AN ECONOMIC ANALYSIS OF CLIMATE CHANGE TREND AND ITS IMPACT IN SIVAGANGAI DISTRICT OF TAMIL NADU, INDIA

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ABSTRACT

The present study was taken up in Sivagangai district to examine the issues of trend in climate change, association between climate change and area, production and productivity of crops and impact of climate change on production of crops. The climate trend in Sivagangai district was studied using the descriptive statistics of skewness, kurtosis, coefficient of variation and compound growth rate of climatic variables of maximum temperature, minimum temperature and rainfall over the past 50 years from 1971 to 2020. Pearson correlation technique was used to analyze the degree of association between climatic variables and area, production and productivity of principal crops namely paddy, black gram and groundnut. Cobb-Douglas production function model was fitted to study the quantitative relationship between the average production of principal crops grown in the district and the climatic variables of temperature and rainfall and cropped area. Maximum temperature and minimum temperature were negatively skewed and rainfall was positively skewed. Kurtosis for maximum temperature was platykurtic and for the minimum temperature and rainfall of Sivagangai district, the kurtosis was Leptokurtic. The maximum temperature and minimum temperature were less variable and rainfall was highly variable. Pearson correlation coefficient revealed that maximum temperature, minimum temperature and rainfall had significant association with area, production and productivity of crops in Sivagangai district of Tamil Nadu. Cobb- Douglas production function analysis revealed that annual rainfall had a positive relationship with production of paddy. On the other hand, climatic variables of temperature and rainfall were not influencing the groundnut and black gram production.

Key words: Skewness, kurtosis, coefficient of variation, compound growth rate, platykurtic, leptokurtic, Pearson correlation coefficient and Cobb- Douglas production function

1. Introduction

Climate change is rapidly emerging as a global critical development issue affecting many sectors in the world and is considered to be one of the most serious threats to sustainable development. Recently, the intergovernmental panel on climate change (IPCC) in its sixth report (August 2021) predicted adverse global climate change impacts in near future. The report states that the global average temperature had risen by 1.10 degree Celsius since the pre-industrial 19th century. If the global temperature increases at the same rate, the temperature would go above 1.50 degree Celsius within 20 years. This was the danger limit prescribed in Paris climate deal. The report suggested the nations to formulate policy interventions to control the emissions that would prevent a red line of 2.00 degrees.

Tamil Nadu State Action Plan on Climate Change (TNSAPCC) predicted that the average maximum temperature and average minimum temperature of Tamil Nadu would increase by 3.10^{o}C and 3.50^{o}C within this century. On the other hand, the average rainfall over Tamil Nadu would be reduced by nine per cent within this century. The report predicted that these climate changes would cause a deficit of 32 per cent of monsoon in delta regions and this would impact the perennial rivers of Cauvery and Thamirabarani in the state.

Among the districts in Tamil Nadu, the minimum temperature had increased in Coimbatore district and decreased in Vellore district. Both maximum and minimum temperature increased significantly in Salem and Madurai districts. In Tamil Nadu, with average rainfall of over 921 mm, the climate change had affected the South-West monsoon with August rainfall increased with more dispersions. On the other hand, September rainfall decreased with less dispersions in Salem, Coimbatore, Madurai and Tiruchirapalli districts. Thus September, the peak rainfall month of the South-West monsoon before climate change has become the monsoon receding month after climate change (Varadan et al., 2017). The Sivagangai district is facing extremes of climate change with increased temperature and deceased rainfall. These studies had analysed the general trends of climatic variables in some districts of Tamil Nadu but not carried out in Sivagangai district of Tamil Naddu. Hence the present study was taken up in Sivagangai district to examine the issues of trend in climate change, association between climate change and area, production and productivity of crops and impact of climate change on production of crops. Further, the studies on trend in climate change with descriptive statistics, analysis on association between climate change and area, production and productivity of crop with Pearson correlation coefficient and analysis on

impact of climate change on production of crops with Cobb-Douglas production function is a novel one in Sivagangai district of Tamil Nadu, India.

2. Materials and methods

i. Climate trend analysis

The climate trend in Sivagangai district was studied using the descriptive statistics of skewness, kurtosis, coefficient of variation and compound growth rate of climatic variables of maximum temperature, minimum temperature and rainfall over the past 50 years from 1971 to 2020. The climate data was collected from Tamil Nadu Government Climate Portal.

Skewness

Skewness refers to the asymmetry or lack of symmetry in the shape of a frequency distribution.

Coefficient of skewness = (mean – mode)/ standard deviation

Its value usually lies between -1 and +1. Skewness will be positive if mean is greater than mode and negative if mean is less than mode.

Kurtosis

It refers to the degree of flatness or peakedness in the region about the mode of a frequency curve. kurtosis equal to 3 is known as mesokurtic. kurtosis less than 3 is known as platykurtic. kurtosis greater than 3 is known as leptokurtic

Coefficient of variation

Coefficient of variation is the ratio of standard deviation to the mean. It have no units. It is expressed as percentage.

Coefficient of variation (%) = Standard deviation/ Mean*100

S. No.	Coefficient of variation (%)	Categorization of variability
1.	Less than 10	Low
2.	10-20	Medium

3.	20-30	High
4.	More than 30	Very high

Compound growth rate

To calculate compound growth rate the following compound function was used.

$$y = a\ b^t$$

$$\text{Log } y = \log a + t \log b$$

where,

t = time in years; y = area / production / yield

a = constant ; b = regression coefficient

The compound growth rate (r) in percentage is calculated by using the formula

r = (Anti log of b) -1 x 100

ii. Pearson correlation coefficient

Pearson correlation technique was used to analyze the degree of association between climatic variables and area, production and productivity of principal crops namely paddy, black gram and groundnut in Sivagangai district. Time series data on area, production and productivity of principal crops in Sivagangai district were collected for 30 years from 1984 to 2014 and were used for correlation analysis.

Pearson coefficient is specified as,

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

where,

r = Pearson correlation coefficient

x = Climate variables representing mean maximum temperature (degree Celsius), mean minimum temperature(degree Celsius) and average rainfall (mm,)

y = Area (in ha.), production (in tonnes.) and productivity (in tonnes./ha.)of principal crops grown over years in the district.

iii. Quantitative relationship between production of crops and climatic variables

In the present study, a Cobb-Douglas production function model was fitted to study the quantitative relationship between the average production of principal crops grown in the district and the climatic variables of temperature and rainfall and cropped area.

The Cobb-Douglas production function specified for the study is given as

$Y = a X_1^{b1} X_2^{b2} X_3^{b3} U_t$

where,

Y_i = average production of paddy/black gram/ groundnut during the i^{th} year (tonnes/ha.)

X_1 = Annual mean temperature during i^{th} year (degree Celsius)

X_2= Annual rainfall during i^{th} year (mm.)

X_3= Gross cropped area of that crop in i^{th} year (ha.)

b_0 = Intercept

μ = Error term

b_1, b_2 and b_3 are coefficients of respective variables.

3. Results and Discussion

The climate trend in Sivagangai district was studied using the descriptive statistics and compound growth rate of climatic variables of Maximum temperature, Minimum temperature and Rainfall over the past 50 years from 1971 to 2020 and the results are presented in the following tables and figures.

3.1 Descriptive statistics

The descriptive statistics was studied by analyzing skewness, kurtosis and coefficient of variation and the results are furnished in table1, table 2, figure1 and figure 2.

Table 1. Descriptive statistics for climatic data for 1970-2020

S .No.	Parameters	Maximum temperature	Minimum temperature	Rainfall
1.	**Mean**	32.51	20.88	910.80
2.	**Standard Error**	0.06	0.11	46.73
3.	**Median**	32.55	20.95	869.72
4.	**Mode**	32.33	21.42	862.13
5.	**Standard Deviation**	0.35	0.76	309.93
6.	**Kurtosis**	-0.40	0.31	5.77
7.	**Skewness**	-0.06	-0.58	0.51
8.	**Coefficient of variation (%)**	0.99	3.63	34.03

It could be seen from the table 1 and Fig. 1 and 2 that maximum temperature and minimum temperature was negatively skewed and rainfall was positively skewed. Kurtosis is measured against the normal distribution. If the kurtosis is close to 0, then a normal distribution is assumed. From the table 1, it could be observed that the kurtosis value for maximum temperature was less than 0 with means the distribution follows light tails at end and are called as platykurtic distribution. While for the minimum temperature and rainfall of Sivagangai district, the kurtosis was positive showing that the distribution was Leptokurtic. The maximum temperature and minimum temperature were less variable with coefficient of variation values of 0.99 per cent and 3.63 per cent. On the other hand, rainfall was highly variable with coefficient of variation values of 34.03 per cent. Similar study was mase by Akinsanola and Ogunjobi (2014) in analyzing rainfall and temperature variabilities in Nigeria showed that the temperature data showed negative coefficient of kurtosis and positive coefficient of skewness in peaked distribution. Irene,Abubakari et al. **(2020) similarly** studied the extremal behaviour of yearly maximum rainfall data of the Upper East Region of Ghana in Navrongo municipality. The least and highest yearly maximum rainfalls recorded in Navrongo Municipality over the period under study were 173.50 mm and 455.50 mm respectively. The data was rightly skewed, leptokurtic and randomly distributed. Sheraz Mahdi et al., (2021) **similarly** analysed the climatic variables to detect the trend of climate change in union territory of Jammu & Kashmir valley especially in North western Himalayas. The results revealed that average mean minimum and maximum temperature of the Kashmir valley has increased substantially at a rate of 0.02^{o}C/year. The skewness indicated that the

December month had high negative skewness with high positive kurtosis which showed that it was heavy tailed. The annual precipitation decreased at a rate of -5.01mm/year. Seasonal precipitation was also found decreasing at rate of -4.95 mm/year, -0.30 mm/year, -0.28 mm/year and -0.06 mm/year for the spring, winter, autumn and summer seasons respectively.

3.2 Compound growth rate for climatic variables in Sivagangai District

From the table 2, it could be observed that the compound annual growth rate for maximum temperature and minimum temperature was positive showing that there was an increasing trend in those climatic parameters over years1970-2020. On the other hand, the compound annual growth rate for rainfall was negative indicating that there was a decreasing trend over years of rainfall in Sivagangai district between 1970 and 2020.

Table 2. Compound growth rate of climate variables from 1970 to 2020

S. No	Parameters	CGR
1	Maximum temperature	0.0522
3	Minimum temperature	0.0623
3	Rainfall	-0.2187

Fig 1 Temperature trend in Sivagangai district between 1970 and 2020

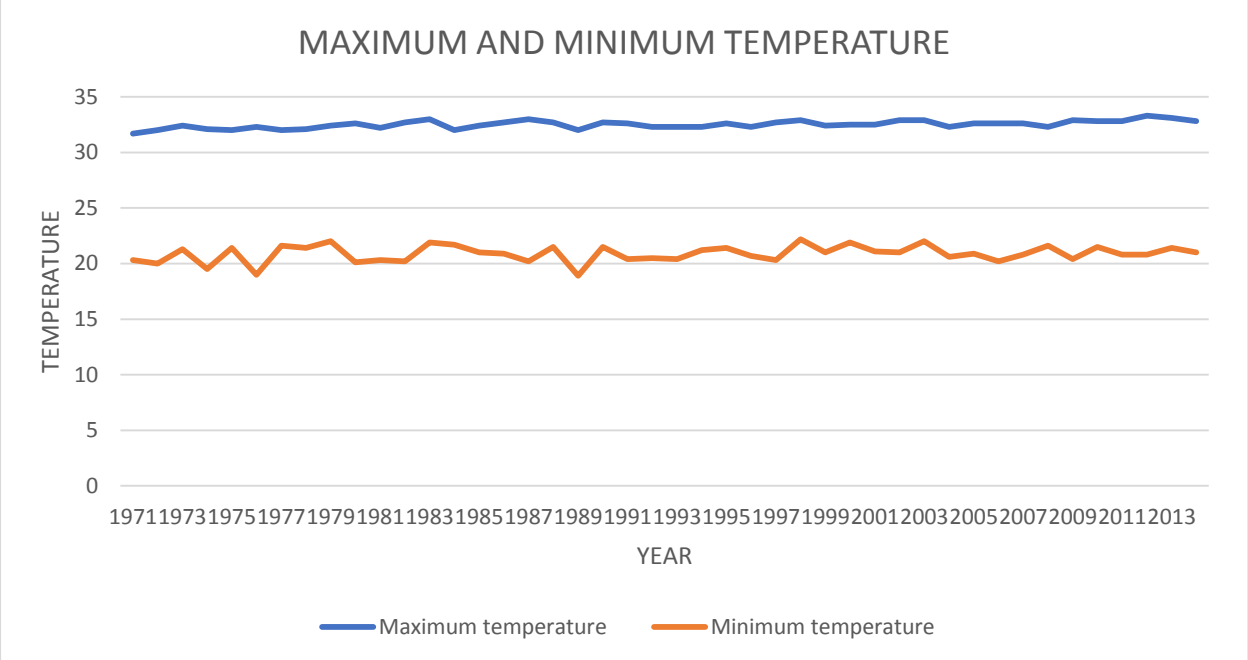
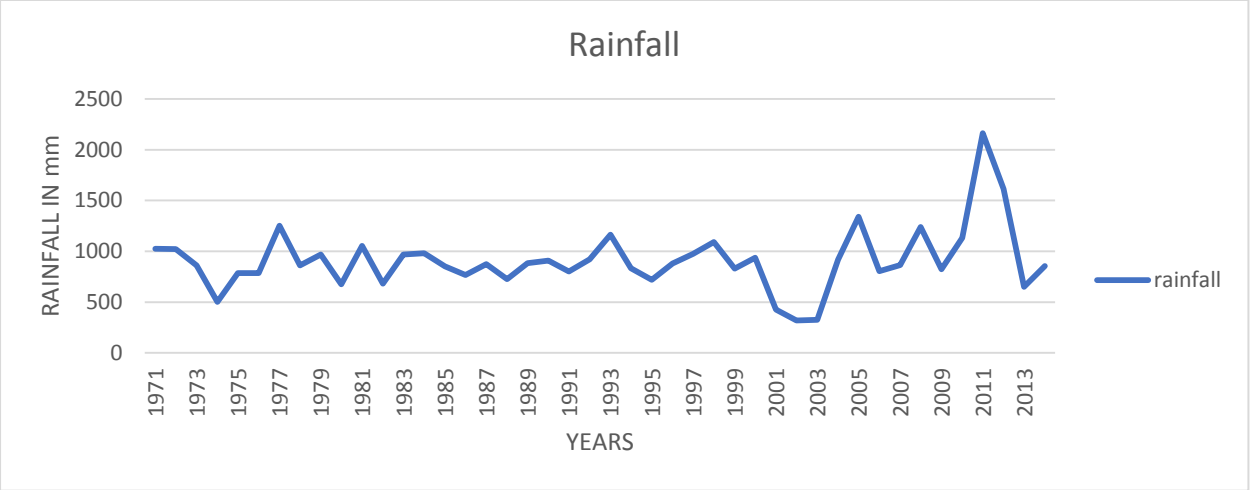


Fig 2 Rainfall trend in Sivagangai district between 1970 and 2020



3.3 Association between area, production and productivity of principal crops and climatic variables in Sivagangai district

Pearson correlation coefficient was used to determine the association between area, production and productivity of principal crops and climatic variables in Sivagangai district and the results are furnished in the tables 3,4 and 5.

3.3.1 Association between climatic variables and area under different crops in Salem district

The results of Pearson correlation coefficient among climatic variables of maximum temperature, minimum temperature and rainfall and area under principal crops cultivated in Sivagangai district were presented in the table 3.

Table 3. Association between climatic variables and area under different crops in Sivagangai district

S. No.	Crops	Maximum Temperature	Minimum Temperature	Rainfall
1	Paddy	-0.31	-0.17	0.16
2	Black gram	-0.05	-0.09	0.30
3	Groundnut	-0.44	0.14	0.01

The table revealed that correlation coefficient between mean maximum temperature and area under crops in Sivagangai district on crops of Paddy, Black gram and Groundnut were found to be negative indicating that the maximum temperature was not conducive among these crops. Likewise, the minimum temperature had negative correlation with area of Paddy and Black gram crops showing that the minimum temperature was not conducive among these crops. On the other hand, rainfall had positive correlation among all the three cops of Paddy, Black gram and Groundnut indicating that rainfall was conducive for all the three crops. Thus, the correlation analyses revealed that climatic variables of maximum temperature, minimum temperature and rainfall had significant association with area under crops in the study area.

3.3.2 Association between climatic variables and production under different crops in Salem district

Correlation analysis was employed to analyze the data so as to establish degree of association between production of crops and different climate variables in the study area and results are presented in table 4.

Table 4. Association between climatic variables and production under different crops in Sivagangai district

S. No.	Crops	Maximum Temperature	Minimum Temperature	Rainfall
1	Paddy	-0.04	-0.13	0.48
2	Black gram	0.17	-0.14	0.39
3	Groundnut	-0.14	-0.04	0.32

The table revealed that correlation coefficient between mean maximum temperature and production of crops in Sivagangai district for Paddy and Groundnut were found to be negative indicating that the maximum temperature in Sivagangai district was not conducive for these crops. On the other hand, correlation between mean maximum temperature and production was positive for black gram indicating that the maximum temperature was conducive. The mean minimum temperature had negative association with production for all the three crops of Paddy, Black gram and Groundnut indicating that the minimum temperature was not conducive. The rainfall had had positive association with production for

all the three crops of Paddy, Black gram and Groundnut indicating that the rainfall was conducive for all the three crops. Thus, the correlation analyses revealed that climatic variables of maximum temperature, minimum temperature and rainfall had significant association with production of crops in the study area.

3.3.3 Degree of association between climatic variables and productivity under different crops in Sivagangai district

The results of Pearson correlation coefficient among climatic variables of maximum temperature, minimum temperature and Rainfall and productivity of various crops grown in Sivagangai district were presented in the table 5

Table 5. Association between climatic variables and productivity under different crops in Sivagangai district

S. No.	Crops	Maximum Temperature	Minimum Temperature	Rainfall
1	Paddy	0.12	-0.01	0.03
2	Black gram	0.10	0.01	0.13
3	Groundnut	0.50	0.10	0.45

From the table it could be observed that correlation coefficient between mean maximum temperature and productivity of crops in Sivagangai district for paddy, black gram and groundnut were found to be positive indicating that the maximum temperature in Sivagangai district was conducive for these crops. Also, correlation between mean minimum temperature and productivity of black gram and Groundnut were found to be positive indicating that the minimum temperature was conducive. On the other hand, the minimum temperature was not conducive for paddy since it had negative correlation with productivity. The rainfall had positive association with productivity for all the three crops of Paddy, Black gram and Groundnut indicating that the rainfall was conducive for all the three crops. Thus, the correlation analyses revealed that climatic variables of maximum temperature, minimum temperature and rainfall had significant association with productivity of crops in the study area.

Thus, it could be inferred from the analyses that maximum temperature, minimum temperature and rainfall had significant association with area, production and productivity of crops in the study area. Similar study was made by Khanal, B. (2015) who had shown that in

Morang district of Nepal, the climatic variables had a strong correlation with crops of Rice, Maize, Finger millet and Wheat. The results had shown that Rice and wheat had positive correlation with rainfall. The minimum temperature had strong positive correlation with maize crop production. On the other hand, millets had a negative correlation relationship with climatic variables.

3.4 Quantitative relationship between average production of crops and climate variables in Sivagangai district.

The quantitative relationship between the average production of principal crops in the district and different climate variables were analyzed by fitting Cobb-Douglas production function and the results of estimated regression function was presented in Table 6, 7 and 8.

3.4.1 Quantitative relationship between average production of crops and climate variables for paddy

It could be observed from table 6 that coefficient of multiple determination (R^2) was 0.21, indicating that 21 per cent of variation in mean production of paddy in Sivagangai district was explained by independent variables in the log-linear form. The coefficient of annual rainfall was positive and significant at one percent level with value of 0.60 showing that an increase in rainfall by one per cent would increase the paddy production of Sivagangai district by 0.60 per cent. The results of the analysis revealed that the annual rainfall had a positive relationship with production of paddy.

Table 6. Quantitative relationship between average production of Paddy and climate variables and cropped area in Sivagangai district

S. No.	Variables	coefficient	t stat
1	Intercept	26.34	1.20
2	Average mean temp (in ^{o}C)	-5.51	-0.85
3	Average rain (in mm)	0.60**	2.42
4	Cropped Area in ha	-0.03	-0.16

*** significant at 1 per cent level* R^2 = 0.21

3.4.2 Quantitative relationship between average production of crops and climate variables for black gram

It could be observed from table 7 that coefficient of multiple determination (R^2) was 0.38, indicating that 38 per cent of variation in mean production of black gram in Sivagangai district was explained by independent variables in the log-linear form. The coefficient of cropped area was positive and significant at one percent level with value of 0.77 showing that an increase in black gram area by one per cent would increase the black gram production of Sivagangai district by 0.77 per cent. The results of the analysis revealed that climatic variables of temperature and rainfall were not influencing the black gram production.

Table 7. Quantitative relationship between average production of Black gram and climate variables and Cropped Area in Sivagangai district

S. No.	Variables	coefficient	t stat
1	Intercept	1.36	0.07
2	Average mean temp (in ^{o}C)	-0.61	-0.10
3	Average rain (in mm)	0.21	0.82
4	Cropped Area in ha	0.77**	3.58

** *significant at 1 per cent level,* $R^2 = 0.38$

3.4.3 Quantitative relationship between average production of crops and climate variables for groundnut

It could be observed from table 8 that coefficient of multiple determination (R^2) was 0.27, indicating that 27 per cent of variation in mean production of groundnut in Sivagangai district was explained by independent variables in the log-linear form. The coefficient of cropped area was positive and significant at one percent level with value of 0.30 showing that an increase in groundnut area by one per cent would increase the groundnut production of Sivagangai district by 0.30 per cent. The results of the analysis revealed that climatic variables of temperature and rainfall were not influencing the groundnut production. Similar study was mase by Gornott and Wechsung (2016) studied three regression models estimating relative climate impacts on relative crop yield changes where the levels of significance was stronger for maize (0.86***) than for wheat (0.66**).

Table 8. Quantitative relationship between average production of Groundnut and climate variables and Cropped Area in Sivagangai district

S. No.	Variables	coefficient	t stat
1	Intercept	0.29	0.02
2	Average mean temp (in^{o}C)	1.43	0.29
3	Average rain (in mm)	0.20	1.13
4	Cropped Area in ha	0.30**	2.94

** *significant at 1 per cent level,* $R^2 = 0.27$

Wu Jian-zhai et al., (2021) similarly analyzed the impacts of climate change on maize yields in China during 1979-2016. The results indicated that increases in temperature negatively impacted the maize yield of China. For every 1°C increase in temperature, the maize yield was reduced by 1.7%. The impact of precipitation on maize yield in China was very negligible. With increase in 1 mm in rainfall, the maize yield increased by 0.014 per cent and the maize crop was very resilient to climate changes in China. Li N et al., (2021) similarly assessed the impact of climate change on global cotton yield. The results inferred that an increased temperature of 4.3^{o}C or change in precipitation over 200 per cent showed a significant decrease in cotton yield. Further the results implied that the yield of cotton decreased by 1.64 per cent for every one degree increase in temperature. For every one per cent increase in rainfall, the cotton yield increased by 0.09 per cent. Raes, D., Waongo, M., Vanuytrecht, E., & Moreno, P. M. (2021) similarly analyzed the climate change and its effect in West Africa. The models projected that temperature would increase by 1.0^{o}C to 2.5^{o}C by 2050 with an increased evapotranspiration between 3 per cent to 7 per cent by 2050. The effects would cause the yields of major crops of rainfed sorghum, rice and maize decrease by 5 to 20 per cent. The model suggested to improve fertility management which would increase the crop yields by 5 to 14 per cent. Getachew F. et al., (2021) similarly studied the climate change impacts over the yield of Sorghum crop using crop specific model in Kobo and Meisso. The model predicted that the average temperature would increase by 6^{o}C by 2085 which would have a detrimental effect on crop yields by reducing the yield of rainfed sorghum by 2 t/ ha. The model suggested that an increase in irrigation during drought periods would increase the yields up to 3 t/ha in Kobo and 2 t/ ha in Meisso.

4. Conclusions

The climate trend analysis for Sivagangai district of Tamil Nadu, India revealed that maximum temperature and minimum temperature were negatively skewed and rainfall was positively skewed. Kurtosis for maximum temperature was platykurtic and for the minimum temperature and rainfall of Sivagangai district, the kurtosis was Leptokurtic. The maximum temperature and minimum temperature were less variable and rainfall was highly variable. The study revealed that due to decreased rainfall the area irrigated of major irrigated crops were decreased. On the other hand, the irrigation for drought tolerant crops such as green gram and Cholam were increased indicating the farmers' preference to less water requirement crops due to decreased rainfall and increased temperature in Sivagangai district. So, less water requirement crops like Greengram and Cholam should be promoted by the Agriculture Department among the farmers of the district.

Pearson correlation coefficient revealed that maximum temperature, minimum temperature and rainfall had significant association with area, production and productivity of crops in Sivagangai district of Tamil Nadu. Even though the rainfall was highly variable, it had significant association with area, production and productivity of principal crops. The correlation analysis between climatic variables and area, production and productivity of crops revealed that there exist differential influences of climate variables on crops. Hence there should be micro level plans in accordance with the seasons and studies should be made at micro levels to find suitable season specific mitigation strategy for each crop. The increase in maximum temperature showed to reduce net income of farmers among small, medium and large farms. Hence to reduce maximum temperature, social forestry should be encouraged. Government should provide free tree samplings and encourage farmers to adopt to location specific drought tolerant varieties to mitigate climate change. Cobb- Douglas production function analysis revealed that annual rainfall had a positive relationship with production of paddy. On the other hand, climatic variables of temperature and rainfall were not influencing the groundnut and black gram production.

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