Original Research Article

Climate driven responses in Cocoa for Tamil Nadu

ABSTRACT

Climate influences the spread of the any crop by imposing environmental restrictions. The present investigation was carried to understand the effect of climate on cocoa in various cocoa growing regions. In order to establish the relationship between weather parameters and cocoa productivity, Coimbatore, Theni, and Tenkasi were chosen as the study regions. Historical climate data was acquired from India Meteorological Department (IMD) for the past 30 years (1991-2020). Cocoa yield was simulated by using the Agricultural Policy/Environmental eXtender (APEX) and it was correlated with the weather variables such as rainfall, maximum temperature, minimum temperature, atmospheric water demand (PET), and crop water requirement (ET). Cocoa crop had positive correlation with rainfall and Actual Evapotranspiration. Whereas, both maximum and minimum temperature had significantly negative effect. Climatic conditions, such as decrease in rainfall, increase in temperature and increase in PET, would significantly reduce the cocoa bean yield. The anticipated increase in temperature and erratic rainfall distribution requires suitable management measures for sustainable cocoa productivity.

Keywords: Cocoa, Tamil Nadu, Correlation analysis, Temperature, Rainfall, APEX

1. INTRODUCTION

Cocoa (*Theobroma cocoa L.*) has been found to be a suitable mixed crop in tropics. Although cocoa is grown in many countries near the equator, Côte d'Ivoire, Ghana, and Indonesia contribute for 70% of global production. Since the early 1970s, cocoa cultivation has gained a prominence and emerged as a commercial crop in India [1]. Cocoa industry in India has expanded to a considerable extent in the current decade. A trend of increasing consumption of chocolates and other cocoa-based products has emerged while the production of cocoa beans hardly meets 30% of the demand projected by the processing industry in India. In Tamil Nadu, cocoa growing regions were spread over all the Agro climatic zones. However, it is mainly concentrated over the Western ghats regions and in high altitude areas.

Climate will have a significant impact on the distribution of crops like cocoa [2,3]. Cocoa can be grown on a wide variety of soils, rich in organic matter and nitrogen, well drained and acidic to neutral in reaction. The growth of cocoa is influenced by a complexity of environmental factors, such as rainfall and temperature. Cocoa requires equitable climate with well-distributed annual rainfall of 1500 to 2000 mm under rainfed environment [4]. It requires fairly well defined dry and wet seasons for proper growth, flushing, flowering, fruiting and productivity [5,6,7]. Optimum mean monthly temperature range for cocoa varies from 21.1^{o}C to 32.2^{o}C. When the temperature falls below 15^{o}C, its productivity starts declining. If the temperature falls to 10^{o}C for several consecutive days, then yields would reduce by 50% [8]. Better growth of cocoa is achieved when the humidity is above 85% [9]. Nair et al. reported the requirement of shading in the early years and possibility of cultivating cocoa without shade in Kerala conditions for higher productivity [10]. The trend of rapidly deteriorating climate had halted cocoa productivity in some countries during the last decade [11,12]. There is concern that anticipated rise in global temperature may also rise the potential evapotranspiration that consequently perturb the suitability of climatic condition for cocoa [13].

With the high level of unstable weather conditions prevailing in the environment, it is important to formulate a relation between the weather parameters and yield. When combined with knowledge of each weather component character's direct and indirect contributions to the final composition of the yield, correlations can be used to effectively select genotypes for use in crop improvement programs. In this regard, Crop weather models are used as an effective tool to understand the relationship between weather, soil, management practices and crop growth/productivity. Agricultural Policy/Environmental eXtender (APEX) can be used for the simulation of crops, trees, and other plants [14]. APEX is capable of simulating growth for both annual and perennial crops. The model is capable of simulating mixed stands of up to ten crops or other plants in a competitive environment [15]. In the current study, yield data obtained from the APEX model was used to formulate the relation between weather parameter and cocoa bean yield to understand the effect of climate in various cocoa growing regions.

2. MATERIALS AND METHODS

2.1. Description of the study region

Tamil Nadu has major cocoa cultivation spread over western ghats with high potential for intercropping with coconut. Though coconut is the predominant crop, cocoa as intercrop is grown in limited pockets. APEX model was set up in the representative sites of three major regions of Tamil Nadu, where cocoa crop is picking up as an intercrop in the coconut gardens viz., Coimbatore, Theni and Tenkasi. Coimbatore fall in the western part of Tamil Nadu. While, Tenkasi and Theni falls in the South western region of Tamil Nadu (Fig.1).

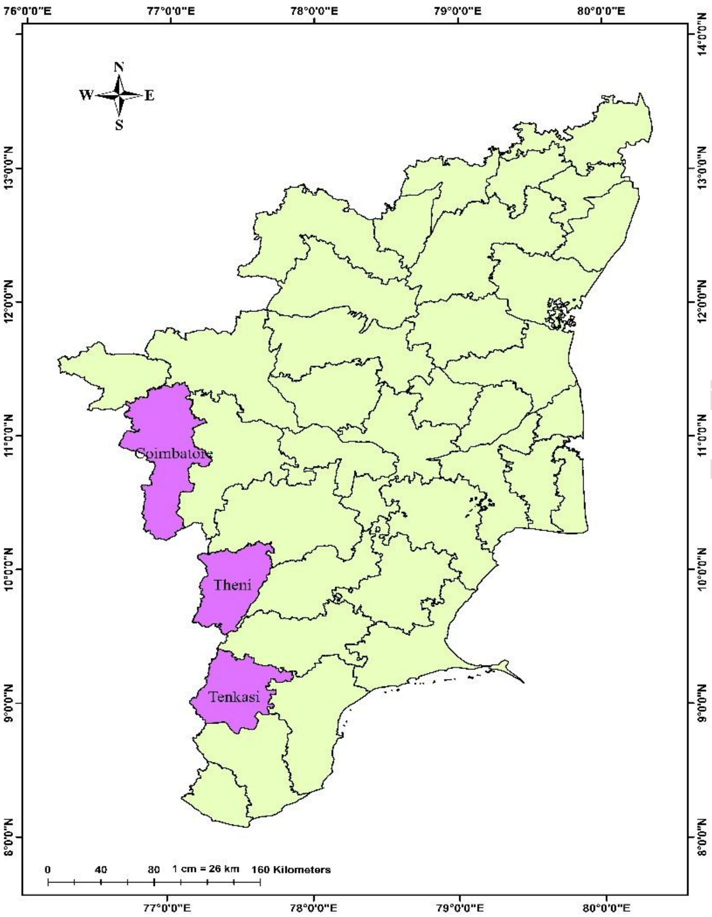

Fig. 1 Study regions

2.2. Weather data

The long-term historical weather data was collected from the India Meteorological Department (IMD). Daily gridded rainfall data with 0.25x0.25 resolution was extracted for the last 30 years period from 1991 to 2020. The daily maximum and minimum temperature data was taken from 1991 to 2020 with a resolution of 0.5x0.5 degree [16,17]. The Climate normal of the study regions were computed using 30 years rainfall and temperature data.

2.3 APEX model parameters

In APEX model, model parameters values have been developed for most of the crops. These values were adopted, and the coefficients were changed to suit the phenology and productivity of Cocoa based on the information from survey and discussions made with the leading cocoa growers. Cocoa crop Management details gathered from the cocoa growers of different study regions through survey were used in the model for calibration and validation as well as for yield prediction. The major information collected were planting density of cocoa, planting season, details on intercultural operations, quantity and time of fertilizer application, time and quantum of irrigation applied, per plant pod yield, per plant dry bean yield and biomass over different years. APEX model was validated with the cocoa yield data collected through survey for the last five years from 2016-2020. Crop performance results were derived from the model. Cocoa yield simulated by the APEX was correlated with the weather variables such as rainfall, maximum temperature, minimum temperature, atmospheric water demand (PET), crop water requirement (ET) estimated for 30 years period to understand the relationship between cocoa productivity and the weather parameters in Tamil Nadu.

3. RESULTS AND DISCUSSION

3.1. Climatic condition of the study area

3.1.1. Rainfall

Uni-model rainfall with peak rainy season in Northeast monsoon was observed for all the study regions. However, rainfall from Southwest monsoon season during the month of September was also predominant in all the study locations. Theni region received highest rainfall among the study locations, followed by Tenkasi region.

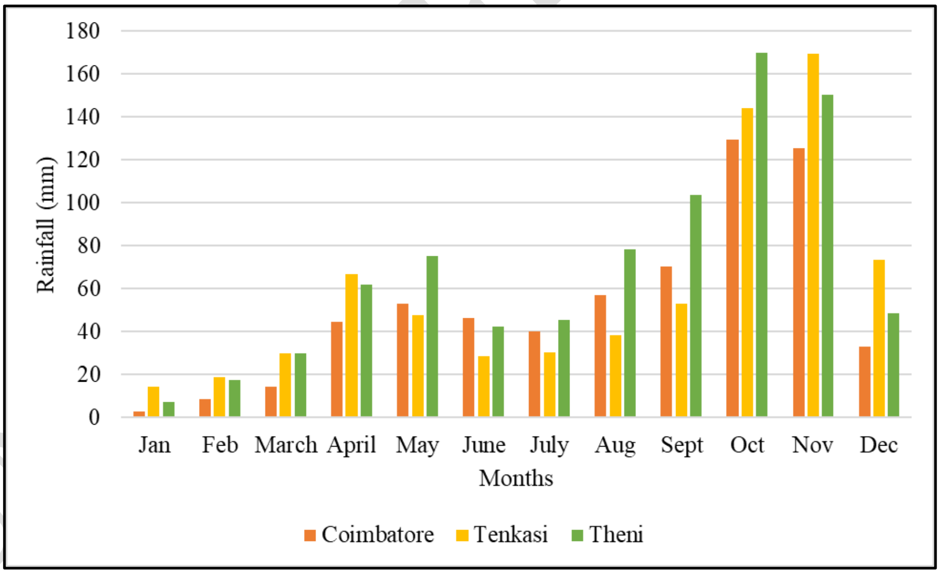

Fig. 2 Mean monthly rainfall (mm) distribution in the study region

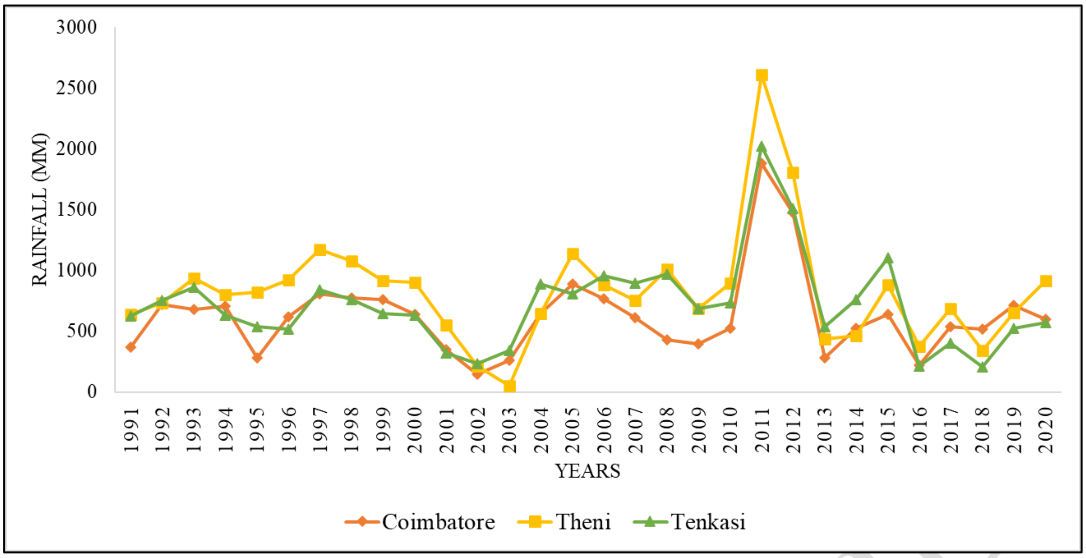

Fig. 3 Annual average rainfall (mm) of regions (1991 – 2020)

Lowest rainfall was noticed in Coimbatore region indicating the requirement of supplemental irrigation from December to July to avoid water stress during flowering phase of cocoa. Mean monthly rainfall distribution of the study region is presented in figure 2. The mean rainfall (1991-2020) recorded was 716 mm, 625 mm and 830.5 mm for Tenkasi, Coimbatore and Theni, respectively. In Tenkasi, the highest rainfall (2022.5 mm) was recorded during 2011, while the lowest rainfall (209.1 mm) was recorded during the year 2018. Highest and lowest rainfall recorded for Coimbatore region was 1884.8 (2011) and 145.7 mm (2002), respectively. The highest rainfall (2610.6 mm) for Theni region was observed during 2011 and the lowest rainfall (51.7 mm) was recorded during 2003. Inter-annual variability in rainfall is also high in the study regions and no trend could be observed in any of the study regions.

3.1.2. Temperature

Maximum temperature in all the study regions increased continuously from January to April months. With the receipt of summer rainfall, the temperatures began to fall from May through July. The temperatures started to soar up during the month of August and continued to increase up to September before the commencement of Northeast Monsoon. Highest maximum temperature of 34.9^{o}C was observed in April over Tenkasi, while Theni records around 33^{o}C during March and April. Coimbatore recorded a maximum temperature of 31.9^{o}C during the month of April. Minimum temperature was comparatively low in Coimbatore region indicating more diurnal variability. Lowest minimum temperature was observed in Coimbatore region (17.3^{o}C) during January month. Tenkasi and Theni were also recorded with low minimum temperature 22.1^{o}C and 20.5^{o}C during the month of January.

Average Maximum and Minimum Temperatures recorded during different months of a year in the study region is presented in figure 4 and 5.

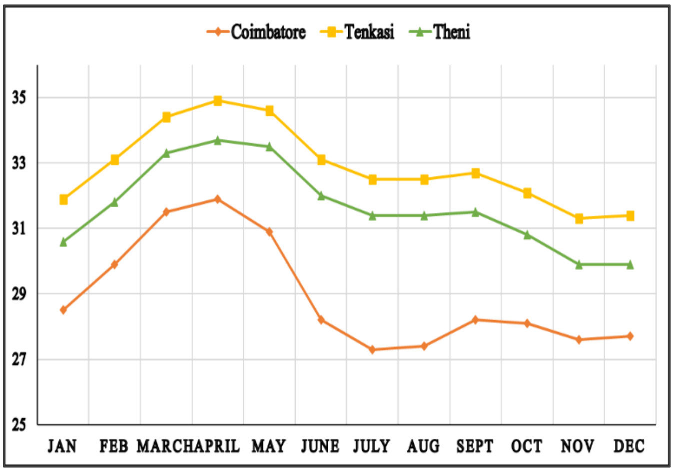

Fig. 4 Mean monthly maximum temperature (°C) over the study regions

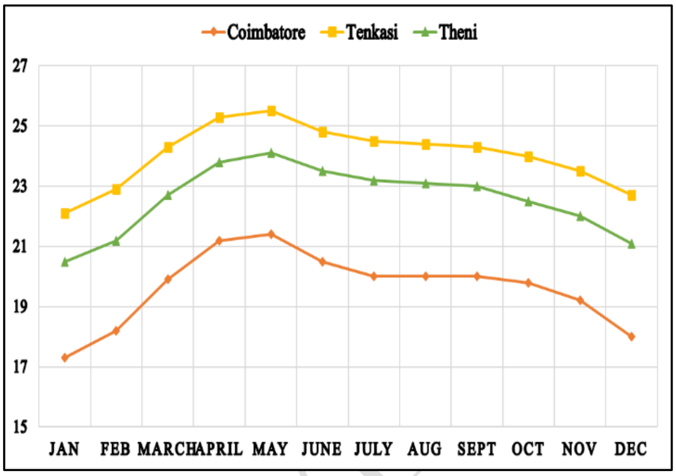

Fig.5 Mean monthly minimum temperature (°C) over the study regions

Warming trend was noticed both in maximum and minimum temperatures for all the study regions. Both maximum and minimum temperatures were higher at Tenkasi compared to all other study regions.

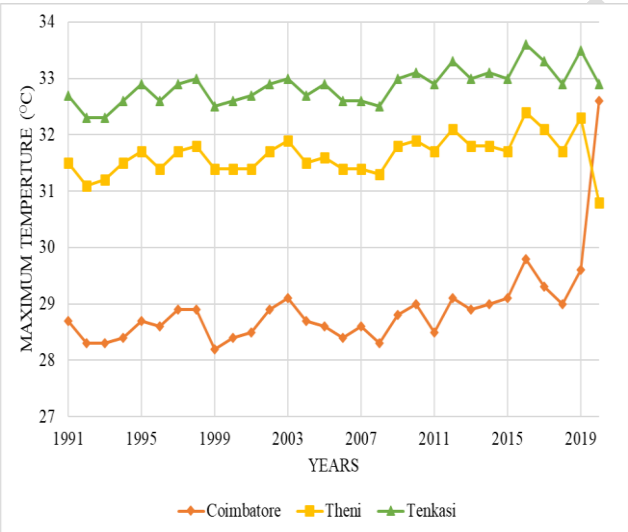

Fig. 6 Average maximum temperatures (°C) over study regions (1991 – 2020).

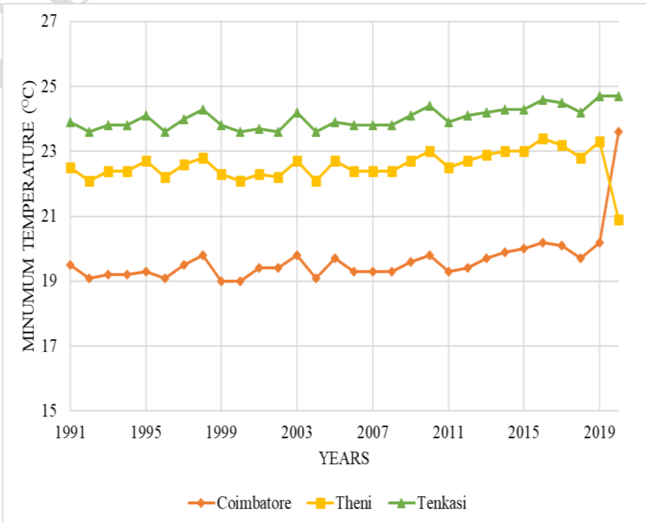

Fig. 7 Average minimum temperatures (°C) over study regions (1991 – 2020).

The annual average maximum and minimum temperature for Tenkasi were 32.9°C and 24.03°C, respectively. The highest mean maximum temperature (33.6°C) was recorded during 2016 and the highest mean minimum temperature (24.7°C) was recorded during 2019. The average maximum and minimum temperature for Coimbatore region were 28.9°C and 19.65°C, respectively. The highest mean maximum temperature (32.6°C) and the highest mean minimum temperature (23.6°C) were observed during 2020. The average maximum and minimum temperature for Theni region were 31.6°C and 22.6°C, respectively. The highest mean maximum temperature (32.4°C) and the highest mean minimum temperature (23.4°C) were noted during 2016 (Fig. 6 and 7). It was also conspicuously seen that all the highest mean temperatures were recorded in the recent years.

3.2. Correlation between weather variables and cocoa productivity

Influence of rainfall, temperature, water stress and temperature stress on cocoa productivity was assessed through APEX model simulations and correlation analysis and the results are presented in Table 1. For correlation analysis past 30 years yield and weather data were considered for establishing the statistically significant relationship between the cocoa productivity and weather parameters.

Table 1 Correlation between weather variables and cocoa growth and productivity

	Annual Rainfall (mm)	Mean Maximum temperature (^{0}C)	Mean Minimum temperature (^{0}C)	Annual PET (mm)	Annual ET (mm)	Water Stress days	Temperature Stress days
Coimbatore							
Cocoa Dry bean yield	.514*	-.673**	-.470*	-.506*	.560*	-.573**	-.410
Cocoa Biomass	.809**	-.807**	-.592**	-.778**	.875**	-.712**	-.636**
Tenkasi							
Cocoa Dry bean yield	.163	-.613**	-.217	-.566**	.479*	-.523*	-.082
Cocoa Biomass	.188	-.681**	-.411	-.628**	.701**	-.765**	-.464*
Theni							
Cocoa Dry bean yield	.222	-.283	-.137	-.167	.194	-.142	-.353
Cocoa Biomass	.326	-.407	-.238	-.367	.636**	-.652**	-.080

*. Correlation is significant at the 0.05 level (2-tailed),

**. Correlation is significant at the 0.01 level (2-tailed).

It could be seen that the annual rainfall had significant positive correlation on biomass and yield of cocoa, identical to the results of Asamoah [18]. Both maximum and minimum temperatures are negatively correlated with biomass and yield. The negative correlation is stronger for maximum temperature compared to minimum temperature indicating that any increase in temperature in future would have negative impact on the yield of cocoa production in all the study regions, which is equivalent to the correlation studies in tea [19].

Similarly, PET has a negative correlation with cocoa production. When PET is more, the atmospheric water demand is also more. Under this condition, the plant would get stressed to take more water from the soil. In contrast, ET indicates the plant water usage, which had positive relationship with cocoa productivity. Water stress days and temperature stress days had negative correlation with all the parameters including cocoa bean yield indicating that any extreme event would affect the yield of cocoa.

It is evident from the results that cocoa responds well to an increase in rainfall in the places receiving less amount of rainfall than in the places which get sufficient quantity of rainfall for cocoa production. Tenkasi and Coimbatore show a significant negative relationship with maximum temperature indicating any changes in the maximum temperature will affect the productivity of cocoa. In Theni and Tenkasi, minimum temperature manifests a weak correlation with cocoa while a slightly negative effect of minimum temperature is observed in Coimbatore. The magnitude of both maximum and minimum temperature effect is found to be higher in the region with less rainfall.

Results indicate that in the less rainfall area, any increase in temperature creates an unfavorable climatic condition for cocoa growth and productivity. Annual evapotranspiration exhibits positive correlation with cocoa in all the study regions. Temperature Stress days show a little influence on cocoa and in all the places it shows weak correlation. Potential evapotranspiration reveals an inverse relationship with cocoa with a significant influence in Coimbatore and Tenkasi regions. Overall, it can be concluded from the correlation that the present weather conditions in Theni had no significant impact in the yield level of cocoa.

4. CONCLUSION

Cocoa crop yield can be highly influenced by the rainfall. Both maximum and minimum temperature showed significantly negative effect whereas the detrimental effect of maximum temperature was observed to be more over the minimum temperature. The atmospheric water demand indicator PET negatively correlated with the cocoa yield. ET had the positive impact on cocoa. Climatic conditions, such as decrease in rainfall, increase in temperature and increase in PET, would significantly reduce the bean yield. Results of correlation analysis clearly indicate the warming environment with dry climatic conditions affects the cocoa productivity considerably. These results can be used to effectively select genotypes for crop improvement programs and adaptation measures in need to cope with the anticipated increase in temperature and erratic rainfall distribution in Tamil Nadu.

5. REFERENCES

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