E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; SP-8(8): 483-487
Received: 09-05-2025
Accepted: 11-06-2025

Neethu RS
College of Agricultrure, Vellayani, Kerala, India

Brigit Joseph
College of Agricultrure, Vellayani, Kerala, India

Ajith K
Regional research station, Kumarakom, Kerala, India

Corresponding Author:
Neethu RS
College of Agricultrure, Vellayani, Kerala, India

Climate change assessment and its impact on paddy production in Kottayam district of Kerala

Neethu RS, Brigit Joseph and Ajith K

DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i8Sg.3646

Abstract
The present paper analysed climate change overtime occurred for a period of 30 years in Kottayam district of Kerala and its impact in productivity of paddy. Trend analysis was performed using non-parametric Mann-Kendall test and Sen's slope estimator for annual and different seasons. The results indicated a significant decreasing trend in annual and north east monsoon rainfall with an increase in north east and south west monsoon maximum temperature. For minimum temperature a negative trend was noticed for all seasons except summer and winter. Multiple linear regression performed to determine the impact of climate change in the paddy production showed maximum temperature in August, minimum temperature in June had positive and significant effect on Virippu paddy production in Kottayam. While the rainfall during July had a negative significant effect, indicated that excess rainfall during July adversely affect the paddy production during Virippu season. However, maximum and minimum temperature during October had a positive significant effect on the production of Paddy for the Puncha crop. Excess rainfall during October and November had a negative significant effect on Paddy production. High temperature especially night temperature have a positive impact on paddy during it's vegetative phase and excess rainfall have negative impact during reproductive phase of the crop.

Keywords: Maximum temperature, minimum temperature, Mann-Kendall test, Sen's slope estimator

Introduction

Climate change is an important problem that directly or indirectly affects the livelihood of the farmers as agricultural activities are impossible under such circumstances. Indian agriculture has been historically considered as a gamble with monsoon because the agricultural activity in most of the parts of the country depends mainly on monsoon. Apart from rainfall, temperature is also an important weather parameter which has substantial influence on the productivity of most of the crops. Generally, paddy cultivation in Kerala takes place during three major seasons *viz*., Virippu (autumn) coincides with south west monsoon (June – September), Mundakan (winter) corresponds to North east monsoon (October – January) and Puncha (summer) during March to May. Kuttanad region is the one of the major rice growing tracts in Kerala which spreads in three districts namely Kottayam, Alappuzha and Pathanamthitta. The land is located 2 – 3 m below MSL, which is one of the few places in the world where farming is practiced 2.5 to 3 meters below sea level. Paddy fields in Kuttanad are known by the name "Punchavayal" and are distributed in three types of land: Karappadam (upland rice), Kayal (wetland rice) and Kari. However, saltwater intrusion from the Vembanad Lake restricts the paddy cultivation in all the three seasons in this region. So, crops are raised only in two season's *viz*., Virippu (additional crop) during May-June to Aug-Sep and Puncha crop during Oct-Nov to Dec- Jan. In Kuttanad, 80 percent of the paddy fields are sown during the *puncha* season and 40 percent of the paddy lands are cultivated in *virippu* season.

Several studies reported that weather parameters including temperature and rainfall have significant influence yield performance of paddy at various phases such as flowering, panicle initiation, *etc*. An attempt has been made here to analyse the change in weather parameter using the meteorological data and to delineate the impact of weather parameters on the production of paddy in Kottayam districts.

Materials and Methods

Secondary monthly data on major weather parameters such as maximum temperature, minimum temperature and rainfall from Regional Agricultural Research Station (RARS), Kumarakom for a period from 1991 to 2020 and area and production data of paddy from Kottayam were used for the study. Mann-Kendall test was used to test the significance of trend and for determining magnitude of trend, non-parametric Sen's estimator was used (Mann, 1945; Kendall, 1975) [2, 1]. It assumes the null hypothesis of no trend versus the alternative hypothesis of the existence of monotonic increasing or decreasing trend of a time series data. The non-parametric Mann-Kendall test will be appropriate where the monotonic nature of trend should be followed *i.e.*, mathematically the trend consistently increasing and never decreasing or consistently decreasing and never increasing and no seasonal or other cycle is present. Two type of test statistics are used in this test depending upon the number of data values *i.e.*, S – statistics and Z – statistics, S- statistic used if the number of data values are less than 10 whereas Z- statistic used (normal approximation/distribution) if the data points are more than or equal to 10 (Salmi *et al.*, 2002) [3].

In MK test the S – Statistics can be calculated by:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \quad (1)$$

where x_i and x_j are annual values in the year i and j, $j > i$ respectively, n is the number of data points, and $sgn\ (x_j - x_i)$ is calculated using the equation

$$sgn(x_j - x_i) = \begin{cases} 1\ if\ x_j - x_i > 0 \\ 0\ if\ x_j - x_i = 0 \\ -1\ if\ x_j - x_i < 0 \end{cases} \quad (2)$$

A positive or negative value of S indicates an upward (increasing) or downward (decreasing) trend. When the number of observations is 10 or more, the S statistics is approximately distributed as normal with the mean and variance given by

$$E(S) = 0,\ V(S) = \frac{n(n-1)(2n+1) - \sum_{i=1}^{n} t_i(t_i-1)(2t_i+5)}{18}$$

where, n is the number of tied (zero difference between compared values) groups and t_i the number of data points in the i^{th} tied group. Therefore, the Z test statistic is defined as follows

$$z = \begin{cases} \frac{s-1}{\sqrt{var(s)}}\ if\ s > 0 \\ 0 \qquad if\ s = 0 \\ \frac{s+1}{\sqrt{var(s)}}\ if\ s < 0 \end{cases} \quad (3)$$

Statistically the significance of trend is assessed by the Z-value. A positive value of Z shows an upward (increasing) trend while the negative value indicates a downward (decreasing) trend.

The Sen's slope estimator provides a linear model for the trend analysis. The slope (Ti) of all data pairs is calculated using equation

$T_i = \frac{x_j - x_i}{j-k}$, where, x_i and x_j are data values at time k and j ($j > k$). The median of these n values of T_i is represented as the Sen's slope estimate for trend (true slope) using equation

$$Q_i = \begin{cases} T_{\frac{n+1}{2}} \qquad for\ n\ is\ odd \\ \frac{1}{2}\left(T_{\frac{n}{2}} + T_{\frac{n+1}{2}}\right) for\ n\ is\ even \end{cases} \quad (4)$$

Sen's estimator (Q_i) is calculated using the equation depending upon the value of n as it is either odd or even and then (Q_i) is computed using 100 (1 – α)% confidence interval using non-parametric test depending upon a normal distribution. A positive value indicates an increasing or upward trend while a negative value shows a downward or decreasing trend for a time series data.

Multiple linear regressions were performed to detect impact of climate change on the production paddy in two seasons and the production was taken as the dependent variable in multiple linear regression and the parameters are estimated using OLS.

For paddy as additional crop the model defined will be:

$$ln\ ln y_t = ln\ ln M_{1t} + ln\ ln M_{2t} + ln\ ln M_{3t} + ln\ ln N_{1t} + ln\ ln N_{2t} + ln\ ln N_{3t} + ln\ ln R_{1t} + ln\ ln R_{2t} + \ ln\ ln R_{3t} + \varepsilon_t \quad (5)$$

where,

y_t is production of paddy in t^{th} period, M_{1t} is maximum temperature during June in t^{th} period, M_{2t} is maximum temperature during July in t^{th} period, M_{3t} is maximum temperature during August in t^{th} period, N_{1t} is minimum temperature during June in t^{th} period, N_{2t} is minimum temperature during July in t^{th} period, N_{3t} is minimum temperature during August in t^{th} period, R_{1t} is rainfall during June in t^{th} period, R_{2t} is rainfall during July in t^{th} period, R_{3t} is rainfall during August in t^{th} period and ε_t is residual at t^{th} period

Similar regression model for the Puncha crop was also estimated by considering the production and weather variables during this period. For detecting multicollinearity variance inflation factor (VIF) of each variable was worked out using the following formula.

The variance inflation factor for the i^{th} variable is calculated as

$$VIF = \frac{1}{1 - R_i^2} \quad (6)$$

where R_i^2 is the coefficient of multiple regression of X_i on the remaining independent variables. If the VIF value is more than 10 for any independent variable, then there exists a serious multicollinearity between that particular independent variable to the remaining variables. Autocorrelation is defined as the correlation between successive terms in a series of observations which is ordered according to time or space. It relates to correlation between successive values of the same variable. The presence of autocorrelation may violate the assumption of ordinary regression and give rise to wrong interpretations. The common test used to detect autocorrelation is Durbin – Watson test and a DW statistic 'd' value of 2 suggests absence of autocorrelation.

Results and Discussion

The trend graph of (Fig. 1, Fig. 2 and Fig.3) annual rainfall, mean maximum temperature, minimum temperature gives the pattern of rainfall and temperature throughout the study period. The annual rainfall was highest during the year 1994 and lowest in the year 2016 and a declining trend was observed in annual and seasonal rainfall over the years (Table 1). While this region was receiving an annual rainfall of 2000 mm to 3000 mm. There was an increase in annual, and north east and south west monsoon maximum temperature and north east monsoon and south west monsoon temperature was found to be significant (Table 2). However, for minimum temperature an increase in trend was noticed for summer and winter seasons (Table 3).

The impact of weather parameters on the production of paddy in Kottayam in two seasons *viz;* virippu during the period May-June to Aug-September and puncha crop season from October-November to December-January for a period from 1995-96 to 2018-19 was estimated using OLS. A number of regressions models were estimated by taking logarithm of both or either dependent or independent and the best model was selected using R^2 and other model selection criteria. The estimated parameters of the best selected model in virippu along with VIF and Durbin-Watson statistics are presented in Table 4. The best estimated model was

$$lny_t = -75.620 + 7.131\, ln\, lnM_1 - 1.642\, ln\, lnM_2 + 15.923\, ln\, lnM_3 + 13.410\, ln\, lnN_1 - 16.501\, ln\, lnN_2 + 8.630\, ln\, lnN_3 - 0.005\, ln\, lnR_1 - 1.061\, ln\, lnR_2 - 0.005\, ln\, lnR_3 \quad (7)$$

It is evident from Table 4 that the estimated model has explanatory power of 61.2 percent only with DW statistic of 1.259. Moreover, VIF values less than 10 for all the independent variables underscore the absence of multicollinearity. The estimated coefficients of maximum temperature in August (15.92), minimum temperature in June (13.41) had positive sign and they are significant at 9 and 8 percent level of significance respectively establishing a positive effect of these two variables on virippu paddy production in Kottayam. In contrast, rainfall during July had a negative significant (10%) influence on production, emphasizing that excess rainfall during July was not a favourable condition for paddy production in virippu season in Kottayam district. Similarly, another regression model was estimated for puncha crop by considering the independent variables as maximum temperature, minimum temperature and rainfall during October, November and December and the dependent variable as production of paddy during *puncha* season without considering the effect of other influencing factors of production. The result of multiple regressions using OLS method is presented in Table 5 and the best estimated model was

$$lny_t = -12.997 + 0.298\, M_1 - 0.428\, M_2 + 0.405\, M_3 + 0.307\, N_1 + 0.155\, N_2 - 0.426\, N_3 - 0.003\, R_1 - 0.004\, R_2 + 0.003\, R_3 \quad (8)$$

As compared to the regression model in virippu season, model estimates for production of the puncha season provides an appealing result. The estimated model was sufficient to explain more than 70 percent variation by the explanatory variables and 'F' for the regression model was significant. The results presented in Table 6 clearly showed that maximum and minimum temperature during October had a positive significant effect on production of paddy in the puncha season while excess rainfall during October and November had a negative significant effect on puncha paddy production. The VIF value of all the independent variables was below 10 indicating the absence of multicollinearity between the independent variables. Durbin-Watson d-statistic value also indicated that there is no autocorrelation. The estimated R^2 value for the model was 0.797, indicating that 79.7 percent of variation in the dependent variable was explained by the independent variables by the regression. Susha (2011) [6] studied climate change impacts and adaptation strategies in paddy production and the study concluded that weather variables in Kerala had been changing which resulted in a shift from wetness to dryness. And the minimum temperature and rainfall had a negative growth rate and maximum temperature had a positive growth rate and particularly the maximum temperature and rainfall during the initial growth phase (first two months) of the crop in Kuttanad region exerting significant positive impact on yield while these variables during the second phase cause a decline in income.

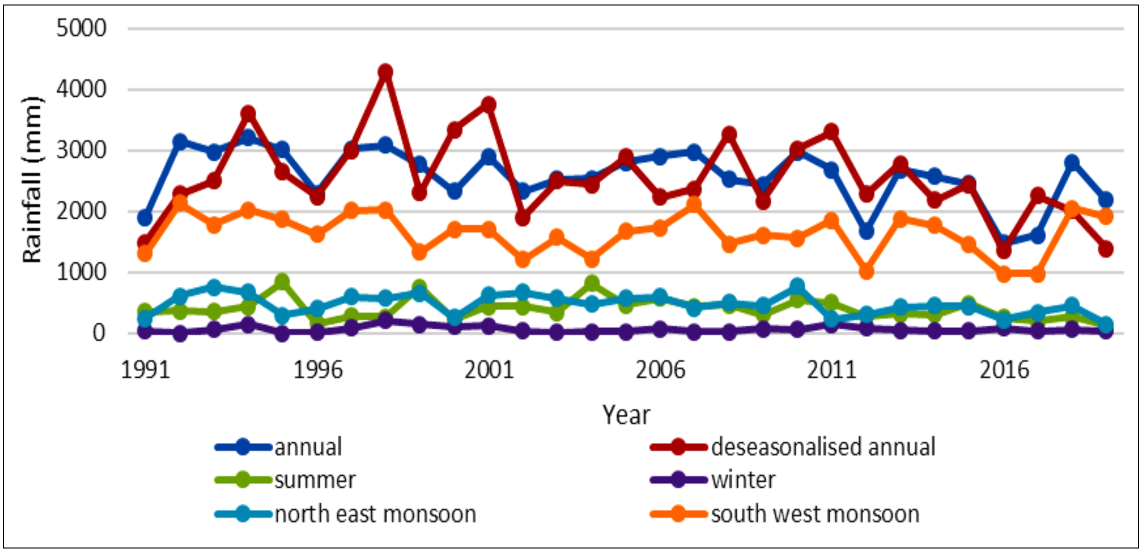

Fig 1: Trends in rainfall (mm)

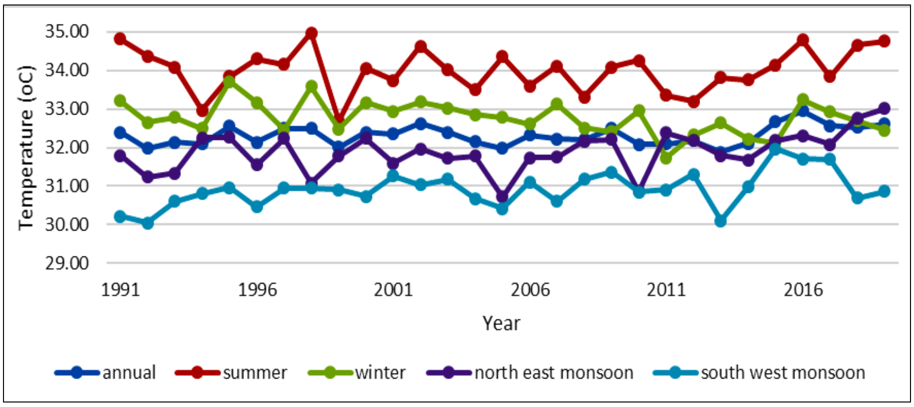

Fig 2: Trends in annual maximum temperature (° C)

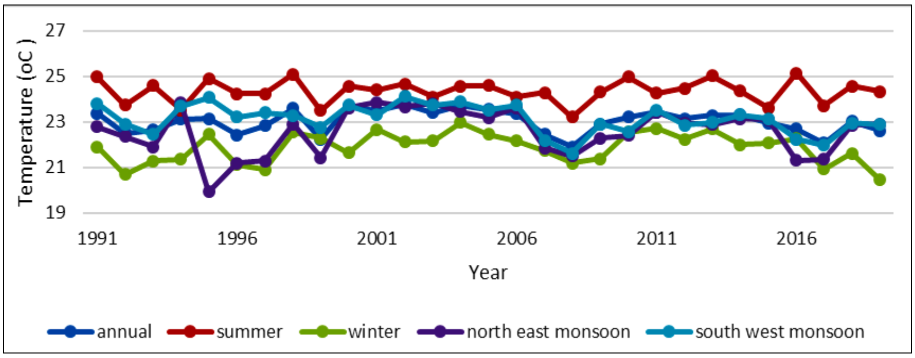

Fig 3: Trends in annual minimum temperature (° C)

Table 1: Results of MK test and Sen's slope estimator for rainfall

Season	Z- Value	P- Value	S	Tau	Sen's slope
Annual	-2.42	0.02*	-130	-0.32	-23.12
Deseasonalized Annual	-1.71	0.09*	-92	-0.23	-20.78
Summer	-1.41	0.16	-76	-0.19	-3.87
North east monsoon	-2.31	0.02*	-121	-0.30	-10.42
South west monsoon	-1.18	0.24	-64	-0.16	-0.03
Winter	0.28	0.78	16	0.003	0.50

Table 2: Results of MK test and Sen's slope estimator for Maximum temperature

Seasons	Z- Value	P- Value	S	Tau	Sen's slope
Annual	1.03	0.30	56	0.14	0.005
Deseasonalized Annual	1.26	0.21	68	0.17	0.006
Summer	-0.09	0.92	-6	-0.01	-0.001
North east monsoon	2.01	0.04**	108	0.27	0.03
South west monsoon	2.42	0.02**	130	0.32	0.03
Winter	-2.23	0.03**	-120	-0.30	-0.02

Table 3: Results of MK test and Sen's slope estimator for Minimum temperature

Seasons	Z- Value	P- Value	S	Tau	Sen's slope
Annual	-0.81	0.42	-44	-0.11	-0.01
Deseasonalized Annual	-0.84	0.40	-46	-0.11	-0.01
Summer	0.02	0.98	2	0.004	0.0001
North east monsoon	-0.02	0.98	-2	-0.004	-0.001
South west monsoon	-2.06	0.04**	111	-0.27	-0.03
Winter	0.45	0.65	25	0.006	0.006

Table 4: Result of Multiple regression for Production of paddy in Virippu season

Particulars	Regression Coefficient	Standard error	P value	t value	VIF
Intercept	-75.620	47.136	0.131	-1.604	
M1	7.131	7.702	0.370	0.926	2.632
M2	-1.642	13.492	0.905	-0.122	6.731
M3	15.923	8.798	0.092*	1.81	2.472
N1	13.410	7.1	0.080*	1.889	4.028
N2	-16.501	10.055	0.123	-1.641	8.681
N3	8.630	6.745	0.221	1.28	4.259
R1	-0.005	0.592	0.993	-0.009	1.835
R2	-1.061	0.567	0.082*	-1.872	3.622
R3	-0.005	0.395	0.989	-0.013	2.613
Number of observations		24			
F (9, 14)		2.456			
R^2		0.612			
Adj. R^2		0.363			
P – value		0.064			
Durbin-Watson d-statistic (9, 23)		1.259			

Table 5: Result of Multiple regression for Production of paddy in puncha season

Particulars	Regression Coefficient	Standard error	P value	t value	VIF
Intercept	-12.997	9.94	0.212	-1.308	
M1	0.739	0.298	0.02**	2.482	2.954
M2	-0.428	0.402	0.305	-1.065	4.364
M3	0.405	0.308	0.210	1.315	3.014
N1	0.307	0.154	0.066*	1.991	2.025
N2	0.155	0.132	0.260	1.173	3.574
N3	-0.426	0.153	0.015*	-2.784	3.153
R1	-0.003	0.001	0.014**	-2.797	1.996
R2	-0.004	0.001	0.028**	-2.448	1.61
R3	0.003	0.003	0.353	0.961	1.482
Number of observations		24			
F (9, 14)		6.105			
R^2		0.797			
Adj. R^2		0.666			
P – value		0.001			
Durbin-Watson d-statistic (9, 23)		1.463			

Conclusion

The present paper analysed the change and trend in weather parameters and its impact on paddy production in the Kottayam district using the time series data of more than two decades. A negative trend in annual rainfall and an increasing trend in maximum temperature showed a clear picture of the climate change phenomenon happening as a part of modernization. The annual rainfall in Kottayam varied from 2000 mm to 3000 and the average monthly maximum temperature varied from 30.68° C to 35.5° C to 35.5 during the period. The results of multiple regression analysis indicated that maximum and minimum temperature during the initial period had a positive effect while excess rainfall had a negative impact on production of paddy in Kottayam district.

References

1. Kendall MG. Rank Correlation Methods. Oxford univ. Press; 1975. p. 202.
2. Mann HB. Nonparametric tests against trend. Econometrica. 1945;13:245-259.
3. Salmi T, Maatta A, Anttila P, Ruoho-Airola T. Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen'sSolpe Estimates the Excel Template Application makesens. Finnish Meteorological Institute; 2002. p. 35.
4. Sen PK. Estimate of regression coefficient based on Kendall’s Tau. J Am Statist Assoc. 1968;63(324):1379-1389.
5. Sonali P, Kumar DN. Review of trend detection methods and their application to detect temperature changes in India. J Hydrol. 2013;476:212-227.
6. Susha PS. Climate change impacts and adaptation strategies in paddy production. Thrissur: Kerala Agricultural University; 2011. p. 122.