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Research Paper

Climatic trends and its impact on reference evapotranspiration and crop water requirement of rice crop in Arunachal Pradesh, India

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ABSTRACT

Arunachal Pradesh in one of the largest states in north eastern states of India, having subtropical humid climate influenced by monsoon. An attempt has therefore, been made to understand the climatic conditions of the state and its influence on the reference evapotranspiration (ETo) and crop water requirement (CWR) of rice crop, using 21 years (2001-2021) data of 14 districts of Arunachal Pradesh. The results revealed that the maximum temperature varied from 13^0C to 30^0C while minimum temperature varied from 3^0C to 20^0C and annual rainfall varied from 1200 mm to 2700 mm across the state. The maximum temperature was found to decrease while the minimum temperature and rainfall were found to increase with varying significant levels in different districts. The mean annual reference evapotranspiration (ETo) was found to vary between 900 mm and 1400 mm. The crop water requirement of rice estimated using CROPWAT model revealed a large spatial variation from 508 mm to 731 mm in different districts of the state.

***Keywords*:** CROPWAT model, Reference evapotranspiration, Mann–Kendall test, Trend analysis, Crop water requirement, Arunachal Pradesh.

Rice (*Oryza sativa*), one of the main food crops, stands out for its size and ability to adapt to a wider variety of edaphic, climatic, and cultural conditions. Approximately 90% of rice is grown in tropical and subtropical Asia, home to 60% of the world's population (Anonymous, 2013). India is the world's second-largest producer of rice, after China, with 44.6 million hectares under rice cultivation. From deep water to high heights, rice can be produced in a variety of environmental circumstances. Since rice is a tropical and subtropical plant, it needs temperatures between 20 and 40^oC and high temperatures have a negative impact on crop. Evaporative transpiration accounts for the majority of the water lost in agriculture, which currently uses the most water worldwide. Both water and energy balance depend on evapotranspiration, which is a crucial step in both processes. The reference evapotranspiration describes the evaporative demand of the atmosphere independent of crop type, crop development and management practices. Bijlwan *et al.,* (2024) used various machine learning techniques to estimate reference evapotranspiration.

The reference evapotranspiration (ETo) plays an important role in estimating net irrigation requirement of crops for agricultural planning, irrigation scheduling, regional water balance studies and agro-climatic zoning and hence, accurate estimate of ETo is a key component in hydrological studies. By applying a crop coefficient (Kc) value, this ETo can be used to estimate the crop evapotranspiration (ETc) (Mehta and Pandey 2015). The crop coefficient is obtained with respect to type of plant, maturity of the plant and local factors such as soil type (Rawat *et al.,* 2019). The adaptation of exact correct amount of water and correct timing of application is very essential for scheduling irrigations to meet the crop's water use demands and for optimum crop production. In view of the above, this study has been attempted to investigate the trend of climatic variables and their impact on ETo and crop water requirement of rice crop in Arunachal Pradesh.

MATERIALS AND METHODS

Arunachal Pradesh is located in northeastern India, bounded by latitudes of 26°30'N and 29°31'N and longitudes of 91°30'E to 97°30'E. The study was carried out in 14 Arunachal Pradesh districts. The Himalayan system and altitudinal fluctuations are the main contributors to the state's climate. The eastern half

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of the country experiences extremely hot and humid weather at lower elevations, as well as in the valleys covered in lush, swampy vegetation. At higher elevations, the temperature drops dramatically. With more than 3500 mm of rain falling there in a year, Arunachal Pradesh has some of the nation's heaviest rainfall.

Data collection

Twenty-one years (2001-2021) of meteorological data like maximum temperature, minimum temperature, rainfall, relative humidity, sunshine duration, wind speed and crop Kc value were collected from ICAR Research Complex for NEH Region, Basar Centre, Lepa Rada, Arunachal Pradesh and KVK, Geku, Upper Siang, Arunachal Pradesh.

Estimation of ETo and ETc

The FAO-CROPWAT model was used to estimate reference evapotranspiration (ETo) and crop evapotranspiration (ETc) or crop water requirement (CWR). The CROPWAT software uses the Penman–Monteith (PM) method to calculate reference evapotranspiration based on the input of climate parameters. Crop evapotranspiration under standard conditions (ETc) which denotes 'the amount of water lost through evapotranspiration' is identical in value to crop water requirement (CWR) which is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field' (Allen *et al.,* 1998).

The crop water requirements (CWR) are calculated as:

ETc = Kc × ETo

Where; Kc- crop coefficient; ETc-crop evapotranspiration; ETo-reference evapotranspiration.

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 coefficient data over the different development stages for rice as presented in Table 1.

Trend analysis

The Mann-Kendall test (Kendall 1975; Mann 1945) is the rank based nonparametric test for assessing the significance of a trend. This method has been used widely across the world to detect trend in climatic and other hydrological variables (Swami, 2024; Zhao *et al.,* 2014).

It is based on the test statics S defined as

where, x1, x2, … xn represent n data points where xj represents the data point at time j.

Table 1: Crop coefficient (Kc) of rice

Crop stages	Crop coefficients
Nursery	1.20
Land prep	1.05
Initial	1.10
Development	1.20
Late	1.05

Sen's slope estimator test

The magnitude of a trend in a time series can be determined using a nonparametric method known as Sen's estimator (Sen, 1968). To estimate the true slope of an existing trend such as amount of change per year, Sen's nonparametric method is used and the test has been performed using XLSTAT 2017 software. A positive value of Sen's slope indicates an upward or increasing trend and a negative value gives a downward or decreasing trend in the time series.

RESULTS AND DISCUSSIONS

Trend analysis

The preliminary data analysis was carried out to find the trend of annual maximum temperature, annual minimum temperature and annual rainfall series for the period 2001-2021. The results of MK test are presented in Table 2. The falling trend in maximum temperature for all the districts where, Anjaw, Lohit and Tirap district showed significant at 5% level, Significant decreasing trends showed in Upper Siang and West Siang at 10% level of significance. Whereas, Changlang, Lower Dibang valley, Siang and Upper Subansiri showed significant decreasing trend with the level of 15% of significance. It indicated a rising trend in minimum temperature for all the districts where, East Kameng, Lower Subansiri, Dibang Valley, Upper Siang, Upper Subansiri and West Siang showed significant at 1% level, Significant increasing trends showed in Changlang, Longding, Lower Dibang Valley, Papumpare, Siang and Tirap at 5% level of significance. Whereas, Anjaw and East Kameng showed significant decreasing trend with the level

Table 2: Results of maximum temperature (Tmax), minimum temperature (Tmin) and annual rainfall trend analysis using MK test.

Districts	Maximum temperature	Minimum temperature	Annual rainfall
Anzaw	-3.02**	2.08*	**4.14**
Changlang	-1.85+	2.71**	1.66+
East Kameng	-0.03	**3.44**	0.57
Lohit	-3.02**	2.07*	**4.20**
Longding	-1.09	2.68**	3.23**
Lower Dibang Valley	-1.95+	3.07**	**3.77**
Lower subansiri	-1.22	**3.83**	3.05**
Papumpare	-0.7	2.89**	2.63**
Siang	-1.95+	3.07**	**3.77**
Tirap	-2.58**	2.63**	3.05**
Dibang Valley	-1.89+	**3.87**	2.99**
Upper Siang	-2.5*	**3.68**	2.93**
Upper Subansiri	-1.92+	**3.38**	**3.41**
West Siang	-2.11*	**3.8**	2.93**

Significant trends at 1 % indicated by bold numbers, significant trends at 5 % indicated by **, significant trends at 10 % indicated by *, significant trends at 15% indicated by +

of 10% of significance. An increasing minimum temperature will support the global warming causing climate change (Kharmeshu, 2012). This suggests that temperature trend shows rising and due to this rising temperature, other climatic variables may experience affected in the hydrologic processes and surrounding environment (Rao, 1993).

The rising trend in annual rainfall for all the districts except for East Kameng. Where, Anjaw, Lohit, Lower Dibang valley, Siang and Upper Subansiri showed significant at 1% level, Significant increasing trends showed in Longding, Lower Subansiri, Papumpare, Tirap, Dibang valley, Upper Siang and West Siang showed at 5% level of significance. Whereas, Changlang showed significant increasing trend with the level of 15% of significance. An increasing precipitation will result in more water availability for the crops.

Spatial distribution of climatic parameters

The spatial distributions of maximum temperature, minimum temperature, rainfall and ETo from 2001 to 2021 were shown in Fig. 1, and their difference was displayed using the IDW interpolation. The results show strong variability in 14 districts. From the visual inspection, it was observed that the spatial pattern of high and low values of max temperature, min temperature, rainfall and annual ETo and the difference all shows similarities to other time scales. The average minimum and maximum valves of temperature were found to be 2.8^{0}C in Dibang Valley and 29.4^{0}C in Longding. That amount of annual rainfall was found lowest for Dibang Valley 1176 mm. While, Upper Subansiri and West Siang received the highest annual rainfall 2505-2705 mm. Similarly, annual average ETo was found minimum in Changlang and Lower Dibang Valley 910-951.9mm/period. While, annual ETo was maximum for the Longding 1401.1mm/period respectively.

Annual and seasonal trend in ETo

Table 3 enlists significant decreasing trend in annual and seasonal scale obtained from Mann–Kendall test and Sen's slope estimator. Significant decreasing trends in annual ETo were observed in all the districts. The magnitude of decreasing trends in annual ETo values varied from -7.824 mm per year for West Siang to -3.346 mm per year for Changlang. Significant decreasing seasonal ETo trend was found mainly in monsoon and pre-monsoon season at all the districts. The magnitude of decreasing trend varied between -2.581 mm for Anjaw to 1.086 mm per year for East Kameng in monsoon season and magnitude of decreasing trend varied between -2.822 mm per year for West Siang to -1.186 mm per year for East Kameng in pre-monsoon season. While, post-monsoon and Winter season showed significant decreasing trends for 12 districts except

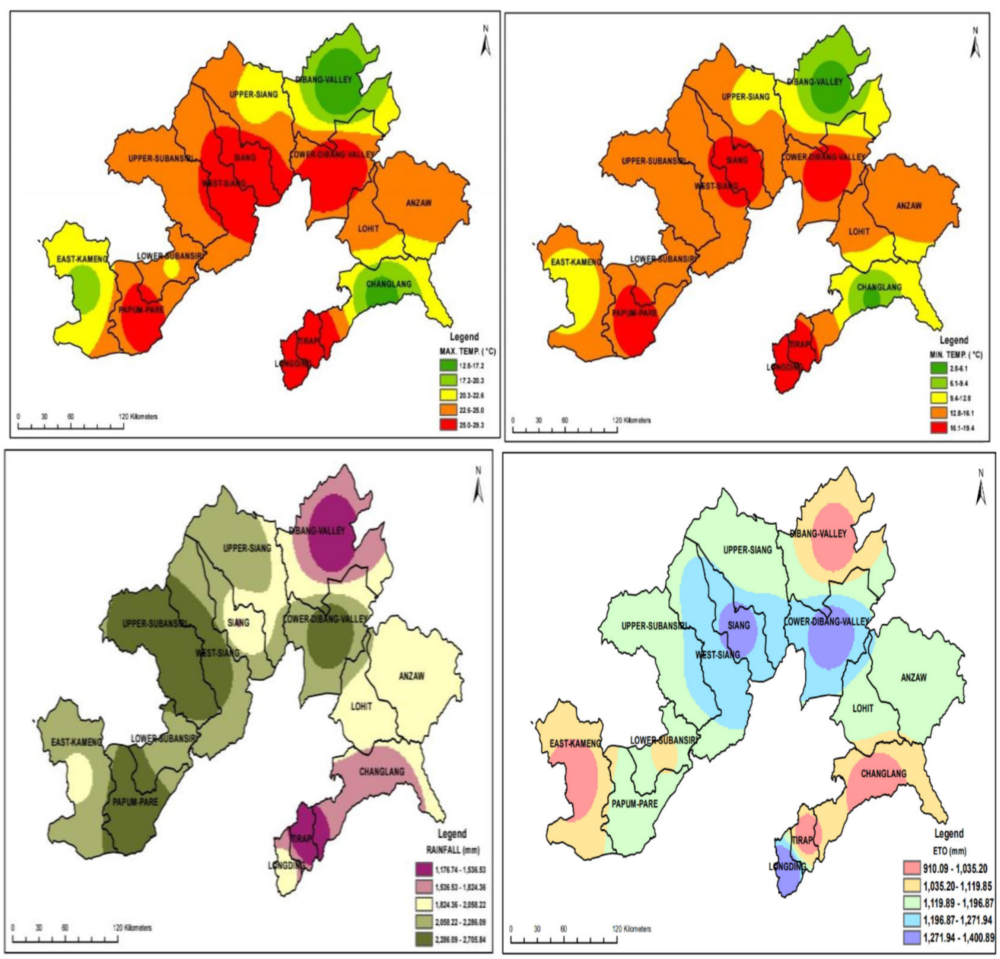

Fig. 1: Spatial distribution maximum temperature, minimum temperature, rainfall and ETo in Arunachal Pradesh, India

Table 3: Annual and seasonal trends in reference evapotranspiration (ET_o) in different districts of Arunachal Pradesh

Seasons	**Annual**		**Monsoon**		**Post-monsoon**		**Winter**		**Pre-monsoon**	
Districts	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
Anjaw	**-4.26**	-6.399	**-4.02**	-2.581	-2.63**	-0.810	-2.51*	-0.602	**-3.59**	-2.318
Changlang	-2.87**	-3.346	-2.02*	-1.086	-1.18	-0.369	-2.51*	-0.401	**-3.53**	-1.832
East Kameng	**-3.53**	-4.134	-1.90+	-1.180	-2.33*	-0.705	-2.33*	-0.419	-3.17**	-1.186
Lohit	**-4.26**	-6.416	**-4.08**	-2.571	-2.57*	-0.795	-2.45*	-0.616	-3.05**	-2.110
Longding	**-3.35**	-5.151	-2.87**	-2.107	-1.60	-0.958	-1.84+	-0.695	-2.87**	-2.022
L. D. Valley	**-4.08**	-5.563	**-3.38**	-2.490	-2.30*	-0.988	-2.24*	-0.533	-2.48*	-1.753
L. Subansiri	**-4.08**	-6.079	-3.11**	-2.013	-2.51*	-0.056	-2.75**	-0.865	**-3.41**	-2.025
Papumpare	**-3.77**	-5.792	-3.05**	-1.869	-3.11**	-0.985	-2.87**	-0.742	-2.87**	-2.125
Siang	**-4.14**	-5.912	-3.17**	-1.889	-2.63**	-1.122	-1.60	-0.513	-2.63**	-2.045
Tirap	**-3.96**	-7.89	-3.17**	-2.36	-2.93**	-1.24	**-3.90**	-1.55	**-3.77**	-2.57
D. Valley	**-4.20**	-3.786	**-3.53**	-1.517	-2.39*	-0.629	-1.57	-0.433	**-3.84**	-1.456
U. Siang	**-3.84**	-6.668	**-3.53**	-2.178	-2.93**	-1.516	**-3.56**	-0.971	**-4.08**	-2.235
U. Subansiri	**-4.20**	-6.920	-2.69**	-2.069	-2.87**	-1.448	**-3.53**	-1.074	**-3.90**	-2.641
W. Siang	**-4.14**	-7.824	**-3.59**	-3.009	-3.08**	-1.501	-2.68**	-0.869	**-3.41**	-2.822

Significant trends at 1 % indicated by bold numbers, significant trends at 5 % indicated by **, significant trends at 10 % indicated by *, significant trends at 15% indicated by +

Table 4: Stage wise crop water requirement of rice in different districts of Arunachal Pradesh

Districts	Nursery + soil prep	Initial stage	Development stage	Mid stage	Late stage	Total ETc
Anjaw	85.3	89.0	138.4	171.3	163.1	647.1
Changlang	68.0	71.9	112.5	135.8	120.3	508.5
E. Kameng	69.7	73.1	114.5	140.6	127.6	525.5
Lohit	84.1	86.9	134.8	166.2	157.5	629.5
Longding	98.0	101.8	159.4	194.5	175.1	728.8
L.D. valley	97.7	100.5	156.0	193.3	184.0	731.5
L.Subansiri	77.2	80.1	124.8	155.0	146.0	583.1
Papumpare	80.7	82.6	126.1	155.0	151.0	595.4
Siang	96.6	99.4	154.5	191.7	182.7	724.9
Tirap	93.8	98.1	153.6	186.5	167.0	699.0
Dibang Valley	73.0	77.1	120.1	143.5	124.1	537.8
U. Siang	83.3	86.8	138.6	170.1	149.6	628.4
U. Subansiri	81.5	85.5	135.8	168.0	151.4	622.2
W. Siang	89.9	93.5	148.3	183.6	167.9	683.2

for Changlang and Longding in post-monsoon season and Siang and Dibang Valley for winter season.

Crop water requirement of rice

The rice evapotranspiration (ETc) is estimated 508.5 mm to 731.5 mm (with nursery and soil preparation phase) during the growth period of 170 days. Among the different districts Changlang showed the lowest amount of crop water requirement (508.5mm) and highest amount of water is needed by crop in Lower Dibang valley (731.5mm). In the nursery and preparation phase of the soil, water (68-98 mm) for irrigation is necessary. This is essential for wetting the soil before sowing the crop. It is being seen from the Table 4 that in Nursery stage of crop (June) highest crop water requirement was found in Longding (98mm) while lowest was found in Changlang (68mm). In initial stage of crop (July) highest crop water requirement was found in Longding (101.8mm) while the lowest was found in Changlang (71.9mm). In development stage of crop (July, August) highest crop water requirement was found in Longding (159.4mm) while lowest was found in Changlang (112.5mm). in mid stage of crop (August, September) highest crop water requirement was found in Longding (194.5mm) while lowest was found in Changlang (135.8mm). In late stage of crop (October, November) highest crop water requirement was found in Lower Dibang Valley (184mm) and lowest was found in Changlang (120.3mm) as presented in Table 4.

CONCLUSION

The trend analysis of temperature and rainfall of Arunachal Pradesh revealed that the maximum temperature is decreasing while minimum temperature and rainfall is increasing with different levels of significance in different districts of the state. Rice crop grown in different districts of Arunachal Pradesh will require different amount of water due to varying climatic parameters and ETo of those districts. The information regarding the temporal and spatial variation of crop water requirement which will be useful in irrigation scheduling and efficient crop water management in the state.

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