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Impact of Climate Change on Banana Production in Thiruvananthapuram District of Kerala, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Global climate change has considerable implications in indian agriculture and hence food security and farmers livelihood. As a result there will be a threatened in food security. In this context, a study on "Impact of climate change on banana production in Thiruvananthapuram district of Kerala, India" was undertaken. The objective of the study was to quantify the impact of climate change on yield of banana in Thiruvananthapuram district of Kerala, India. The impact of climate change on banana

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production was quantified by using multiple linear regression model for Thiruvananthapuram district. Quarterly data on climatic variables such as temperature, rainfall, relative humidity and wind speed for a period of 31 years from 1991 to 2021 were taken as independent variables and that of production of banana from Thiruvananthapuram was taken as the dependent variable. To determine the growth trend and variability, CAGR and coefficient of variation were calculated for the area, production, productivity, and climatic variables. It showed that Q4 (October to December) temperature was positively influencing and significant at 1 per cent level of significance. This means that one per cent increase in temperature during Q4 will increase the production by 13.9 per cent and one per cent increase in rainfall during Q4 will increase the production of banana by 0.42 per cent due to optimum temperature and rainfall. Positive trend in the growth of area (5.35 per cent per annum) and production (2.86 per cent per annum) were observed in spite of having a negative trend in productivity (-2.36 per cent per annum). The impact of climate change has positive effect on banana production in Thiruvananthapuram district. Increase in Q4 temperature resulted in increased production of banana in the district.

Keywords: Climate change impact; multiple linear regression; CAGR; banana; Thiruvananthapuram.

1. INTRODUCTION

Global agricultural production systems are vulnerable to extreme weather events, including floods, droughts, and hailstorms, as well as severe climate change and variability. We live at a time when humanity is becoming more aware of the importance of climate change and its impact on human wellbeing. According to recent estimates, the world's population will increase from 7 billion to more than 9 billion by 2050 [1]. By 2050, it is anticipated that worldwide agricultural production will need to expand in order to feed the growing population [2]. The difficulty of quickly increasing productivity is made more difficult by the current and anticipated effects of climate change.

The banana (*Musa paradisiaca* L.) is one of the least expensive, healthiest, and most widely accessible fruits. For millions of people around the world, bananas and plantains are staple foods that offer a more balanced diet than any other fruit or vegetable. Among them are the Robusta, Red Banana, Poovan, Rasthali, Nendran, Virupakshi, Monthan, Karpuravalli, Sakkai, Peyan, Matti, and Dwarf Cavendish, which vary in size, colour, and form.

The IPCC issued a warning in August that the observed rise in global surface temperature indicated exceptional warming between 1850 and 2020. By 2100, the difference between the expected emissions reduction and the actual demand might cause a 2.7^0C increase in temperature. As considering India, which promised to reduce emissions by 33-55 per cent of GDP by 2030, reported that as of the year 2020, it had reached 24 per cent of this objective. Based on commitments made for 2030, the G20 countries, which account for up to 80 per cent of global emissions, are not clearly on a trajectory to attaining net zero [3].

Due to climate change's increasing air temperature and changing rainfall pattern, banana farming may encounter high temperatures, soil moisture stress, flooding, and water logging [4]. Temperature has a significant impact on the pace of fruit growth; hence, using bunch covers to warm the fruit has increased growth. In general, higher temperatures (31-32^0C) accelerate banana plant maturation and shorten the time it takes for the bunch to grow [5]. Bananas flooded for longer than 48 hours are severely stunted for growth, and after 72-96 hours of rain, mature shoots fail to recover and frequently perish [6]. On commercial plantations, bananas need mean annual temperatures between 26^0C and 30^0C and 2,000 mm of yearly rainfall [7]. Strong transport costs for bananas to markets, low prices during the wet season, and high demand for the fruit during the dry season are thought to be the main effects of climate change [8]. In 2019 [9], Varma and Bebber evaluated how climate change may affect banana yields globally. A changing climate since 1961 has raised annual yields for 27 nations, which produce 86 per cent of the world's dessert bananas, by an average of 1.37 T ha^{-1}. Under the climate scenarios, however, worldwide yield gains could be muted or eliminated, falling to 0.59 T ha^{-1} and 0.19 T ha^{-1} by 2050, respectively, due to decreased yields in the top producers and exporters.

In India, the area under banana was 8,97,000 ha and the production was 3,25,97,000 MT during

2020. As recent data shows that area under banana was about 9,23,000 ha and production was 3,33,79,000 MT during 2020-21. Since, banana quantity (in Number) consumed in a month by rural people was 4.18 and urban people was 6.69 during 2011- 12 [10]. In Kerala, the area of banana cultivation during 2020-21 is 57694.67 ha and production under banana is 5,44,188 tonnes. It occupied 18.26 per cent in the category of fresh fruits and it has third top position in this plantation crops. About 4.91 per cent area has decreased during 2020-21 in banana cultivation than that of 2019-20. As compared to 2021, the area and production under banana was 60678 ha and 548425 tonnes which was more in the year 2019-20. The productivity of banana during 2021 and 2020 is 9432 kg/ha and 9038 kg/ha respectively. Area covered under banana cultivation in Thiruvananthapuram was 3507 ha during 2019-20 [11].

Many panchayats have proposed the idea of carbon neutrality in recent years; one notable example and role model is Meenangadi grama panchayat in Kerala's Wayanad district. Additionally, an inventory of greenhouse gas emissions was created. One of the ground-breaking programmes to support carbon-neutral activities was tree banking, which offered interest-free loans to encourage the planting of more trees. Another example is the Palli grama panchayat in Jammu and Kashmir, which has implemented the same people-centric concept and carried out particular regional activities [12].

2. MATERIALS AND METHODS

Secondary data is confined to Thiruvananthapuram district as it was purposively selected for study as vulnerable to climate change. From 1991 to 2021, secondary data on monthly averages of temperature, precipitation, relative humidity, and wind speed was gathered from the NASA power data access website [13]. The Directorate of Economics and Statistics, Vikas Bhavan, Thiruvananthapuram, provided data on area, production, and productivity under banana from 1991 to 2021 for the previous 31 years.

2.1 The Study Area

Thiruvananthapuram the Southernmost district of the coastal State of Kerala in South India came into existence on 1st November 1956. Being capital of Kerala often known as “God’s own country”, Thiruvananthapuram is also called “God’s own capital”. The district has an area of 2192 sq km which forms 5.64 per cent of the total area of the state consisting of 11 blocks, 4 municipalities and one corporation. The district is part of South Kerala coast and is divided into three sub micro regions. Geographically district can be divided as highland, midland and lowland regions. Thiruvananthapuram lies within North Latitude 8^0 17’ and 8^0 51’ and East Longitude 76^0 41’ and 77^0 17’. District has a sea coast which is about 75 km long and also suited for backwater fishing due to the presence of continuous stretch of lakes and backwaters. The forest reserves (1304 sq km) favourably affect the climate and include more rain in the district.

2.2 Impact of Climate Change on Banana Production

The impact of climate change on banana production was quantified by multiple linear regression model for Thiruvananthapuram district. Log values of the quarterly data on climatic variables such as temperature, rainfall, relative humidity and wind speed for a period of 31 years from 1991 to 2021 were taken as independent variables and that of production of banana was taken as the dependent variable. In multiple linear regression, there are two or more independent variables are used to predict the outcome, and the relationship between the dependent variable and model is represented by the following equation:

$$Yt = \beta1+\beta2Q1Tt +\beta3Q2Tt+ \beta4Q4Tt + \beta5Q1Rt+ \beta6Q3Rt + \beta7Q4Rt+ \beta8Q1RHt+ \beta9Q2RHt+ \beta10Q3RHt + \beta11Q2WSt+ \beta12Q4WSt+ ui$$

Yt = Banana production during t^{th} period.
β1 = The y- intercept
Q1Tt = Temperature during January to March during t^{th} period.
Q2Tt = Temperature during April to June during t^{th} period.
Q4Tt = Temperature during October to December during t^{th} period.
Q1Rt = Rainfall during January to March during t^{th} period.
Q3Rt = Rainfall during July to September during t^{th} period.
Q4Rt = Rainfall during October to December during t^{th} period.
Q1RHt = Relative Humidity during January to March during t^{th} period.

Q2RHt = Relative Humidity during April to June during t^{th} period.
Q3RHt = Relative Humidity during July to September during t^{th} period.
Q2WSt = Wind Speed during April to June during t^{th} period.
Q4WSt = Wind Speed during October to December during t^{th} period.
β2, β3, β4, β5, β12 = Slope of the independent variables
ui = Random error or stochastic component [14]

The coefficient of multiple determination (R^2) shows the percentage of the total variation of Y explained by the regression plane, that is, by changes in independent variables. Statistical package STATA version SE 14.1 was used to analyse the secondary data. Natural logarithm was taken for both dependent and independent variable to avoid too much fluctuation in the results.

Variance Inflation Factor (VIF) was calculated to check the multicollinearity in the function. It was calculated using formula:

$$VIF = 1/1\text{-}R^2$$

Where,

VIF = Variance Inflation Factor.
R^2 = Coefficient of multiple determination.

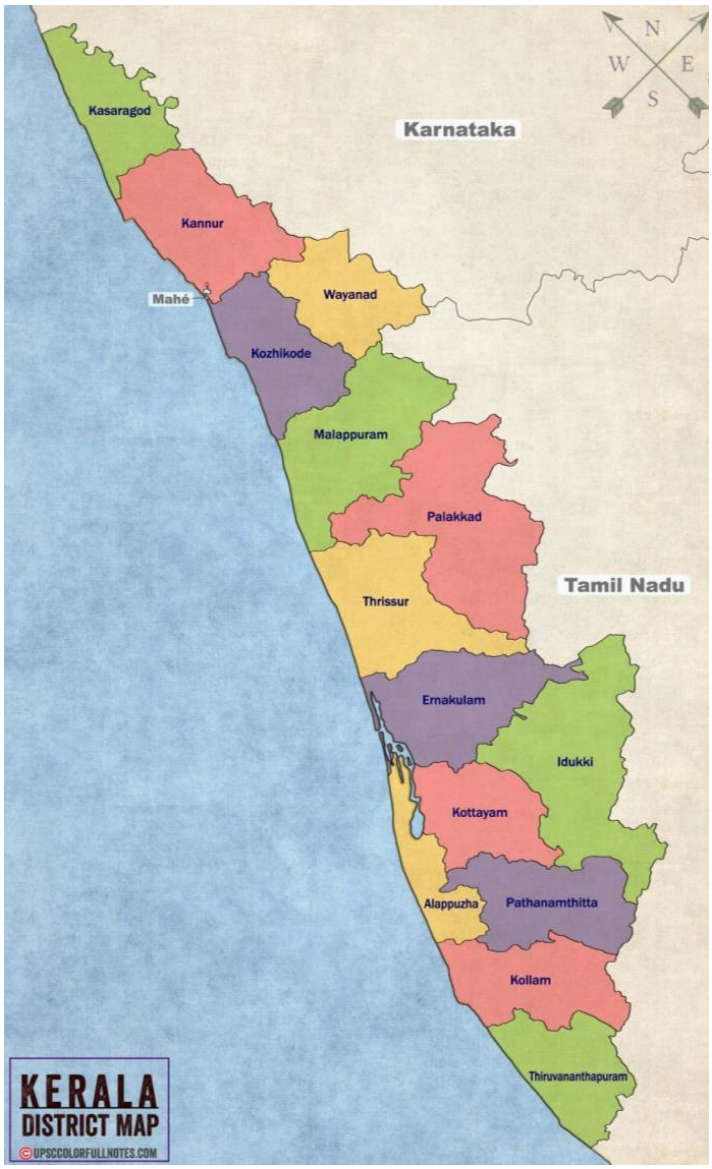

Fig. 1. Political map of Kerala state

If the VIF value is equal to or more than 10, then the particular independent variable is considered to have high multicollinearity with one of the other independent variables.

Durbin - Watson test was done to check the autocorrelation. It was calculated using the formula:

$$d = 2 (1 – \rho)$$

Where,

d = Durbin – Watson value.
ρ = Correlation coefficient of error term.

If d value is equal to 2 then, the model is said to have no autocorrelation.

2.3 Compound Annual Growth Rate and Coefficient of Variation

To determine the growth trend and variability, CAGR and coefficient of variation were calculated for the factors related to area, production, productivity, and climate. Compound Annual Growth Rate of independent variable is the rate of change per unit time, usually yearly. It is expressed in the per cent and gives a general trend in growth of agricultural income over specified time period. It was calculated using following formula:

$$Y = ab^{t}et \text{ [15]}$$

Where,

Y= Dependent variable for which area/ production/ productivity of banana/ climatic variables
a= Intercept
b= Co-efficient of independent variables
t= Number of years
e= Error term taking the logarithm on both the sides it takes the linear form

$$\log Y = \log a + t \log b$$

The Compound Annual Growth Rate (CAGR) is calculated as:

$$CAGR(\%) = [\text{Anti} (\log b) – 1] * 100$$

The significance of the regression coefficient was tested using the student's t- test as

$$t = bi / SE (bi)$$

Where, (bi) = regression co-efficient
SE (bi) = standard error of regression co-efficient bi
t = calculated t- value

3. RESULTS AND DISCUSSION

3.1 Impact of Climate Change on Banana Production

The impact of climate change on banana production was quantified by multiple linear regression model for Thiruvananthapuram district. Log values of the quarterly data on climatic variables such as temperature, rainfall, relative humidity and wind speed for a period of 31 years from 1991 to 2021 were taken as independent variables. Log value of production of banana from 1991 to 2021 was taken as the dependent variable. Multiple linear regression was used as, production is a function of climatic variables. Results are represented in Table 1.

From Table 1, it shows that Q4 (October to December) temperature was positively significant at 1 per cent level of significance. This means that increase in temperature during this period resulted in increased production of banana in the district. Also Q4 (October to December) rainfall was positively significant at 5 per cent level of significance. This means that increase in rainfall during this period resulted in increased production of banana in the district. This means that one per cent increase in temperature during Q4 will increase the production by 13.9 per cent and one per cent increase in rainfall during Q4 will increase the production of banana by 0.42 per cent due to optimum temperature and rainfall. Q4 is the important growth stage in banana. For those who planted in Q2 (April-June), Q4 coincided with flowering, pollination and fruit formation. It was also reported that optimum temperature for balanced growth and development of banana is around 27^{0}C [16] which coincides with 27.69^{0}C, the average temperature in this district.

For the collected data, to check the multicollinearity VIF test was done and values are presented in Table 1. VIF value ranges from 1.64 to 7.04. Hence, multicollinearity was not a serious problem among the independent variables included in the analysis. Test for autocorrelation was done using Durbin – Watson test. D-W value was 1.91 and hence it can be concluded that there is no autocorrelation in the function. R^2 value was 0.74 for the multiple linear

Table 1. Multiple linear regression model (1991-2021)

Sl. No.	Particulars	Coefficient	Standard error	t - value	p- value	VIF
1	Intercept	-161.48	29.103	-5.55	0	-
2	Q1 Temperature (Jan.- March)	10.143	5.202	1.95	0.066	6.58
3	Q2 Temperature (April- June)	7.587	5.937	1.28	0.217	7.04
4	Q4 Temperature (Oct. - Dec.)	13.901***	4.796	2.90	0.009	4.14
5	Q1 Rainfall (Jan.- March)	0.0514	0.047	1.08	0.293	2.03
6	Q3 Rainfall (July – Sep.)	0.1353	0.104	1.30	0.21	1.64
7	Q4 Rainfall (Oct. - Dec.)	0.4291**	0.183	2.34	0.030	2.89
8	Q1 RH (Jan.- March)	3.0763	1.751	1.76	0.095	5
9	Q2 RH (Oct. - Dec.)	4.7891	2.903	1.65	0.115	4.18
10	Q3 RH (July – Sep.)	5.9823	3.137	1.91	0.072	2.25
11	Q2 WS (Oct. - Dec.)	1.2946	0.649	1.99	0.061	2.15
12	Q4 WS (Oct. - Dec.)	0.8941	0.631	1.42	0.173	2.31
13	F	5.13				
14	Prob.>F	0.0009				
15	No. of observation	31				
16	R2	0.7482				
17	Adjusted R^2	0.6023				

******** *Significant at 5 per cent level*
********* *Significant at 1 per cent level*
Note: The coefficients were obtained with log values

regression analysis, indicating that 74 per cent of variation in the dependent variable was explained by the independent variables included in the model. Since F calculated value (5.13) is greater than F(11, 19) table value at one per cent level of significance, the overall multiple linear regression model was a good fit.

3.2 Status of Banana Production in Thiruvananthapuram

The status of banana production in Thiruvananthapuram district can be understood by analyzing the area, production and productivity under banana. The data for the period 1991-2021 (31 years) was analysed. The CAGR and coefficient of variation were calculated to understand the rate of growth and variability over the period of time and is given in Table 2. Positive trend in the growth of area (5.35 per cent per annum) and production (2.86 per cent per annum) were observed in spite of having negative trend in productivity (-2.36 per cent per annum). It is graphically represented in Fig. 2. The productivity was found to be declining over years. This can be attributed to the decrease in efficiency of production due to insufficient input usage and lack of scientific management practices. The Directorate of Economics and Statistics, Vikas Bhavan, Thiruvananthapuram, provided data on area, production, and productivity under banana from 1991 to 2021 for the previous 31 years.

Coefficient of variation (CV) was high in area as compared to that in production and productivity of banana in Thiruvananthapuram and coefficient of variation for area, production and productivity were 42.68, 32.62 and 32.71 per cent respectively.

In a similar attempt, CAGR for area, production, and productivity of bananas in Kolhapur district were estimated to be 7.72, 6.08, and -1.29 percent per annum, respectively, for the period from 2003-04 to 2012-13, according to a study by Bondar et al. [17] on the economics of banana production in Kolhapur district of Maharashtra.

Table 2. CAGR and Coefficient of Variation of area, production and productivity of banana in Thiruvananthapuram

Sr. No.	Particulars	Area (ha)	Production (tonnes)	Productivity (kg/ha)
1	CAGR (% per annum)	5.35*** (10.19)	2.86*** (7.04)	-2.36*** (-5.41)
2	Standard Deviation	878.93	5488.64	3000.92
3	Mean	2059.12	16827.10	9174.26
4	Coefficient of Variation (%)	42.68	32.62	32.71

Note: Figures in parentheses indicate t-value.
**** significant at 1 per cent level*

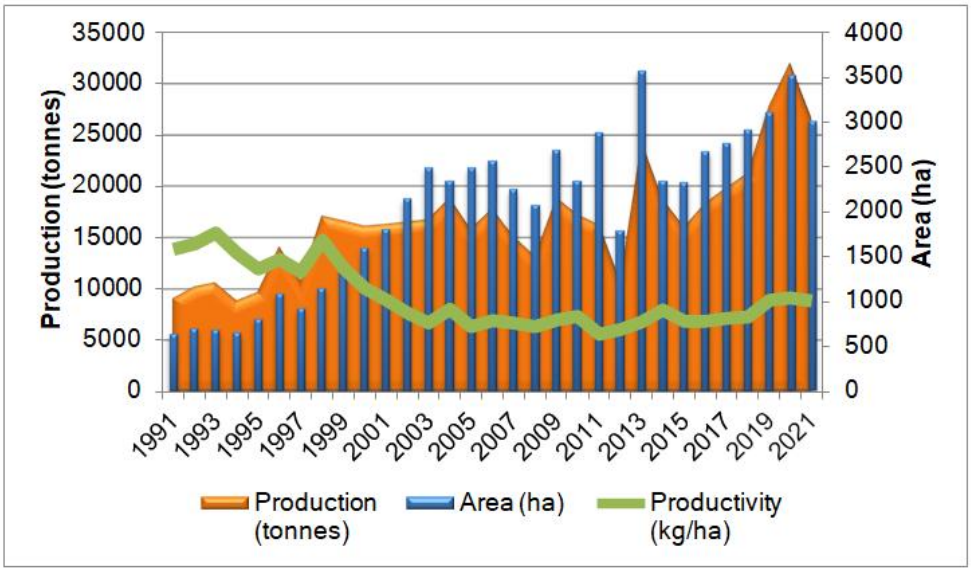

Fig. 2. Trend in area, production and productivity of banana in Thiruvananthapuram district (1991-2021)

3.3 Climate Change

In Thiruvananthapuram district, average maximum temperature, average minimum temperature, average rainfall, average relative humidity and average wind speed were 35.65°C, 19.73°C, 1748.07 mm, 80.09 per cent and 4.15 m/s respectively as given in Table 3. Coefficient of variation was highest for rainfall, among all the weather parameters, i.e., 19.52 per cent. All weather parameters have positive growth rate except wind speed (-0.24 per cent per annum significant at 1 per cent level of significance). Positive trend of minimum temperature was 0.13 per cent per annum significant at 5 per cent level of significance and shown in Fig. 2. The trend analysis is shown graphically in the Figs. 3, 4, 5.

Table 3. CAGR and coefficient of variation of weather parameters in Thiruvananthapuram (1991-2021)

Sl. No.	Particulars	Mean	Coefficient of Variation (%)	Compound Annual Growth Rate (% per annum)
1	Minimum Temperature (^{0}C)	19.73	3.24	0.13** (2.15)
2	Maximum temperature (^{0}C)	36.65	1.96	0.02 (0.60)
3	Rainfall (mm)	1748.07	19.52	0.04 (0.08)
4	Relative Humidity (%)	80.09	1.64	0.03 (0.98)
5	Wind Speed (m/s)	4.15	4.47	-0.24 ***(-2.92)

Note: Figures in parentheses indicate t-value.
*** Significant at 5 per cent level*
**** Significant at 1 per cent level*

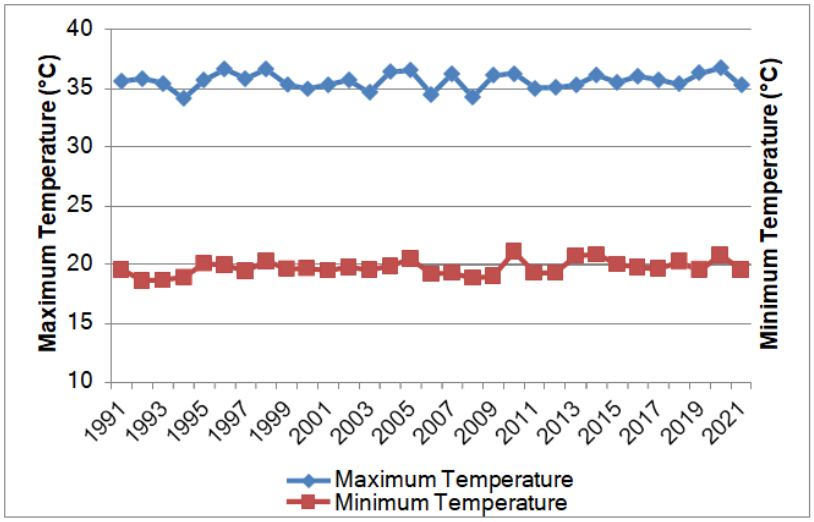

Fig. 3. Trend in maximum and minimum temperature in Thiruvananthapuram (1991-2021)

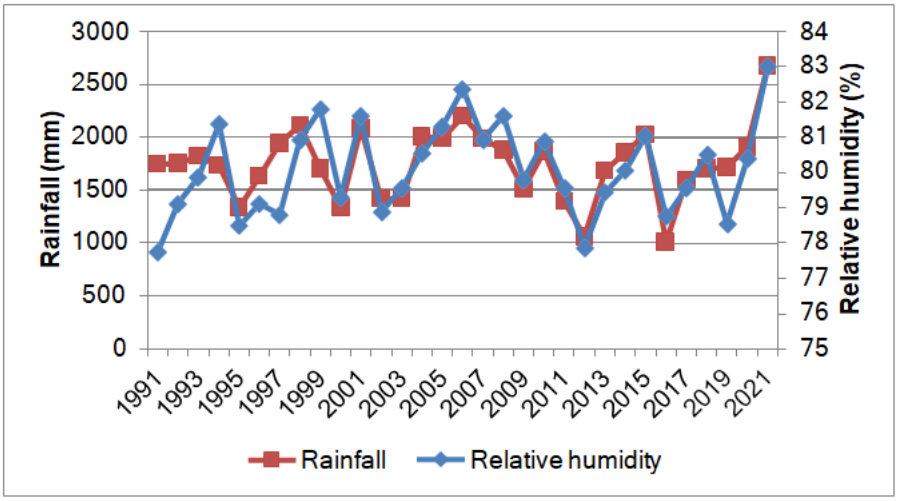

Fig. 4. Trend in rainfall and relative humidity in Thiruvananthapuram (1991-2021)

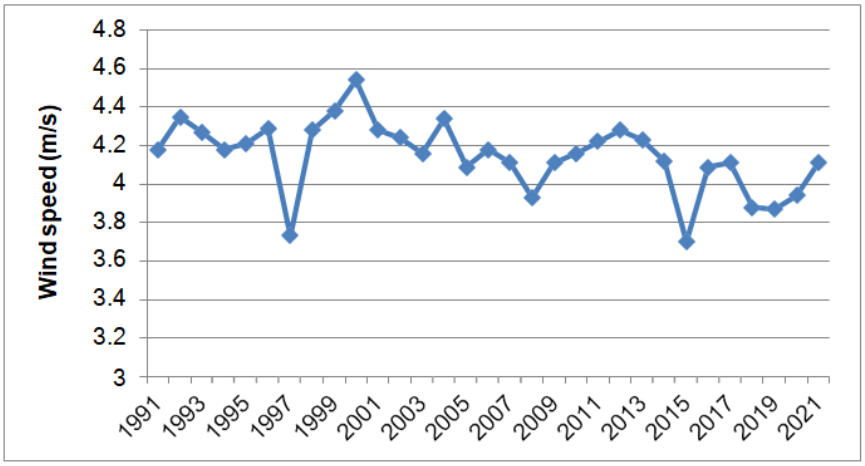

Fig. 5. Trend in wind speed in Thiruvananthapuram (1991-2021)

The results obtained from this analysis are in harmony with the results obtained by Salvacion [18] who conducted studies on the effect of climate on provincial-level banana yield in the Philippines for the period from 1991 to 2016. Multiple regression analysis showed that only 10 per cent of the banana producing areas in the country is significantly affected by climate. It was also reported in his study that, rise in temperature and rainfall will affect the banana production. Salau et al. [19] analyzed data collected for the period 1998 and 2012 from Ondo State, Nigeria, to examine the effects of changes in significant climate variables such as temperature, rainfall, and relative humidity on the production of a significant agricultural commodity called banana. The results indicated that a satisfactory annual banana production over 61,000 T in Ondo State will result from a mean temperature of 26 °C, average rainfall of about 1,891 mm, and relative humidity of about 77 per cent.

4. CONCLUSION AND RECOMMENDATION

From the multiple linear regression, it was revealed that climate change was positively influencing the yield of banana in Thiruvananthapuram district. Q4 (October to December) temperature was positively significant that increase in temperature during this period resulted in increased production of banana in the district. Also Q4 (October to December) rainfall was positively significant that increase in rainfall during this period resulted in increased production of banana in the district. Positive trend in the growth of area (5.35 per cent per annum) and production (2.86 per cent per annum) were observed in spite of having negative trend in productivity (-2.36 per cent per annum). The productivity was found to be declining over years. This can be attributed to the decrease in efficiency of production due to insufficient input usage and lack of scientific management practices. Coefficient of variation was high in area as compared to that in production and productivity of banana in Thiruvananthapuram. Coefficient of variation was highest for rainfall, among all the weather parameters.

The overall results indicate positive impact on the yield of banana production for last 31 years. In future climate change, there is chance of decline in the production of banana, hence to adapt situation people needs to adapt the adaptation practices such as change in the planting time, crop insurance, planting of mixed crops, mulching with banana leaves, paddy straws, tissue culture plants etc. Farmers should be made aware of the need of adaptation practices to combat climate change. Problem specific practical training is to be provided to farmers regarding the time of adopting the adaptation practices and input material to be used. Efforts should be taken to simplify the procedure of crop insurance, such that all transactions are made through Krishi Bhavan and creation of awareness and conviction about the benefits of crop insurance should be given to the farmers.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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