying the MK test all the series are tested for serial correlation using Trend free Pre whitening at 0.05% significance level to eliminate the effect of lag1 autocorrelation. All the series are found serially independent and MK test is directly applied to original data series to detect the trend.TREND software which uses Mann-Kendall is used to calculate the value of Z and XL-STAT software is used for the calculation of magnitude of the trend.

Mann–Kendall (MK) test

The MK test [15], [17] is the rank based nonparametric test for assessing the significance of a trend. This test has the several advantages over parametric methods.

Some of these advantages include: (1) does not require the assumption of normality or the assumption of homogeneity of variance (2) compare medians rather than means and, as a result, if the data have one or two outliers, their influence is negated (3) prior transformations are not required, even when approximate normality could be achieved; (4) greater power is achieved for the skewed distributions (5) data below the detection limit can be incorporated without fabrication of values or bias. This method has been used widely across the world to detect trend in ETo and other hydrological variables [2]; [8]; [11]; [12]; [14] [26], [30], [32], [33] It is based on the test statics S defined as

$$\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(X_j - X_i)$$

where, x_1, x_2, …, x_n represent n data points where x_j represents the data point at time j. A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend.

It has been documented that when $n > 10$, the statistic S is approximately normally distributed with the mean. $E(S) = 0$

And its variance is

$$\operatorname{var}(S) = \frac{n(n-1)(2n-5) - \sum_{i=1}^{m} t_i(t_i -1)(2t_i +5)}{18}$$

where n is the number of data points, m is the number of tied groups (a tied group is a set of sample data having the same value), and t_i is the number of data points in the i^{th} group. The standardized test statistic (Z) is computed as follows:

Theil–Sen's estimator

The slope of n pairs of data points were estimated using the equation which is given by the following relation:

$$\beta = Median\left(\frac{X_j - X_i}{j - i}\right) \quad \text{for all} \quad i < j$$

In which $1 < j < i < n$ and b is the robust estimate of the trend magnitude. A positive value of b indicates an upward trend while the negative value indicates downward trend.

Spatial Analysis of Reference Evapotranspiration Using Arc-gis

Change magnitude as percentage of mean:

Some trends may not be evaluated to be statistically significant while they might be of practical interest and vice-versa(yue and Hashino, 2003). In the present study, change percentage has been computed by approximating it with linear trend. That is change percentage equals the slope multiplied by the period length divided by the corresponding mean, expressed as percentage.

$$\text{Percentage change}(\%) = \frac{\beta * \text{length of year}}{\text{mean}} * 100$$

The percentage changes from 1901-2002 showed increase in reference evapotranspiration. It can be concluded that increase in temperature and reference evapotranspiration was detected during the entire historical time period (1901-2002).

Interpolation by Kriging method

Interpolation is estimating the attribute values of location that arewithin the range of available data using the known data values.In the present study, spatial interpolation was done using kriging method in ARC-GIS.Kriging is one of the spatial interpolation algorithm and falls within the field of geo statistics. It is known to be more realistic spatial behaviour of climate variables. The procedures involved in krinqing incorporate measure of error and uncertainity when determining estimations.In this method, every known data value and every missing data value has an associated variance.

RESULTS AND DISCUSSION

Annual and seasonal trends in ETo

The below table enlists significant increasing trend in annual and seasonal scale obtained from Mann–Kendall test. Significant increasing trends in annual ETo were observed at all the stations. The magnitude of increasing trends in annual ETo values varied from 0.297 mm/year for Zunheboto station to 0.324mm/year for Tirap station. No significant increasing ETo trend was found in winter season except sibsagar and tirap station at 95% confidence level. Significant increasing trend was observed in almost all the stations during summer season with magnitude varying from 0.167-0.186 mm/year. In Monsoon ,non significant increasing trend was observed in almost all the stations with slope varying from 0.063-0.078 mm/year.

Spatial Analysis of Reference Evapotranspiration

Fig. (2a-2d) shows the spatial analysis of reference evapotranspiration series on annual and seasonal basis for the time period (1901-2002). Fig. 2(a) shows spatial variation of reference evapotranspiration on annual basis for the entire time period (1901-2002). Figure shows that highest increase in percentage change was at tuensang station with value between 2.52% to 2.66%.

Fig. 2(b) shows spatial variation of reference evapotranspiration for Monsoon season for the entire time period(1901-2002).Figure shows that highest increase in percentage change was at tirap station with value between 2.26% to 2.49% and lowest at Mon station with value between 1.72% to 1.95%. Fig. 2(c) shows spatial variation of reference evapotranspiration for summer season for the entire time period (1901-2002). Figure shows that highest increase in percentage change was at mokokchung and tuensang station with value between 2.72% to 2.89% and lowest was between 1.18% to 2.14%. From the above figures, it can be inferred that Mokokchung station showed the highest increase in percentage change with respect to other stations while the station Mon showed lower percentage change. Fig. 2(d) shows spatial variation of reference evapotranspiration for winter season for the entire time period (1901-2002). Figure shows that highest increase in percentage change was at mokokchung and Mon station with value between 2.72% to 2.89% and lowest at Zunheboto station with value between 1.422%-1.603%. Figure 3(a) and 3(b) shows the linear variation in ETo time series (annual and summer), both annual and summer respectively, showed increasing trend but annual ETo is increasing at a faster rate.

DISCUSSION

Trend analysis was done in reference evapotranspiration for the time period 1901-2002. using Mann-Kendall (MK) and Sen slope estimator tests. Reference evapotranspiration showed increasing trend for both annual and seasonal time scale especially during summer season. During the entire study period, the average annual value of the reference evapotranspiration was between 1104 and

Table
Annual and seasonal trends in Reference Evapotranspiration (1901-2002)

	annual		*Winter*		*summer*		*Monsoon*	
Station	Z-value	β (mm/year)	Z-value	β (mm/year)	Z-value	β (mm/year)	Z-value	β (mm/year)
Mokochung	**3.238**	0.303	1.691	0.066	**2.964**	0.182	1.408	0.070
Mon	**3.238**	0.303	1.691	0.066	1.579	0.071	1.408	0.070
Sibsagar	**3.120**	0.323	**1.969**	0.071	**2.831**	0.186	1.472	0.070
Tirap	**3.149**	0.324	**1.998**	0.071	**2.897**	0.177	1.706	0.078
Tuensang	**3.238**	0.309	1.81	0.064	**2.894**	0.167	1.579	0.071
Zunheboto	**3.163**	0.297	1.781	0.064	**2.961**	0.170	1.379	0.063

1377 mm. The highest values of ETo are registered where the air temperature has higher valuei.e. at sibsagar station. The Monthly ETo reached a peak value in May, for all the sites, in the range of 108-176mm. The lowest ETo has been observed in january (98-110 mm).The largest amount of water evaporates during April-august as a result of an increase in wind speed and temperature. The trends in annual and seasonal ETo were investigated using the MK test and the magnitudes of trends were estimated using Theil-Sen's nonparametric test. The effect of significant lag-1 serial correlation was removed from the data series by Trend Free Pre-Whitening approach prior to trend analysis. Statistically significant increasing trends in annual and seasonal ETo were obtained during the study periods in almost all the stations. The magnitude of increase for annual was 0.303 mm/year, for winter was 0.071 mm/year, for summer was 0.186 mm/year and for Monsoon was 0.078 mm/year. Fig. 3 shows avearge annual and summer ETo for entire study area.

Only annual and summer time series were shown because winter and Monsoon season showed non significant increasing trend.

CONCLUSION

The spatial variation of reference evapotranspiration for annual and seasonal basis for the entire time period (1901-2002). The result showed that rate of ETo was more in annual time series as compared to the summer season.

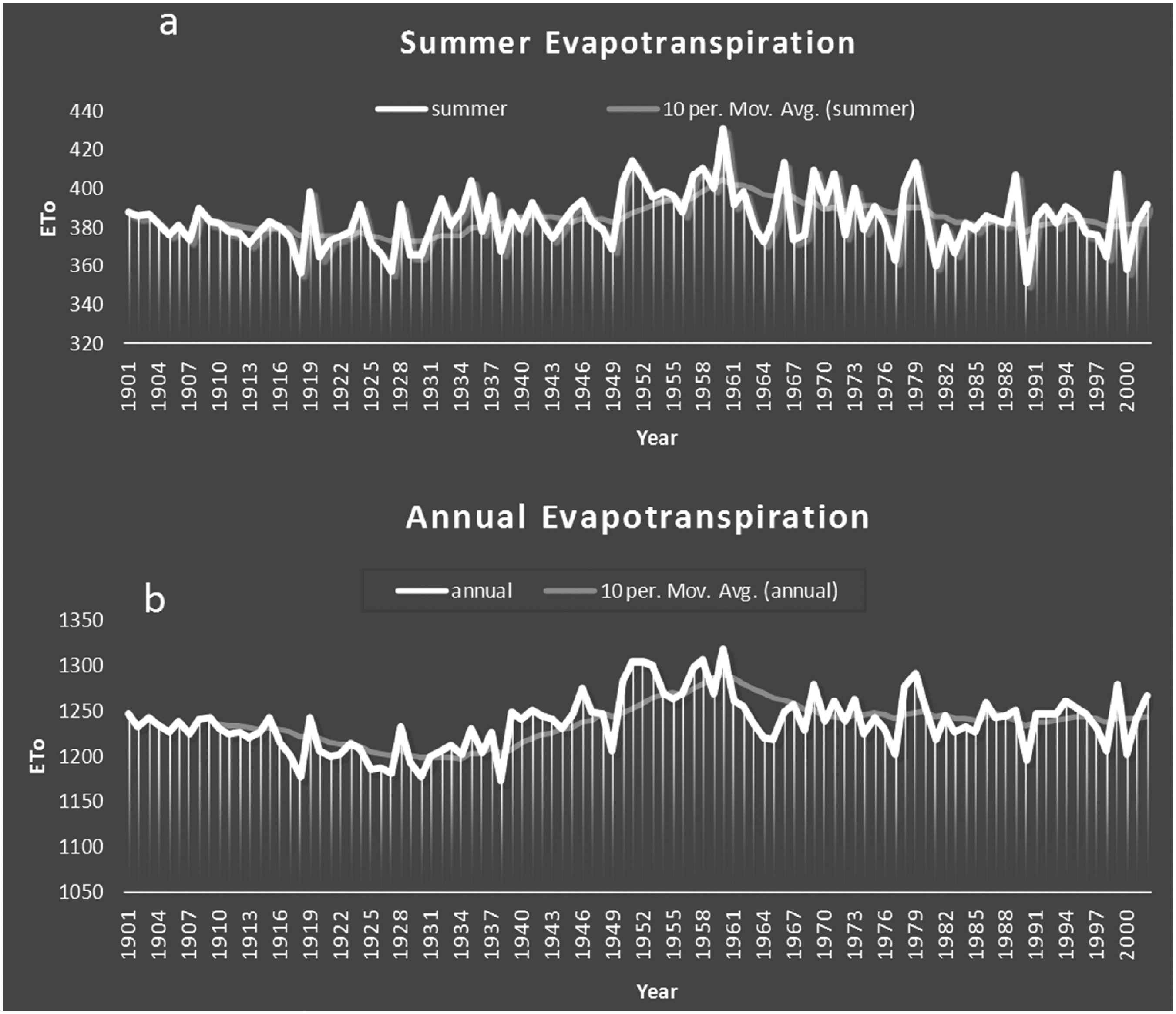

Figure 3: Evapotranspiration time series from 1901-2002(a) for annual and(b) for summer

Hence it can be inferred that Mokokchung station showed the highest increase in percentage change with respect to other stations while the station Mon showed lower percentage change.The highest increase in percentage change was at mokokchung and Mon station with value between 2.72% to 2.89% and lowest at Zunheboto station with value between 1.422%-1.603%. Also linear variation in ETo time series (annual and summer), both annual and summer respectively, showed increasing trend but annual ETo is increasing at a faster rate. The linear variation for annual and summer series increased earlier and then reached its peak in the year 1961 and then decreased.

FUTURE SCOPE

Time series represents a set of obsevations that measure the variation in time of some dimension of phenomenon such as precipitation, temperature, windspeed,river flow etc. So there is urgent need to detect trend for future time series also. Quantification of hydrometerological variables will help the farmers as well as hydrologists to plan the water resource projects and better utilization of land and water resources. Evapotranspiration (ET) affects crop water requirement and future planning and management of water resources. Therefore, for future crop planning and management of water resources, expected change in Evapotranspiration will be a prerequisite. Quantitative estimation of the ETo trend using long term data may provide insight into the possible impacts of climate change on the future water balance and water resource planning in the Dikhow catchment.

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