Analysis of reference Evapotranspiration trends for crop-water requirement estimation in Manipur

Abstract: - The study was aimed to analyse the trend of Reference Evapotranspiration for estimation of Crop Water Requirement for Rice (Oryza sativum) cultivation in Manipur from 2011-2021 in 16 districts (Bisnupur, Churachandpur, Jiribam, Imphal East, Kamjong, Senapati, Imphal West, Tengnoupal, Ukhrul, Thoubal, Noney, Pherzwal, Chandel, Kakching, Tamenglong and Kangpokpi)using CropWAT 8.O. For trend analysis, Mann-Kandell Test and Sen's slope Estimator were considered

. The climate of Manipur is moderate. Climate in the western part of the state is tropical whereas the rest part of the state experiences sub tropical climate with distinct summer, winter and rainy seasons. The valley gets the reflection of the heat of the summer and the cold of the winter from the neighboring hills. Average annual rainfall ranges from 1250 mm to 2700 mm. The months of November, December, January and February remain dry and the remaining eight months are more or less rainy. January is the coldest month and May-June are hottest months.

Introduction: -

Water demand is rising day by day in order to support the quicker rise of the human population, while water availability per person is falling year by year. This depletion of natural resources on Earth poses a threat to all life. Water is a necessary component of all living things; it is also crucial for the socioeconomic development of a nation, food security, supporting life, industrial output, and environmental sustainability. Focus must be placed on the effective exploitation and management of the available water resources due to the rising demand for water brought on by improved farming techniques and fast urbanization. Planners and managers of water resources face a new issue as a result of the rise in water demand required for increased crop production. Climate, soil, and cropping patterns all play a role in influencing agricultural water consumption. With increased scarcity of water resources and rising production costs, sustaining food production sustainably presents numerous issues. Due to a lack of accurate geographic time series data on real Evapotranspiration (ETo), relatively few research on the long-term trend and variability in ET at a national scale throughout the Indian subcontinent have been done. Crop water requirements (CWR) are defined as the depth of water [mm] required to meet the water consumed by a disease-free crop growing in large fields under non-restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment. Crop Evapotranspiration is defined. 2 2 (ETc) as the rate of evapotranspiration (mm d1) of a certain crop as impacted by its developmental stages, environmental factors, and crop management to attain the crop's potential production, then the CWR is the total of ETc over the course of the crop's growth cycle. Adjusted or actual crop evapotranspiration (ETc) is the term for the rate of evapotranspiration that must be used when management or environmental conditions differ from the ideal. Irrigated or rainfed crops can both benefit from the CWR and ETc ideas **Falkenmark (2004).** Evapotranspiration is a critical process in water balance and an important component of energy balance. Its precise estimation is critical for climate change research and water resource assessment, but it also has many practical uses in crop water management, drought forecasting and monitoring, water resource development and efficient use, and so on. Actual Evapotranspiration is the single notion that connects the balance of water and energy on the land's surface, making it a critical phase in the hydrological cycle.

India does not have enough water resources, and the country is further challenged by the detrimental effects of climate change, as well as by massive wastage brought on in part by bad management and unfair water pricing practices. While the Southern River Basin has minimal resources but significant levels of surface and groundwater contamination, the Northern Ganga River Basin has an abundance of water resources. Demand for water (mostly for irrigation) has increased in both urban and rural regions due to population growth and changing lifestyles. India has 18% of the world's population and 4% of the freshwater supply, of which 80% is used for farming. India experiences annual precipitation of 4,000 billion cubic meters on average. But only 48% of it is utilized in the surface and groundwater systems in India. Only 18–20% of the water is actually utilised as a result of inadequate infrastructure, a lack of storage methods, and poor water management. India receives 1183 mm of rainfall year, of which 75% falls in just four months from July to September, when the monsoon season is in full swing. As a result, there are runoffs during the monsoon, necessitating year-round irrigation investments. **(Dhawan *et al.*, 2017).**

The CROPWAT model can contribute significantly to the creation of useful recommendations for increasing yield output under water-scarce situations. The water requirements and irrigation planning for significant crops like sugarcane, wheat, cotton, and rice, among others, are determined using the CROPWAT model. It makes it possible to create recommendations for better irrigation practices, manage irrigation schedules under different water utilization needs, and estimate productivity under rainfed or shortfall irrigation scenarios.

In present study, the crop of interest is Rice (*Oryza sativum*), which is a staple food for the vast majority of people in Asia, particularly in South and Southeast Asia, where more than 90% of the world's rice is produced and eaten. The majority of the world's rice is farmed in tropical regions, with temperature playing a key role in growth. Being a tropical and subtropical plant, rice needs temperatures between 20 to 40°C, which is a rather high range. Crop is negatively impacted by both high temperatures in the tropics at lower altitudes and cold temperatures in temperate zones. The variety, duration of the critical temperature, tidal variations, and physiological changes of the plant all affect this temperature differently. Low temperatures slow down germination and cause it to take longer than the ideal six days. Because of the high respiration rate, germination was stopped by temperatures of 35°C or above. (**Sreenivasan, 1985**). The objectives of the study was ………………………

MATERIALS & METHODS

An experiment was conducted during 2011-2021 year. Details of materials used and experimental methodology followed during the course of present study were described in this chapter

3.1 Description Of Study Area: The study was conducted at all districts of Manipur. It lies at a latitude of 23°83'N – 25°68'N and a longitude of 93°03'E – 94°78'E, with a total area of 22,327 square kilometers (8,621 sq. mi). The slope of the valley is from North to South. The mountain ranges create a moderated climate, preventing the cold winds from the North from reaching the valley and barring cyclonic storms. The climate of Manipur is largely influenced by the topography of this hilly region. Lying

790 meters above sea level, Manipur is wedged among hills on all sides. This northeastern corner of India enjoys a generally amiable climate, though the winters can be chilly. The maximum temperature in the summer months is 32 °C (90 °F). The precipitation ranges from light drizzle to heavy downpour. The normal rainfall of Manipur enriches the soil and helps in agriculture and irrigation. The South Westerly Monsoon picks up moisture from the Bay of Bengal and heads toward Manipur, hits the eastern Himalaya ranges and produces a massive amount of rain.

Fig.1 Map of study area (Manipur)

3.2 Climate and weather condition :

The climate of Manipur is moderate. Climate in the western part of the state is tropical whereas the rest part of the state experiences sub tropical climate with distinct summer, winter and rainy seasons. The valley gets the reflection of the heat of the summer and the cold of the winter from the neighboring hills. Average annual rainfall ranges from 1250 mm to 2700 mm. The months of November, December, January and February remain dry and the remaining eight months are more or less rainy. January is the coldest month and May-June are hottest months.

3.3 DATA ACQUISITION

1. Collection of weather data:

The monthly meteorological data of maximum temperature, minimum temperature and rainfall data were collected from NASA Power, Manipur for the period of 2011-2021.

2 Software used: CROPWAT Model.

3. Soil data: Mostly Alluvial soil data collected from FAO.

4. Crop data: Kc-value at different physiological stages for Rice from FAO

3.4 Software Used

CROPWAT 8.0 model:

CROPWAT 8.0 is an FAO-developed decision-support computer application that uses soil, crop, and climatic data to determine reference evapotranspiration (ET0), crop water need, irrigation schedule, and irrigation water requirement. The programme provides general data for various crop characteristics, local climate conditions, and soil attributes and it aims to improve the irrigation schedules and the estimation of water supply for various crop patterns for both irrigated and rain-fed cropping systems. CROPWAT 8.0 can also be used to assess farmers' irrigation practices and to estimation the reference Evapotranspiration, crop Evapotranspiration, and irrigation water requirement.

The development of irrigation schedules in CROPWAT 8.0 is based on a daily soil-water balance using various user-defined options for water supply and irrigation management conditions. Scheme water supply is calculated according to the cropping pattern defined by the user, which can include up to 20 crops.

CROPWAT 8.0 is a Windows includes a host of updated and new features including:

- Daily, monthly and decade input of climatic data for calculation of reference evapotranspiration (ETo)
- Backward compatibility to allow use of data from CLIMWAT database
- Possibility to estimate climatic data in the absence of measured values
- A decade and daily calculation of crop water requirements based on updated calculation algorithms including adjustment of crop-coefficient values
- Calculation of crop water requirements and irrigation scheduling for paddy & upland rice, using a newly developed procedure to calculate water requirements including the land preparation period
- Interactive user adjustable irrigation schedules
- Daily soil water balance output tables
- Graphical presentations of input data, crop water requirements and irrigation schedules
- Easy import/export of data and graphics through clipboard or ASCII text files
- Extensive printing routines, supporting all windows-based printers
- Context-sensitive help system

- Multilingual interface and help system: English, Spanish, French and Russian.

Fig:2 CROPWAT 8.0 Model

3.5 MAKESENS 1.0

This Ms Excel template is developed for detecting and estimating trend in time series of annual values of atmospheric chemistry. The used statistical methods are the non-parametric Mann-Kendall test for testing the presence of the monotonic increasing or decreasing trend and the non-parametric Sen's method for estimating the slope of a linear trend. The Mann Kendall test requires at least 4 values and calculation of the confidence intervals for the Sen's slope estimate requires at least 10 values in time series. The functional part of the template consists of three worksheets: Annual data, trend statistics and Figure.

3.6 Input data for CROPWAT model

3.6.1 Site data: Country and station name, location data, longitude (East or West), latitude (North or South) and altitude (m) were required for site identification in CROPWAT.

3.6.2 Climatic data: The daily meteorological data of maximum temperature, minimum temperature and rainfall data were collected from NASA POWER for the period 2011-2021. Where rainfall data was collected with a grid size of 0.25 x 0.25 and temperature data was collected with grid size of 0.5 x 0.5

3.6.3 Rainfall input data

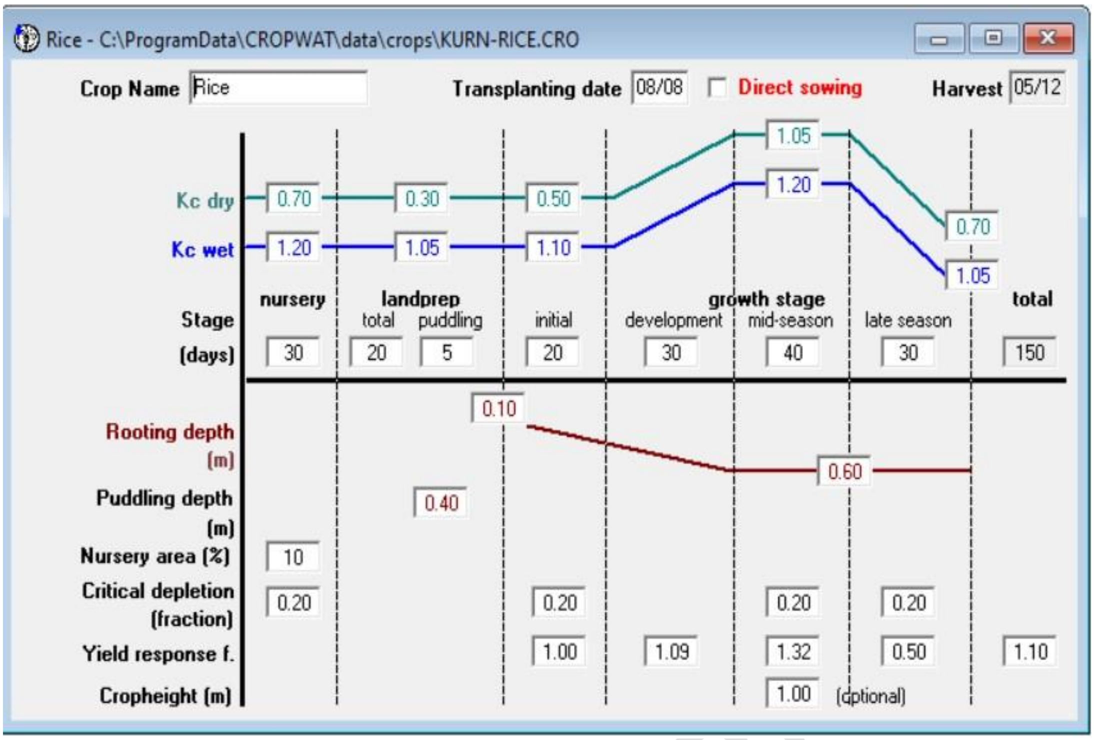
The precipitation data required for CROPWAT 8.0 can be daily, decade or monthly rainfall, commonly available from many climatic stations. In addition, substations may be found with single rainfall records. For larger schemes, records of several rainfall stations may be available, allowing an analysis of the spatial variability.

3.6.4 CROP data :

The CROPWAT model requires crop data over different development stages and is defined as follow :The Crop coefficient (Kc) integrates the effect of characteristics that distinguish a specific crop from the Reference crop. According to the Crop coefficient Approach, Crop Evapotranspiration under standard conditions (ETc) is calculated by multiplying the Reference Evapotranspiration (ETo) by the suitable Kc.Kc is influenced mostly by crop type and to a minor extent by climate and soil evaporation. Moreover, the Kc for a given crop varies over the crop growing Stages, since ground cover, Crop height and leaf area change as the crop develops.

Duration and sowing date mentioned in the software helps in determine the phenophase of the crops. At each phenophase Kc value, rooting depth (m), critical depletion value and crop yield response factor is decided based on the duration of the crops. The yield response factor (Ky) is the ratio of relative yield reduction to relative Evapotranspiration deficit that integrates the weather, crop and soil conditions that make crop yield less than its potential yield in the face of deficit evapo-transpiration also estimated in the model. In Arunachal Pradesh, during kharif season, the cultivation of rice generally sown around 3rd July and this crop takes approximately 170 days.

The crop module requires crop data over the different development stages for rice:



Rice - C:\ProgramData\CROPWAT\data\crops\KURN-RICE.CRO

Crop Name Rice **Transplanting date** 08/08 ☐ **Direct sowing** **Harvest** 05/12

	nursery	landprep total	landprep puddling	initial	growth stage development	growth stage mid-season	growth stage late season	total
Kc dry	0.70	0.30		0.50		1.05	0.70	
Kc wet	1.20	1.05		1.10		1.20	1.05	
Stage (days)	30	20	5	20	30	40	30	150
Rooting depth (m)				0.10		0.60		
Puddling depth (m)			0.40					
Nursery area (%)	10							
Critical depletion (fraction)	0.20			0.20		0.20	0.20	
Yield response f.				1.00	1.09	1.32	0.50	1.10
Cropheight (m)						1.00	(optional)	

Fig 3 :Screenshot of Kc values from CROPWAT 8.0

3.6.5 Calculation of Reference Evapotranspiration (ETo)

The Evapotranspiration rate from a reference surface, not short of water, is called the reference Evapotranspiration and is denoted as ETo. The reference surface is a hypotheticalgrass reference crop with specific characteristics. The use of other denominations such as potential ET is strongly discouraged due to ambiguities in their definitions. The reference Evapotranspiration (ETo) was computed by Penman Monteith Model **(Allen *et al.* 1998)**. In this model, most of the equation parameters are directly measured or can be readily calculated from weather data. The equation can be utilized for the direct calculation of any crop Evapotranspiration (ETC). The FAO Penman-Monteith equation is a close, simple representation of the physical and physiological factors governing the Evapotranspiration process. The concept of the reference Evapotranspiration was introduced to study the evaporative demand of the atmosphere independently of crop type, crop development and management practices. As water is abundantly available at the reference Evapotranspiration surface, soil factors do not affect ET. Relating ET to a specific surface provides a reference to which ET from other surfaces can be related. It obviates the need to define a separate ET level for each crop and stage of growth. ETo values measured or calculated at different locations or in different seasons are comparable as they refer to the ET from the same reference surface **(FAO 56, 1998).**

The mathematical expression for the sake of calculation simplified as

$$ETo = \frac{0.408\Delta(Ra-G+\gamma\frac{900}{T+273}u2(es-ea)}{\Delta+\gamma(1+0.34u2)}$$

Where, ETO = Reference Evapotranspiration (mm per day)
Ra = Net radiation at the crop surface (MJ/m^2 per day)
G =Soil heat flux density (MH/m^2 per day)
T =Mean daily air temperature at 2m height (°c)
u_2 = Wind speed at 2m height (m/s)
E_s = Saturation vapor pressure (kPa)
e_a = Actual vapor pressure (kPa)
e_s-e_a = Saturation vapor pressure deficit (kPa)
γ= Psychometric constant
Δ = Slope vapour pressure curve [kPa °C-1]

3.6.6 Effective rainfall (ER)

Total rainfall is not utilized by the plants, effective rainfall is defined as a part of rainfall which is effectively used by the crop after rainfall losses due to surface run off and deep percolation have been accounted **(Babu *et al.* 2015)**. According to **Dastane (1974)** effective rainfall is defined as that portion of rainfall which is useful directly and/or indirectly for crop production at the site where it falls. Consideration of effective rainfall can help in predicting more precisely the water requirement of crops. Effective rainfall is influenced by factors such as quantity and intensity of rainfall, Evapotranspiration and percolation losses; crop and irrigation management practices. Estimates of effective rainfall are extremely useful for operation planning and management issues including determine optimal cropping pattern; determining optimal operational policies for irrigation systems; design of drainage systems and real-time control. The model has available four Effective Rainfall methods but the USDA Soil Conservation Service method is the default. To calculate the effective rainfall from 1990- 2019, the USDA Soil Conservation Service method was used. For the present study USDA Soil Conservation Service method **(Smith, 1991)** was chosen for calculating the effective rainfall and estimated by using following formula:

$Peff=Ptot\times^{128-0.2\times Ptot}$ for $P_{tot}<250$mm
128

$Peff=125+0.1*Ptot$for $P_{tot}>$ 250mm

Where,

Peff= Effective rainfall (mm)
Ptot = Total rainfall (mm)

3.6.7 Estimation of Crop Water Requirement (ETc)

Crop Water Requirement is the amount of water needed to meet the water loss through Evapotranspiration Estimation of the crop water requirement is derived from crop Evapotranspiration (crop water use) which is the product of the reference Evapotranspiration (ETo) and the crop coefficient (Kc)The reference Evapotranspiration (ETo) is estimated based on the FAO Penman-Monteith method, using climatic data **(FAO, 1998)**

$$ETc=ETo \times Kc$$

Where, ETc = Actual Evapotranspiration by the crop (mm/day),
ETo= Reference crop Evapotranspiration (mm/day),
Kc =Crop coefficient at a certain growth stage.

3.7 Trend Analysis Mann-Kandell Test

In the present study, trend analysis has been done by using non-parametric Man- Kendall test. This method tests whether there is a trend in the time series data. It is a statistical test widely used for trend analysis, used for detection of statistically significant trend in variables like rainfall, temperature and stream flow. According to this test, the null hypothesis Ho assumes that there is no trend and this is tested against the alternative hypothesis H1, which assumes that there is a trend **(Karmeshu 2012)**. The trend detection of the data is analyzed using the Mann-Kendall test.

Here is how to calculate the MK test:

Step 1: Arrange the time series data in ascending order.

Step 2: Calculate the difference between each pair of observations in the time series data.

Step 3: Assign a value of +1 for each upward trend (i.e., when the difference between two consecutive observations is positive) and a value of -1 for each downward trend (i.e., when the difference between two consecutive observations is negative). If the difference between two consecutive observations is zero, assign a value of 0.

Step 4: Calculate the MK statistic (S) using the following formula:

S=Σ Σ*sgnnj=i*+1 n−1

S = Σ(sign(rank(j)) x [Σ(sign(rank(i))-1)])

where,Σ = summation
sign = the sign function
rank = the rank of the data
i = index of data from 1 to n-1
j = index of data from 2 to nn is the number of data points in the time series.

Step 5: Calculate the variance (Var(S)) of the MK statistic using the following formula:

$$\mathbf{Var(S) = [n(n-1)(2n+5) - \Sigma tj(tj-1)(2tj+5)]/18}$$

where,
Σ = summation
tj = the number of tied groups of data for the jth value
n is the number of data points in the time series.

Step 6: Calculate the standard normal variable (Z) using the following formula:

$$\mathbf{Z = (S-1)/\sqrt{Var(S)}}$$

where,
$\sqrt{}$ = square root

Step 7: Determine whether the trend is statistically significant or not based on the critical value of Z. If $|Z| > Z\alpha/2$, where α is the significance level and Z
i=1 (xj-xi) Where the xi is the actual time data for a time series of i= 1. 2... n.
When the data $n \geq 10$ the S statistic follows the normal distribution in a series with the mean
of E(S)=0 and the variance.
A positive (negative) value of S indicates an upward (downward) trend.

3.8 Sen's slope Estimator

Sen's slope estimation **(Sen 1968)** is another non-parametric method for trend analysis of precipitation data. It is used to detect the magnitude of the trend.
Where is the data values for j and k times of a period where j>k. Median is computed from N observations of the slope to estimate the Sen's Slope estimator.
When the N Slope observations are shown as Odd the Sen's Estimator is computed as Qmed (N+1)/2 and for Even times of observations the Slope estimate as Qmed = [(N/2) +((N+2)/2)]/2. The two sided test is carried out at 100(1-α) % of confidence interval to obtain the true slope for on parametric test in the series **(Mondal *et al.* 2012)** The positive or negative slope Qi is obtained as upward (increasing) or downward (decreasing) trend.

RESULTS AND DISCUSSION

Result obtained from the study entitled as “Analysis of Reference Evapotranspiration Trends for Crop Water Requirement Estimation in Manipur’’ over different all districts of Manipur by using CROPWAT" has been presented in this chapter with the help of tables and water wherever it is necessary. The result obtained from the present study has been finalized in the following subheads:

4.1 Temporal variation of temperature and rainfall for different of all 16 districts of Manipur.
4.2 Annual maximum, minimum temperature and rainfall for trend analysis of different of all 16 districts of Manipur.
4.3 Spatial-temporal and Trend analysis for seasonal rainfall
4.4 Spatial-temporal and Trend analysis for annual effective rainfall
4.5 Spatial-temporal and Trend analysis for annual ETo
4.6 Spatial-temporal and Trend analysis for seasonal ETo

4.7 Estimation and Trend analysis for annual crop water requirement of Ricefor all 16 districts of Manipur.

4.1 Temporal variation of temperature and rainfall for different of all 16 districts of Manipur.

The value of annual variation in temperature and rainfall for all 16 districts of Manipur during the period of 2011-2021 has been shown in Table 1 Generally in Manipur the highest temperature is observed in the month of June and lowest in December. The minimum temperature out of 16 districts of Manipur was observed in Senapati and maximum temperature in Bisnupur. From the Table 1 it has been observed that minimum average temperature is lowest in case of Senapati (11.00°C) and Ukhrul (12.16°C) stations. While the highest average maximum temperature has been observed in Bisnupur (34.64°C) and Tengnoupal (33.42°C) station. The overall range of average maximum temperature for different 16 districts lies between 28.44°C to 34.64°C and average minimum temperature lies between 11.00°C to 17.10°C

Table no. 1: Average minimum, maximum temperature and rainfall of all 16 districts of MANIPUR for 11 years (2011-2021)

S.No.	Districts	T min	T max	Rainfall
1	IMPHAL WEST	13.49	28.44	1441.36
2	IMPHAL EAST	13.49	28.44	1441.36
3	CHURACHANDPUR	13.99	29.96	1387.58
4	THOUBAL	13.99	29.96	1387.58
5	CHANDEL	13.99	29.96	1387.58
6	UKHRUL	12.16	28.94	1311.96
7	BISNUPUR	17.10	34.64	1518.68
8	KAKCHING	13.99	29.96	1387.58
9	TENGNOUPAL	15.41	33.42	1184.47
10	TAMENGLONG	13.49	28.44	1441.36
11	SENAPATI	11.00	27.25	1456.14
12	PHERZWAL	15.87	32.72	1955.12
13	NONEY	13.49	28.44	1441.36
14	KANGPOKPI	13.49	28.44	1441.36

15	KAMJONG	12.16	28.94	1311.96
16	JIRIBAM	15.70	31.60	1962.12
	SD	2.084	1.526	206.97
	MEAN	29.973	13.925	1466.09
	CV	6.953	10.962	0.141

4.2 Annual maximum and minimum temperature trend analysis of different 16 districts of Manipur.

4.2.1 Trend analysis of Annual Maximum Temperature.

Mann-Kendall and Sen's slope estimator have been used for the determination of temperature trend detection. The trend analysis for annual temperature (maximum and minimum) from2011-2021 has been done in this study. The results of Mann-Kendall test for annual maximum temperature has been presented in Table 2.

The results shown in Table 2 indicated that Z value of maximum annual temperature was positive trend except Bisnupur and Pherzwal for all the 16 districts of Manipur ieImphal Weast,Imphal East, Churachandpur, Thoubal, Chandel, Ukhrul, Kakching, Tengnoupal, Tamenglong, Senapati, Noney, Kangpokpi, Kamjong, and Jiribam found positive value except Bisnupur(-0.16) and Pherzwal (-0.16) which means all districts showed increasing trend for annual maximum temperature, showed non-significance in all districts. It was also observed from the Sen's slope that the rate of change of maximum temperature during the period 2011-2021 for Bisnupur (-0.01°C/11) years and Pherzwal (-0.05°C/11) years and remaining 14 districts 0.05 °C/11 years, 0.05 °C/11 years, 0.03°C/11 years, 0.03°C/11 years, 0.03°C/11 years, 0.03°C/11 years,0.11°C/11 years,0.03°C/11 years,0.07°C/11 years, 0.05°C /11 years,0.05°C /11 years,0.05°C /11 years,0.05°C /11 years, 0.11°C/11 years and 0.05°C/11 years Out of the 16 districts only 2 districts Bisnupur and Pherzwal has negative trends rest all districts positive trends and non-significant. Similar results were reported by **Kumar *et al.,* (2014)** has analyzed the temperature data of 102 years from 1901 to 2002 to determine the trend of temperature in the High-Altitude Regions of Uttarakhand. The Z Test value of MK Test for annual temperature in his case was 1.11 for all regions showing an increasing trend in the temperature.

Table 2:Trend analysis of Annual Maximum temperature

DISTRICTS	Zc	Qi
IMPHAL WEST	0.31	0.05
IMPHAL EAST	0.31	0.05
CHURACHANDPUR	0.31	0.03
THOUBAL	0.31	0.03
CHANDEL	0.31	0.03
UKHRUL	1.48	0.11
BISNUPUR	-0.16	-0.01
KAKCHING	0.31	0.03
TENGNOUPAL	0.78	0.07
TAMENGLONG	0.31	0.05
SENAPATI	0.62	0.05
PHERZWAL	-0.16	-0.05
NONEY	0.31	0.05
KANGPOKPI	0.31	0.05
KAMJONG	1.48	0.11
JIRIBAM	0.47	0.05

4.2.2 Trend analysis of Annual Minimum Temperature data 2011-2021 for 16 districts of Manipur

The results shown in Table 3 indicated that Z value of minimum annual temperature was positive for all the 11 districts of Manipur except Kakching, Churachandpur,Thoubal and Chandel are negative trends, Out of all 16 districts only

Senapati has showed significant positive trend at 0.1 level of significance. This indicates an increasing trend of minimum annual temperature for all 11 districts, though they all are not significant. Imphal Weast, Imphal East,, Ukhrul, Bisnupur, Tengnoupal, Tamenglong, Pherzwal, Noney, Kangpokpi, Kamjong and Jiribam has showed non-significant change with Sen's slope value of 0.03°C /11 years, 0.03°C /11 years,0.05°C/11 years, 0.03°C/11 years, 0.06°C/11 years, 0.03°C /11 years, 0.02°C /11 years,0.03°C /11 years, 0.03°C /11 years, 0.05°C /11 years and 0.45°C/11 respectively at non-significance. While Kakching, Churachandpur,Thoubal and Chandel showed trends decreasing change with Sen's slope value 0.01°C/11 years,0.01°C/11 years, 0.031°C/31 and 0.01°C/11 years respectively at non-significance.

Table 3: Trend analysis of Annual Minimum Temperature

DISTRICTS	Zc	Qi
IMPHAL WEST	0.31	0.05
IMPHAL EAST	0.31	0.05
CHURACHANDPUR	0.31	0.03
THOUBAL	0.31	0.03
CHANDEL	0.31	0.03
UKHRUL	1.48	0.11
BISNUPUR	-0.16	-0.01
KAKCHING	0.31	0.03
TENGNOUPAL	0.78	0.07
TAMENGLONG	0.31	0.05
SENAPATI	0.62	0.05^{+}
PHERZWAL	-0.16	-0.05
NONEY	0.31	0.05
KANGPOKPI	0.31	0.05
KAMJONG	1.48	0.11
JIRIBAM	0.47	0.05

4.2.3 Trend analysis of annual rainfall for all 16 districts of Manipur.

The analysis of annual rainfall trend was presented in Table 4. From the sen's slope estimator it was observed that all 16 districts of Manipur showed non-significant rainfall trend. It may be seen from Table 4 that the Z value of annual rainfall showed positive as well negative trends in the Manipur, although the values are not significant for all 16 districts of Manipur. Bisnupur, Senapati ,jiribam and Pherzwal have positive Z values found. While Imphal West, Imphal East, Churachandpur, Thoubal, Chandel, Ukhrul,Kakching, Tengnoupal, Tamenglong, Noney, Kangpokpi, Kamjong has negative Z values found The annual rainfall over 11 years (2011-2021) showed non-significance.

Agnihotri *et al.,* (2017)analyzed on spatio-temporal variations in precipitation in terms of month wise, seasonal and annual trends in West Flowing River Basin of Kutch, Saurashtra and Marwar (WFR-KSM basin). The trend was calculated in ProUCL5.0.00 and ArcMap 10 software using Indian Meteorological Department (IMD) Precipitation grid data (0.25° x 0.25°) with a temporal resolution of 1964-2013 representing 50 years daily data. The direction and magnitude of annual, monsoon and month wise trends in long-term precipitation data were calculated for every grid using Mann-Kendall (MK) test and Theil- Sen's (TS) slope. Annually and in monsoon season, the increasing trend in precipitation was exhibited by the major part of the basin. The decreasing trend was confined to northern and north-eastern regions. The month wise trend analysis indicated either no grid or few grids exhibited a trend in non-monsoon months. The June, July, August, September (monsoon) months exhibited spatial variation in trends. The majority of the grids in June, July and August months exhibited increasing trends and a few grids with declining trend were clustered mainly in western and north-eastern part of the basin.

Table 4 Trend analysis of Annual Rainfall data 2011-2021 for all 16 districts of Manipur

DISTRICTS	Zc	Qi
IMPHAL WEST	-1.02	-31.30
IMPHAL EAST	-1.02	-31.30
CHURACHANDCPUR	-0.78	-23.79

THOUBAL	-0.78	-23.79
CHANDEL	-0.78	-23.79
UKHRUL	-0.62	-12.31
BISNUPUR	0.62	26.37
KAKCHING	-0.78	-23.79
TENGNOUPAL	-1.40	-24.32
TAMENGLONG	-1.02	-31.30
SENAPTY	0.93	10.55
PHERZWAL	0.62	36.91
NONEY	-1.02	-31.30
KANGPOKPI	-1.02	-31.30
KAMJONG	-0.62	-12.31
JIRIBAM	0.62	36.04

4.3 Spatial-temporal variation in seasonal rainfall

This figure 4 shows changes in the average seasonal rainfall for each season across the 16 districts of Manipur from 2011 to 2021. Seasons are defined as follows: monsoon (June, July, August), post-monsoon (September, October, November), winter (December, January, February) and pre-monsoon (March, April, May). It may be observed from the table that in Jiribam district highest rainfall has been observed during monsoon season (1218.56 mm).Similarly lowest rainfall was observed in Senapati district during winter season (31.17mm).

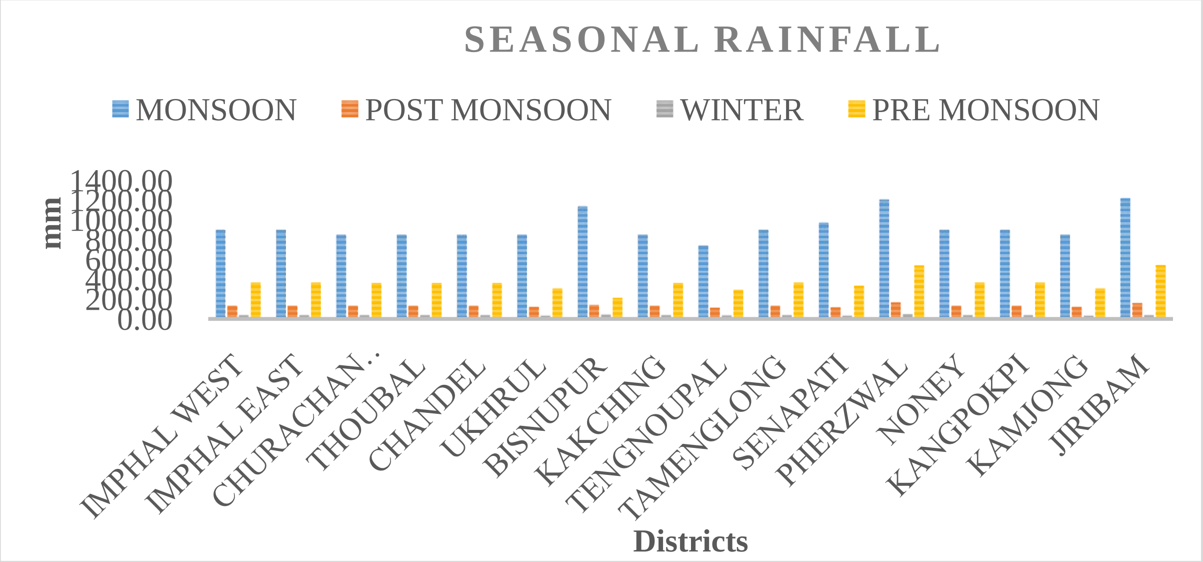


Fig 4. Annual seasonal rainfall

4.3.1 Trend analysis for seasonal rainfall

The seasonal rainfall data were identified from the rainfall series of 16districts under study. Table 5 indicated that the Z value of monsoon and post-monsoon rainfall was non-significantly for all the 16 districts except for monsoon seasonal was shown negative as well positive trends i.eImphal West, Imphal East, Churachandpur, Thoubal, Chandel, Ukhrul, Kakching, Tengnoupal, Tamenglong, Noney, Kangpokpi, Kamjong are negative trends similarly Bisnupur, Senapati, Pherzwal, Jiribam are shown positives trends. The resultswas revealed that out of 16 districts, 4 districts are showed positive trend while 12 districts has shown negative trendsin 16 districts of Manipur from 2011-2021

Mondal *et al.,* (2012) determined that the Zc value of MK Test represents both positive and negative trend in the area although not much significant. Individually months of January, May, June, September, October and November are showing positive trend and months of February, March, April, July, August and December are depicting negative trend in the Zc value. Rainfall varies in different months for different years which are evident in the graphs. There are six months with increasing trend and Zc value along with the increasing slope magnitude, and six months with decreasing or negative Zc value and Sen's Slope. Therefore, it can be concluded that there is evidence of some change in the trend of precipitation of the region in these 40 years in different months.

Table 5: Trend analysis of monsoon and post monsoon rainfall

DISTRICTS	Monsoon		Post monsoon	
	Zc	Qi	Zc	Qi
IMPHAL WEST	-0.93	-25.00	0.86	6.59
IMPHAL EAST	-0.93	-25.00	0.86	6.59
CCPUR	-1.33	-22.12	1.17	10.02
THOUBAL	-1.33	-22.12	1.17	10.02
CHANDEL	-1.33	-22.12	1.17	10.02
UKHRUL	-0.39	-10.55	1.33	8.44
BISNUPUR	0.16	8.79	0.70	3.96
KAKCHING	-1.33	-22.12	1.17	10.02
TENGNOUPAL	-1.56	-25.31	1.02	5.94
TAMENGLONG	-0.93	-25.00	0.86	6.59
SENAPTY	0.00	4.61	1.33	10.34
PHERZWAL	1.02	13.56	1.40	17.33
NONEY	-0.93	-25.00	0.86	6.59
KANGPOKPI	-0.93	-25.00	0.86	6.59

KAMJONG	-0.39	-10.55	1.33	8.44
JIRIBAM	0.47	19.34	1.40	14.50

The table 6 indicated that the Zc value of winter rainfall was positive as well as showed the significance from 0.1 to 0.05 level of significant in 12 districts and 4 districts are shown non significant out of 16 districts of Manipur while showed non significance in pre-monsoon results revealed that out of 16 districts, 2 districts are showed significantly positive trend.

Krishan *et al.,* (2015) concluded that the rainfall trend in annual, monsoon, pre-monsoon and post-monsoon seasons increases, however, the MKK test indicated that the rainfall trend has been observed only in annual, monsoon and pre-monsoon seasons at 1% level of significance. Winter rainfall is found decreasing in 11 districts. In future, the variability of rainfall is likely to increase in Punjab. Rainfall has a rising trend at some districts in south-west Punjab namely Bhatinda and Moga which currently receive low annual rainfall. The increasing trend in annual and monsoon rainfall was found statistically significant in 11 and 9 districts, respectively.

Table 6: Trend analysis of winter and pre-monsoon rainfall

Districts	**Winter**		**Pre-monsoon**	
	Zc	**Qi**	**Zc**	**Qi**
IMPHAL WEST	1.72	2.64+	-1.56	-14.5
IMPHAL EAST	1.72	2.64+	-1.56	-14.5
CCPUR	2.19	2.99*	-1.25	-12.85
THOUBAL	2.19	2.99*	-1.25	-12.85
CHANDEL	2.19	2.99*	-1.25	-12.85
UKHRUL	1.72	2.64+	-1.09	-10.95
BISNUPUR	1.17	4.61	0.7	4.39
KAKCHING	2.19	2.99*	-1.25	-12.85
TENGNOUPAL	1.11	2.35	-1.4	-15.07
TAMENGLONG	1.72	2.64+	-1.56	-14.5
SENAPTY	1.74	1.98+	-0.62	-7.38
-PHERZWAL	1.34	3.18	-0.31	-3.12

NONEY	1.72	2.64+	-1.56	-14.5
KANGPOKPI	1.72	2.64+	-1.56	-14.5
KAMJONG	1.72	2.64+	-1.09	-10.95
JIRIBAM	0.7	1.76	0	0

4.4 Spatial-temporal variation in annual effective rainfall

It is clear from fig 5 that amount of annual effective rainfall was found lowest in Tengnoupal district 834.94mm while Pherzwal districts 1079.71mm and Jiribam districts 1079.00mm received the highest annual effective rainfall

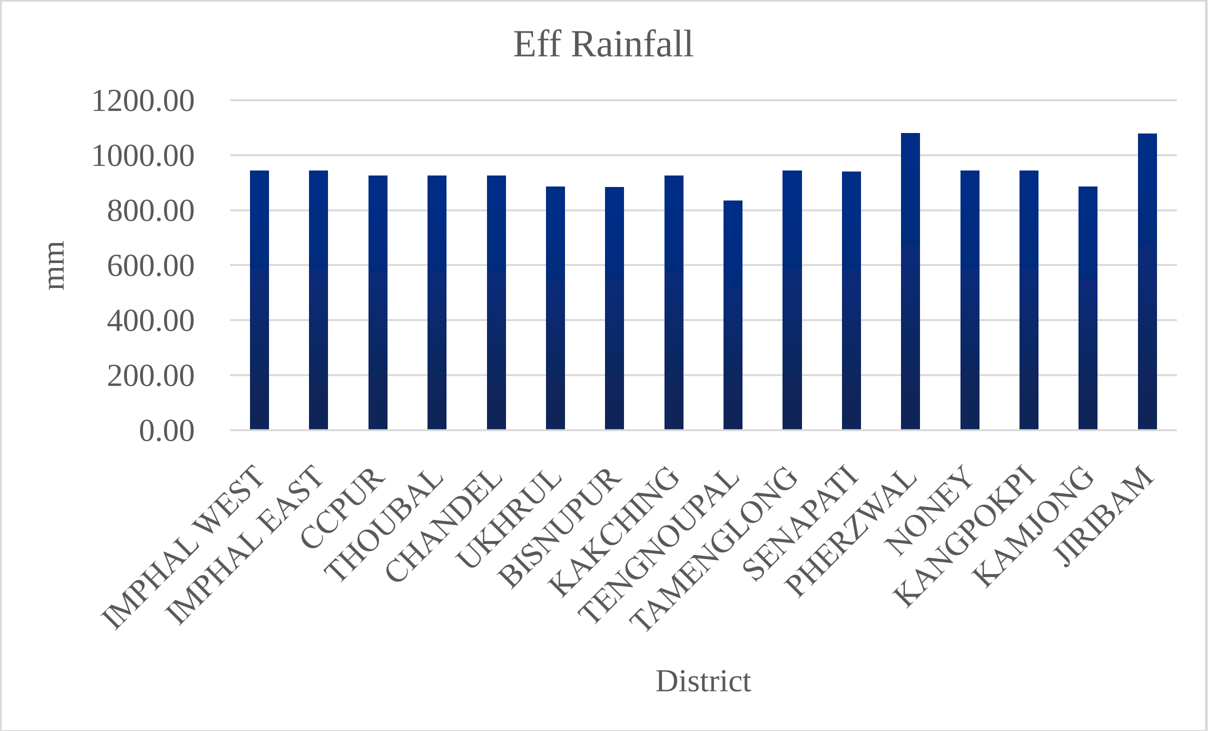


Fig 5. Variation in annual effective rainfall (2011-2021)

4.4.1 Trend analysis for effective rainfall

The results shown in Table 7 indicated Z value of effective annual rainfall was positive and negative for 16 districts . All the 15 districts showed positive trend except for Tengnoupaldistrict which showed a negative trend but there was showed non- significant trend out of 16 districts in Manipur from 2011-2021

Mojid*etal.,* (2020) stated that monthly total rainfall and seasonal effective rainfall for the major crops and cropping patterns decreased gradually in Bogura and Rajshahi districts over the years 1985–2013 except in January, August and October. Effective rainfall occurred might not be utilized fully because of their non-uniform temporal distributions. So, the dry season crop period (November–April) became drier over this period.

Table 7: Trend analysis for effective rainfall

Stations	Zc	Qi
IMPHAL WEST	0.31	0.74
IMPHAL EAST	0.31	0.74
CCPUR	0.16	5.20
THOUBAL	0.16	5.23
CHANDEL	0.16	5.23
UKHRUL	0.47	3.50
BISNUPUR	1.09	10.33
KAKCHING	0.16	5.23
TENGNOUPAL	-0.93	-8.09
TAMENGLONG	0.31	0.74
SENAPTY	1.25	10.54
PHERZWAL	1.25	18.76
NONEY	0.31	0.74
KANGPOKPI	0.31	0.74
KAMJONG	0.47	3.50
JIRIBAM	0.93	14.67

4.5 Spatial-temporal variation in annual ETo

It is clear from the fig 6 that mean ETo was found maximum in Bisnupur and Tengnoupal 1972.05-1916.59mm/period. While, Eto was minimum for the Imphal West and Imphal east 1581.07-1581.15mm/period. Similarly,

Tadesse *et al.,* (2021) observed maximum ETo around the extreme southern tip and extreme eastern tip region. Whereas smaller values were founded around western and southern part. The temporal variation of ETo was significant, the highest ETo value was recorded during dry season in March (4.61mm day-1) and the smallest in July during major rainy season. Lastly, Results of this study may literally help for designing purposes for engineers and irrigation practitioners in the absence of data.

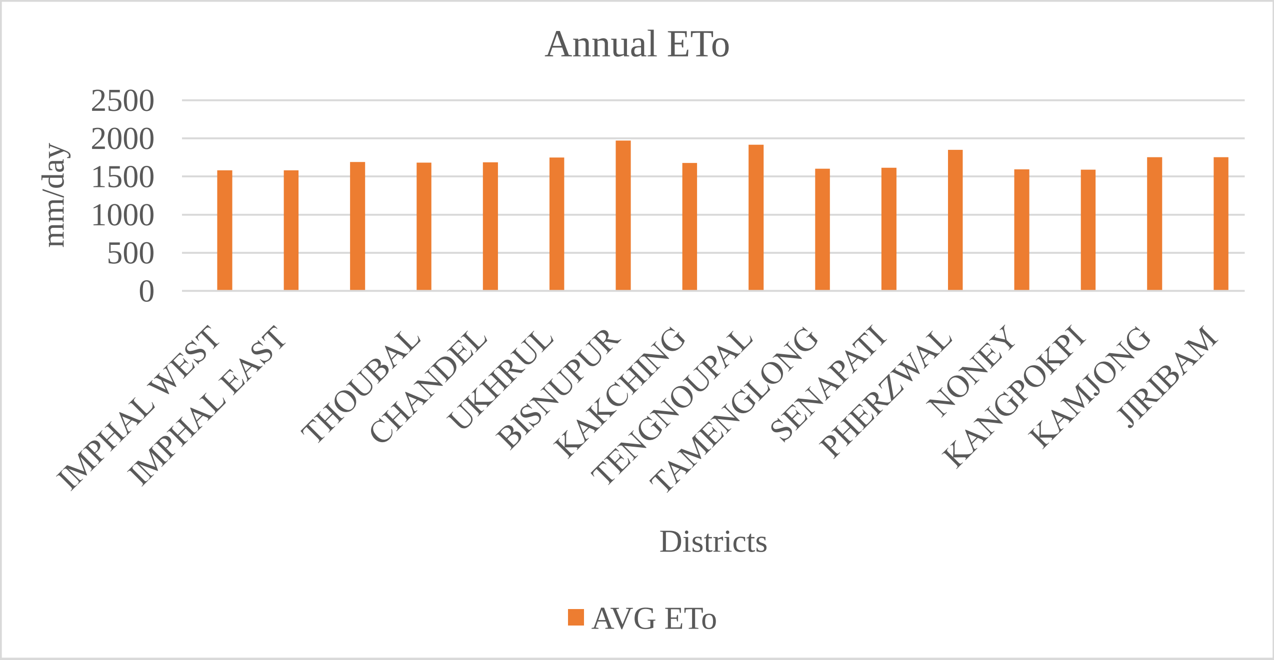


Fig 6: Variation in annual ETo (2011-2021)

4.5.1 Trend analysis in annual ETo

The Man-Kendall test results of annual ETo of different districts (Table 8) revealed that all the 16 districts showednon significant and 15 districts was positives trend except 1 districts Bisnupur has shown negative trends. The annual T max, T min and rainfall trends are mentioned in Table 2, 3, 4. There is non-significant trend in minimum temperature, maximum temperature. It may be observed that there is similar pattern in T max and ETo trends, which may be one of the factors for non-significant ETo in combination with other parameters such as solar radiation. Similarly,

Jhajharia*et al.,* (2011) showed significantly decrease of ETo at annual and seasonal time scales for 6 sites in NE India and NE India as a whole. The seasonal decreases in ETo have, however, been more significant in the pre-monsoon season, indicating the presence of an element of a seasonal cycle. The decreases in ETo are mainly attributed to the net radiation and wind speed, which are also corroborated by the observed trends in these two parameters at almost all the times scales over most of the sites in NE India. The steady decrease in wind speed and decline in net radiation not only balanced the impact of the temperature increases on ETo, but may have actually caused the decreases in ETo over the humid region of northeast India.

Table 8: Trend analysis for annual ETo

Districts	Zc	Qi
IMPHAL WEST	0.62	3.80
IMPHAL EAST	0.78	3.89
CHURACHANDPUR	0.31	3.01
THOUBAL	0.31	3.82
CHANDEL	0.47	3.92

UKHRUL	0.62	6.54
BISNUPUR	-0.62	-3.36
KAKCHING	0.47	6.08
TENGNOUPAL	0.47	4.94
TAMENGLONG	1.09	6.46
SENAPTY	0.47	3.27
PHERZWAL	0.16	2.36
NONEY	0.62	3.79
KANGPOKPI	0.47	4.53
KAMJONG	0.62	6.43
JIRIBAM	0.16	4.37

4.6 Spatial-temporal variation in seasonal ETo

This fig 7 shows changes in the average ETo for each season across the 16 districts of Manipur from 2011 to 2021. Seasons are defined as follows: monsoon (June, July, August), post-monsoon (September, October, November), winter (December, January, February) and pre-monsoon (March, April, May). It is clear from the table that ETo was minimum for all the seasons in Tamenglong district i.e., Post-monsoon (204.3mm/period), winter(271.5mm/period), Monsoon (345.4mm/period) and Summer(455.9mm/period). While, maximum ETo for monsoon was found in Ukhrul (676mm/period). Similarly, maximum ETo for post-monsoon,summer and winter was found in Bisnupur i.e., (236.6mm/period), (680.2mm/period)and (360.6mm/period)

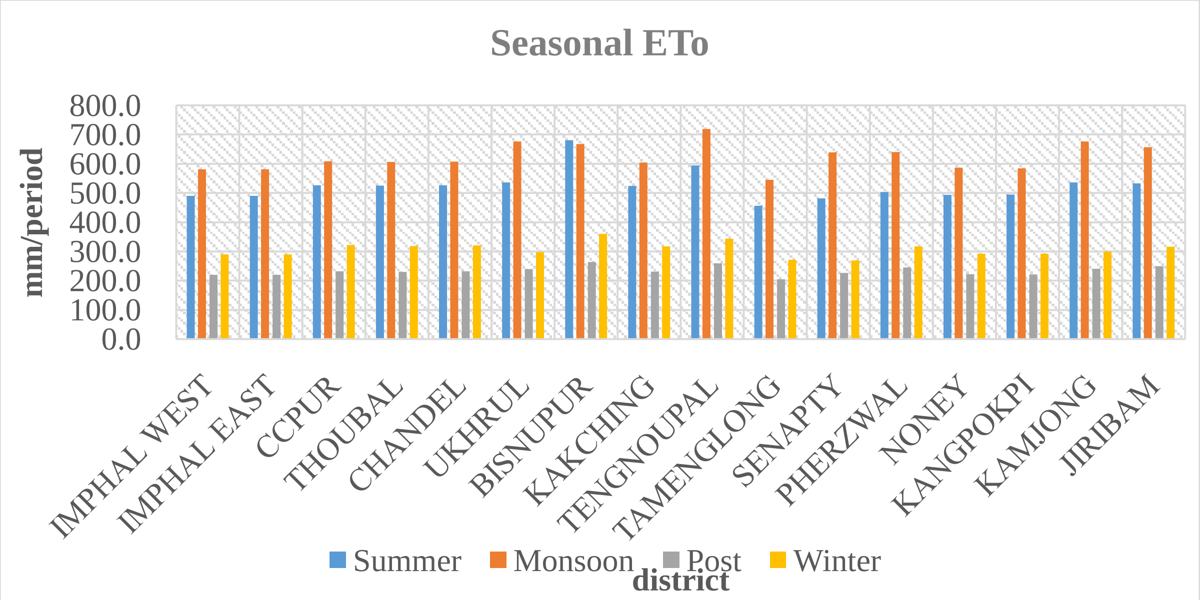


Fig 7: Variation in seasonal ETo

4.6.1 Trend analysis of winter and Post-monsoon ETo

Table 9: Trend analysis of winter and post monsoon ETo

Districts	Winter		Post-Monsoon		
	Zc	Qi	Zc	significance	Qi
IMPHAL WEST	0	0.02	1.56		2.09
IMPHAL EAST	0	0.03	1.56		2.09
CHURACHANDPUR	0	0.19	0.31		0.27
THOUBAL	0	0.28	0.31		0.37
CHANDEL	0.16	0.2	0.31		0.59
UKHRUL	0	-0.26	2.8	**	3.02
BISNUPUR	0	-0.33	0.31		0.38
KAKCHING	0.16	1.35	0.31		0.36
TENGNOUPAL	-0.16	-0.78	2.02	*	1.88
TAMENGLONG	-0.31	-1.59	0.31		0.18
SENAPTY	-0.62	-0.98	2.49	*	1.57
PHERZWAL	-0.31	-0.33	0.78		1.36
NONEY	0	0.06	1.71	+	2.09
KANGPOKPI	-0.31	-1.77	1.25		1.89
KAMJONG	0	0.14	2.8	**	2.99
JIRIBAM	-1.09	-0.79	1.87	+	2.14

Table 9 indicated that the Z value of winter ETo was significantly negative and positive trends out of 16 districts of Manipur. 8 districts has shown negatives trends ranging -0.2mm/11 years to -1.7mm/11 years and rest all 8 districts has positivestrends ranging 0.2mm/11years to 1.35mm/11years. Similarly, for post-monsoon ETo results revealed that out of 16 districts,10 districts are shown non significance trends from ranging 0.18mm/11years to 2.09mm/11years while 6 districts are showed significance 0.1 level of significance,0.01 level of significance,0.050.01 level of significance trend ranging from 1.88 mm/11years to 30.2mm/11years.

Table 10: Trend analysis of winter and pre-monsoon ETo

Districts	Pre-monsoon		Monsoon		
	Zc	Qi	Zc	significance	Qi
IMPHAL WEST	0.31	1.23	1.56		2.08
IMPHAL EAST	0.31	1.23	1.56		2.08
CHURACHANDPUR	0.62	1.01	0.31		0.27
THOUBAL	0.62	0.78	0.31		0.37
CHANDEL	0.62	1.44	0.31		0.58
UKHRUL	0.31	1.39	2.80	**	3.02
BISNUPUR	-0.78	-1.27	0.31		0.38
KAKCHING	0.62	1.62	0.31		0.35
TENGNOUPAL	0.16	0.85	2.02	*	1.88
TAMENGLONG	-0.78	-6.10	0.31		0.18
SENAPTY	0.16	0.65	2.49	*	1.57
PHERZWAL	0.78	2.41	0.78		1.36
NONEY	0.16	1.20	1.71	+	2.09
KANGPOKPI	0.93	2.73	1.25		1.88
KAMJONG	0.16	1.04	2.80	**	2.98
JIRIBAM	0.47	0.80	1.87	+	2.14

Table 10 indicated that the Z value of pre-monsoon ETo wassignificantly positive and negative.The 2 districts has negative out of 16 districts with trend ranging from -1.27mm/11years to -6.10mm/11years. While, for monsoon ETo results revealed that all the 6 districts showed significantly 0.1 level of significance,0.01 level of significance,0.050.01 level of significance trend ranging from 3.02mm/11years to1.88mm/11years. But the rest 10 districts are shown non-significance trends out of 16 districts of Manipur

Farooq *et al.,* (2018) Overall trend in ET0 have been found to be minimum in January (winter) and then it gradually increases and reaches its peak value in July (summer) and then again decreases. 2. On annual basis it has found to be maximum in 2009 and minimum in year 1996 in Kashmir, where as in Ranichauri it has found to be maximum in year 1987 and min in 1990. An increasing trend has been witnessed in case of ET0 in seven months (January, March, June, July, October, November and December) at 5% significance level. In the month of September increasing trend was has been observed at 10% significance level. 4. Trend analysis on seasonal basis revealed that only ET0 (autumn and winter season) witnessed statistically significant increasing trends only at 5% level of significance 5.

4.7 Estimation of Crop water requirement for Rice

		Districts															
Month	**Stage**	**Imphal west**	**Imphal east**	**CCPUR**	**THOUBAL**	**CHANDEL**	**UKHRUL**	**BISNUPUR**	**KAKCHING**	**TENGNOUPAL**	**TAMENGLONG**	**SENAPTY**	**PHERZWAL**	**NONEY**	**KANGPOKPI**	**KAMJONG**	**JIRIBAM**
May	Nurs	1.35	1.35	1.44	0.72	1.44	0.74	1.90	0.71	0.84	0.67	0.67	0.75	0.65	0.67	0.74	1.46
May	Nurs/LPr	17.39	17.39	18.73	12.95	18.68	13.52	24.57	12.85	15.05	12.24	12.35	13.33	12.18	12.32	13.52	19.23
May	Nurs/LPr	63.79	63.79	68.42	68.17	68.23	72.74	90.49	67.70	80.12	64.75	66.71	71.42	64.37	64.82	72.67	70.62
		82.53	**82.53**	**88.58**	**81.84**	**88.35**	**86.99**	**116.96**	**81.25**	**96.00**	**77.65**	**79.73**	**85.50**	**77.21**	**77.81**	**86.93**	**91.31**
Jun	Init	56.29	56.29	60.15	59.70	59.93	65.43	81.48	59.38	71.32	57.01	60.40	63.79	56.62	56.64	65.35	62.28
Jun	Init	55.69	55.69	59.29	59.04	59.03	66.25	81.70	58.78	71.45	56.63	61.36	64.12	56.24	55.97	66.13	61.69
		111.98	**111.98**	**119.45**	**118.74**	**118.95**	**131.67**	**163.18**	**118.16**	**142.76**	**113.64**	**121.76**	**127.91**	**112.85**	**112.61**	**131.47**	**123.97**
Jun	Deve	55.04	55.06	58.42	58.15	58.21	64.95	74.28	57.94	70.25	55.95	60.78	64.42	55.55	55.27	64.87	61.68
Jul	Deve	55.39	55.43	58.64	58.32	58.46	64.90	66.21	58.15	70.52	56.25	61.44	66.21	55.81	55.55	64.84	62.93
Jul	Deve	55.84	55.89	58.95	58.68	58.86	65.33	59.75	58.55	71.29	56.75	62.59	68.20	56.29	55.98	65.27	64.30
		166.26	**166.38**	**176.01**	**175.15**	**175.54**	**195.18**	**200.24**	**174.64**	**212.06**	**168.95**	**184.81**	**198.83**	**167.65**	**166.80**	**194.98**	**188.91**

Jul	Mid	62.06	62.10	64.97	64.75	64.91	72.66	64.40	64.44	78.97	63.08	69.80	76.06	62.59	62.34	72.65	71.03
Aug	Mid	55.98	56.01	58.02	57.92	58.00	65.42	56.74	57.47	70.71	56.97	63.00	68.64	56.57	56.38	65.41	63.50
Aug	Mid	55.34	55.34	56.73	56.65	56.78	64.27	53.94	56.09	69.14	56.28	62.09	67.73	55.92	55.79	64.30	62.23
Aug	Mid	59.58	59.57	61.50	61.38	61.51	69.64	59.03	61.03	75.05	60.54	66.64	72.95	60.17	60.03	69.71	67.49
		232.96	**233.02**	**241.22**	**240.71**	**241.20**	**271.99**	**234.10**	**239.03**	**293.87**	**236.87**	**261.53**	**285.38**	**235.25**	**234.54**	**272.06**	**264.25**
Sep	Late	52.76	52.74	54.76	54.82	54.86	62.28	53.07	54.80	67.36	53.66	58.97	64.73	53.35	53.19	62.39	60.27
Sep	Late	49.76	49.75	51.96	52.15	52.07	59.34	50.78	52.38	64.35	50.65	55.64	61.23	50.41	50.26	59.47	57.28
Sep	Late	46.09	46.08	48.30	48.38	48.34	54.38	49.22	48.60	58.67	46.90	51.13	56.58	46.68	46.52	54.53	53.05
Oct	Late	21.51	21.51	22.67	27.10	22.65	30.07	24.27	27.25	32.17	26.21	28.31	31.56	26.09	26.00	30.18	24.82
		170.13	**170.07**	**177.7**	**182.45**	**177.92**	**206.07**	**177.35**	**183.04**	**222.55**	**177.43**	**194.05**	**214.10**	**176.5**	**175.97**	**206.57**	**195.42**
Total		**763.85**	**763.96**	**802.9**	**798.91**	**801.94**	**891.93**	**891.83**	**796.07**	**967.26**	**774.55**	**841.89**	**911.69**	**769.4**	**767.74**	**891.99**	**863.85**

Table 11: Crop water requirement for Rice

The most significant cereal crop in the world is rice (Oryza sativa). Water use for agriculture is increased by poor soil and water management techniques. Understanding the water management techniques that optimize the use of water for agriculture is essential, as are adopting techniques that increase water use effectiveness in crop production. Agricultural crops are widely grown under rainfed conditions in tropical regions, which improves water use efficiency. Typically, farmers don't have an effective irrigation plan. They literally have no idea when and how much water are required to irrigate their crops, let alone how much agricultural output may be boosted by efficient irrigation. Therefore, it is essential to understand how much water is needed by the crops in various regions in order to increase water use efficiency.

The sowing period of rice in Manipur is May to august as per different literature. In the study 3 July has been selected as sowing date for rice crop in Manipur. Table 11 showed the crop water requirement of rice (2011-2021) showed that highest amount of water is required during mid stage of crop in the month of August. Among the different districts of Manipur , Noney districts has the lowest amount of crop water requirement (77.21mm) and highest amount of water is needed by crop grown in Tengnoupal district (293.87mm).

It is being seen from the Table no.11 that in Nursery stage of crop (May) highest crop water requirement was found in Bisnupur (116.96mm) while lowest was found is Noney (77.21mm). in initial stage of crop (June) highest crop water requirement was found in Bisnupur (163.18mm) while the lowest was found in Imphal west and Imphal east (111.98mm). In development stage of crop (July) highest crop water requirement was found in Imphal west (166.26mm) while lowest was found in Tengnoupal (212.06mm). in mid stage of crop (July,August) highest crop water requirement was found in Tengnoupal (293.87mm) while lowest was found in Imphal west (232.96mm). In late stage of crop (September,October) highest crop water requirement was found in Tengnoupal (222.55mm) and lowest was found in Imphal east (170.07mm).

4.7.1 Trend analysis of Cop water requirement of Rice

The trend results of crop water requirement for Rice crop in different districts of Manipur has been showed in Table 12. The Z value of CWR showed negative and positive trend for all the 16 districts of Manipur.total 14 districts are shown positive trends from 2.84mm/11 years to 0.56/11 years and the rest of 2 districts Bisnupur and Pherzwal has shown negative trends from -0.60mm/11years to -6.60mm/11years . This is similar to the trend of ETo for Manipur. Similarly, **Lolhande*et.al.*, (2017)** observed that the for Akola district of Maharashtra for duration 2005-2014. Here also monthly and seasonal ETo has showed decreasing trend with futuristic decrease in CWR.

Districts	Zc	Qi
IMPHAL WEST	0.31	2.84
IMPHAL EAST	0.31	2.84
CCPUR	0.62	2.55
THOUBAL	0.62	2.37
CHANDEL	0.78	2.66
UKHRUL	0.62	2.65
BISNUPUR	-1.09	-6.60
KAKCHING	0.62	2.29
TENGNOUPAL	0.31	0.75
TAMENGLONG	0.31	2.49
SENAPTY	0.47	1.30

PHERZWAL	-0.31	-0.60
NONEY	0.31	2.39
KANGPOKPI	0.00	0.56
KAMJONG	0.62	2.66
JIRIBAM	0.31	2.13

Table 12: Annual trend of CWR of rice for duration 2001-2021

CONCLUSION

The finding of this study also revealed that a particular crop grown in different 16 districts will require different amount of water due to varying ETo of those districts. It may also be stated that in a particular district selection of crop should be made on the basis of its CWR and ETo of the district. Water use for agriculture in Manipur is increased by poor soil and water management techniques. Understanding the water management techniques that optimize the use of water for agriculture is essential, as are adopting techniques that increase water use effectiveness in crop production.In order to save water and meet crop water requirement, farmers can use the study's findings as a guide when deciding how frequently and how much to irrigate the crops that are the subject of the study. The findings of this study need to be verified in other climatic conditions, especially in arid climates where ETo variations are crucial for water management of cultural crops

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