Research Article

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Climate variability and change in the spices and plantation cropping systems in Kerala state, India

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Abstract

Kerala state in India has rich bio-diversity and tropical rain forests and is spread in 13 agro-ecological zones under the humid tropics. Rainfall decline (annual as well as monsoon), increase in temperature and climate shift towards lesser humid zones within the humid climate are the notable characteristics of the state. Cropping system changes, as well as changes in the production of spices and plantation crops in Kerala, were analyzed from 1952-53 to 2018-19. Area and production changes of various crops in the Idukki district have also been studied and presented in this paper. The average temperature in Kerala has risen by 0.65 °C from 1956 to 2014. In Idukki high ranges, the maximum temperature is increasing, and the minimum temperature is declining, resulting in a widening of temperature ranges. Such a scenario may adversely affect the thermo-sensitive crops, which may need urgent attention as these crops are grown in the forest-agro-ecosystems across the Cardamom Hill Reserve (CHR) of the Idukki district. Deforestation, the shift in cropping systems, declining wetlands, and depletion of surface and groundwater resources had deepened the adverse effects of floods and droughts on spice and plantation crops. Therefore, there is an urgent need for proactive steps on a short and long-term basis against the climate change risks for the sustenance of crop production both in terms of quality and volume.

***Keywords*:** Climate change, cropping system, plantation crops, spices, temperature range

Introduction

Climate change/variability is a reality across the world. At the national and regional levels, the repercussions of climate change/variability are felt in one form or another (IPCC, 2021). Weather extreme events, *viz*., drought and flood, cold and heat waves, severe cyclonic storms, hail storms, *etc*., are common in recent times, as the top warmest years experienced were after 1995. The hottest year was 2016, followed by 2020. Globally, the year 1995 was regarded as a weather-related disaster year. Torrid heat in Alberta (Canada) and parts of Europe and Asia during the late-winter period in February 2021, extreme heat in parts of Russia and eastern Europe in June and July of the same year, with temperatures in the Arctic Circle above 30 °C and highest June temperature recorded in Moscow and St. Petersburg are few examples of the latest weather abnormalities around the world. The global average temperature has increased by more than 1°C over the past 100 years. It is projected to rise by 1.0 to 3.0 °C in the present century if strict measures are not taken to cut greenhouse gas emissions into the atmosphere (World Meteorological Organization, 2021). Hingane *et al.* (1985) reported that the country as a whole experienced an increase in annual surface air temperature by 0.4 °C over 100 years in the 20th century, but in the recent four decades, the rate of increase had slowed down. The seasonal monsoon rainfall declined over East Madhya Pradesh and adjoining areas, northeast India and parts of Gujarat and Kerala (Kumar *et al.,* 2002).

The temperature and rainfall trends vary significantly at the regional level, and studies are scanty.

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The year 1987 was the warmest. Recent years also recorded higher temperatures in tune with global warming. The recent past decade, 2011-20, was the warmest in the state, followed by 1981-90 (India Meteorological Department, 2021). Monsoon rainfall is declining across the state, with large inter-annual variability (Gopakumar and Rao, 2018). However, 2013, 2017, 2018 and 2019 witnessed heavy rainfall events leading to waterlogging and floods across the state. In 2020 and 2021, some pockets received heavy to very heavy rainfall. Continuous heavy to very heavy rainfall events are often received in the midlands and high ranges, triggering landslides. The years 2007, 2013, 2018, 2019, 2020 and 2021 recorded large numbers of landslides in the mid and highlands of the state, which caused human causalities and damage to life and properties. The distribution of rainfall often leads to heavy rainfall within a very short span of time during the second half of the monsoon season (August and September). This may result in sudden floods during monsoon or sometimes drought during summer in the event of a preceding poor monsoon. This frequent phenomenon can be attributed to global warming, which is due to man-made interventions. It could result in severe consequences in the agricultural sector, including food security. An attempt was made to analyze rainfall and temperature trends, climate shifts and shift in cropping patterns in Kerala and Idukki district, where spices and plantation crops are grown extensively and intensively.

Materials and methods

Area, production and productivity of major crops grown in Kerala were collected from the Department of Economics and Statistics, Government of Kerala, from 1952-53 to 2018-19. The major trends in the area, production and productivity of major crops in Kerala were worked out. The area, production and productivity data of the Idukki district were also collected from the same source. Monthly rainfall during the period 1871-2014 was collected from Parthasarathy *et al.* (1995). Daily rainfall data from 1995 to 2018, obtained from India Meteorological Department (IMD), Trivandrum, were used. Monthly temperature (maximum and minimum) data were collected from the IMD for the study period. The mean temperature and temperature range were derived from the maximum and minimum temperatures. The climatic parameters related to high ranges of Idukki were sourced from the meteorology station attached to the Indian Cardamom Research Institute, Spices Board, Ministry of Commerce and Industry, Government of India. The temperature range was computed by calculating the maximum and minimum temperatures. Time series analysis was carried out, and trends were examined for rainfall. Climate shifts were worked out to understand the negative impact of climate on cropping systems over Kerala and the Idukki district.

The moisture index was calculated and used to work out climate shifts over Kerala. Thornthwaite and Mather (1955) water balance procedure was used to compute the yearly water balance of the state for the period from 1901 to 2009. The monthly aridity index (Ia), humidity index (Ih) and moisture index (Im) were computed from 1901 to 2009 using the formula:

$$Ia = WD/PE \times 100;$$

$$Ih = WS/PE \times 100;$$

$$Im = Ih - Ia$$

Where PE is potential evapotranspiration, WS is water surplus, and WD is water deficit.

Results and discussion

The annual and monsoon rainfall in Kerala showed a declining trend from 1950 to 2018, while the post-monsoon showed an increasing trend (Figs. 1, 2 and 3). The same trend was noticed across the Idukki district, where spices are grown abundantly. The average surface air temperature across the state increased by 0.65 °C from 1956 to 2014. The decline in annual rainfall was 17 mm decade^{-1}, and that of the southwest monsoon was 10.6 mm decade^{-1}. At the same time, post-monsoon rainfall exhibited an increasing tendency (@ 8.5 mm decade^{-1}). The climate of Kerala also exhibited a tendency to move from wetness to dryness within the humid tropical climate (B_4 to B_3 category within the humid regime) during the period 1901 to 2009, according to the climate classification of Thornthwaite and Mather (1955), (Fig. 4) and has shown the same trend in the succeeding years. This trend might be disturbed in the events of continuous high rainfall.

The maximum temperature increase (Fig. 5) was 0.99 °C. In comparison, the increase in minimum

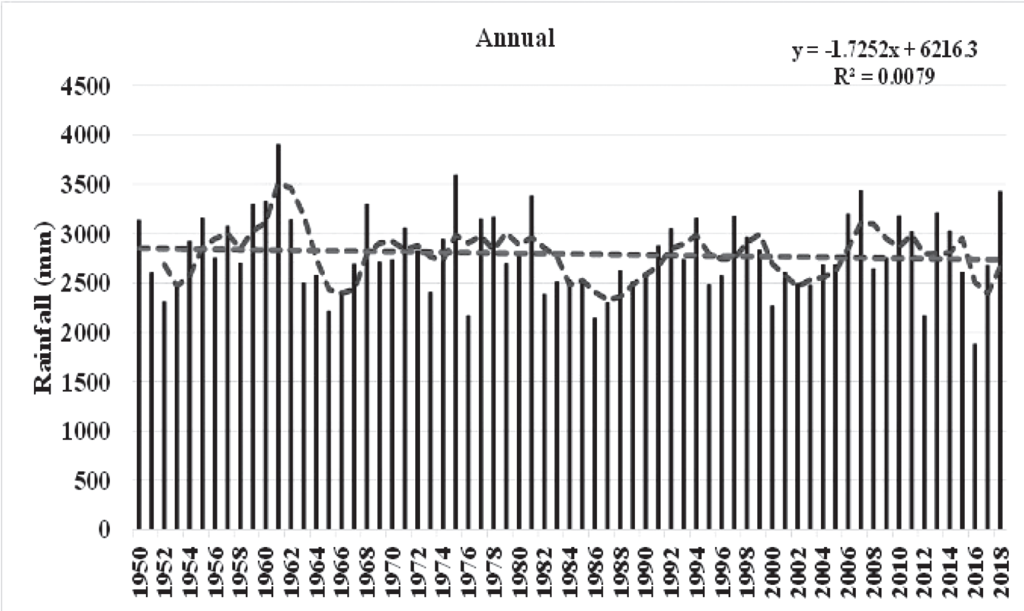

Fig. 1. Trend in annual rainfall over in Kerala from 1950-2018

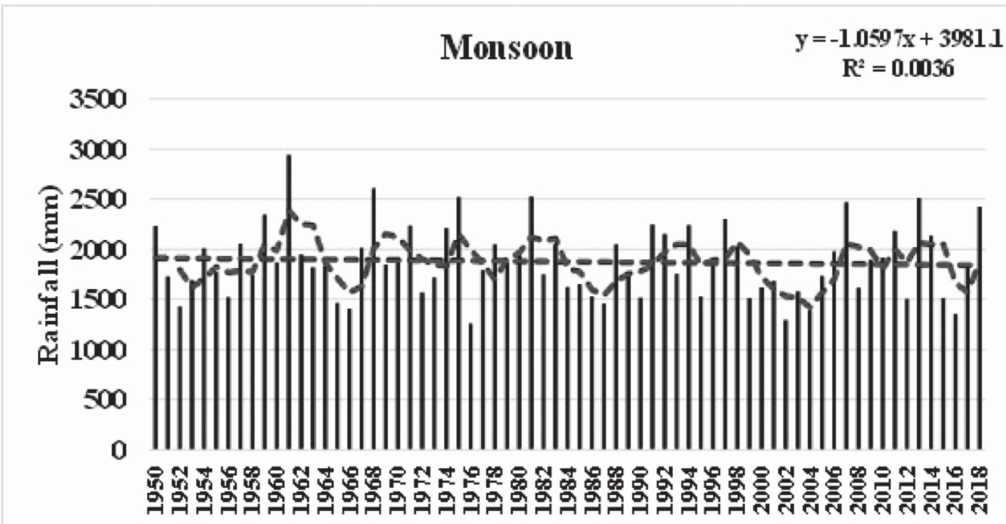

Fig. 2. Trend in monsoon rainfall over Kerala from 1950-2018 (June-Sept.)

temperature was only 0.33 °C from 1956 to 2014 (Fig. 6). Temperature increase of 0.65 °C was reported in the mean surface air temperature over the state of Kerala since 1956 (Fig. 7).

Temperature variability across the high ranges (Idukki district) has been examined to understand the trend. It revealed that the maximum temperature had shown an increase of 0.25 °C per decade while the minimum temperature showed a declining trend (0.31 °C per decade) during the period 1989 to 2020 (Figs. 9 and 10), indicating that the temperature range is widening, which was of the order of 0.46 °C per decade (Fig. 11). Temperature range was computed as the difference between the maximum and minimum temperature at a given place. Earlier studies also confirmed that temperature across the high ranges of the state is increasing (Rao *et al.,* 2008; Krishnakumar *et al*., 2008). An increase in

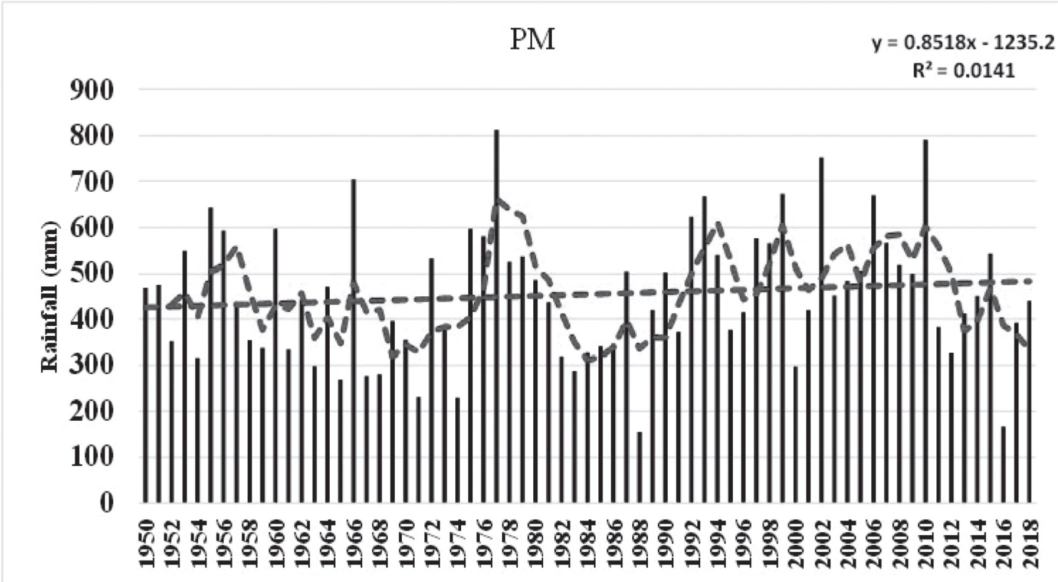

Fig. 3. Trend in post monsoon rainfall over Kerala from 1950-2018 (Oct. & Nov.)

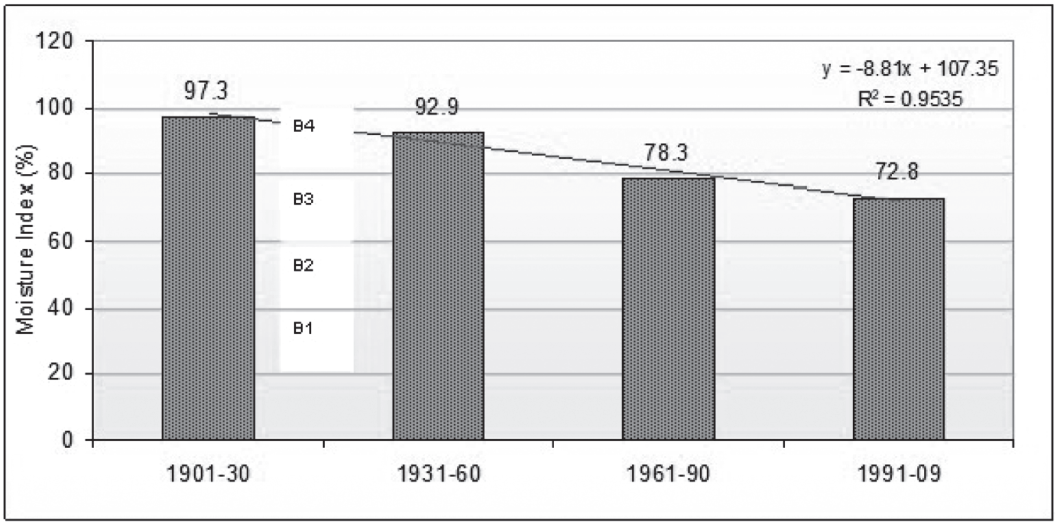

Fig. 4. Trend in climate shift over Kerala

temperature range may not be good for crops growing across Kerala's high ranges. Widening the temperature range (an increasing trend in maximum temperature while a declining trend in case of minimum temperature) may adversely affect the thermo-sensitive crops (crops which are sensitive to changes in ambient air temperature, *viz*., cardamom, cocoa, coffee, tea, cashew *etc*.) grown in high ranges in the long run as they are adapted to the prevailing weather of the high ranges (Rao *et al*., 2008). In the context of climate change and the global warming scenario, this can cause a major threat to thermo-sensitive crops.

The shift in the area of major plantation crops and spices across the state was also examined. The area under rubber has shown a maximum increase (314 per cent) from 1952-53 to 2018-19 (Table 1). The area under the important beverage crop, tea, has declined by 18.9 per cent, while coffee has increased by 107 per cent. The area under coconut, cashew, cardamom, arecanut and black pepper also recorded an increase (Fig. 8). Rubber has moved to

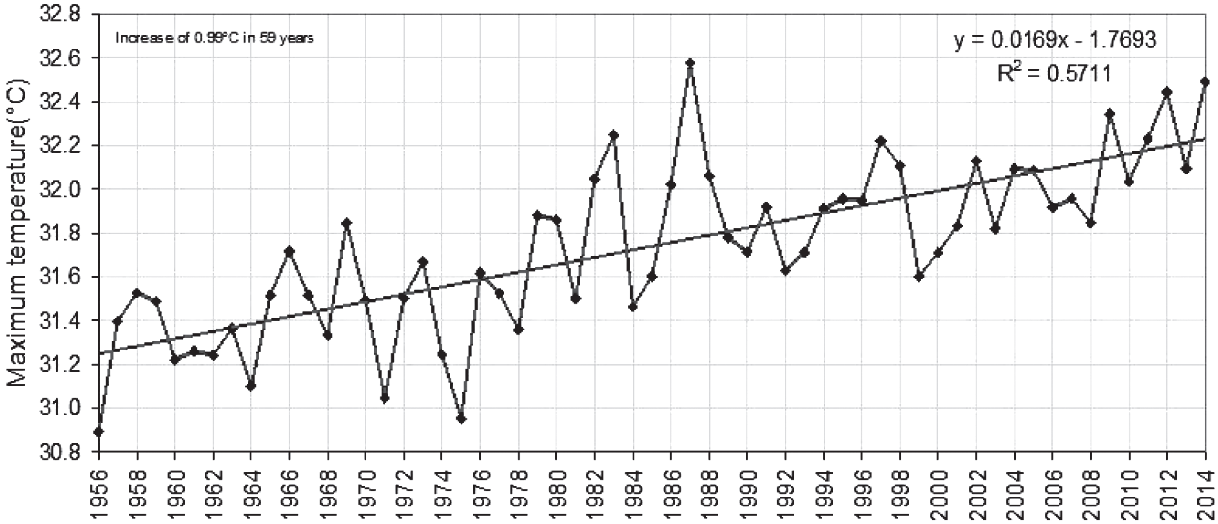

Fig. 5. Trend in max. temperature over Kerala from 1956-2014

many zones in Wayanad over the above period**.** The highest increase in area was noticed in Rubber (314%), followed by coffee (108%), coconut (86%), arecanut (88%) and banana (71%). Paddy area reduction is alarming (73%). Rubber has spread to more and more areas of the state in mid-highlands and high ranges. The paddy cultivating areas of the high ranges either paved the way for rubber cultivation or other seasonal crops like pineapple, arecanut, banana *etc*. The changes in the production of the above crops in the state were also examined. It revealed that cardamom, rubber, arecanut and coffee recorded maximum increase of 9282 per cent, 2871 per cent, 2144 per cent and 1202 per cent, respectively (Fig. 8). Decline in production was noticed in the case of cashew (72%).

The area under fruit crops, *viz*., mango, jackfruit, banana and pineapple, showed a significant increase in the Idukki district from 1984-85 to 2018-19 (Table 2). The area under banana

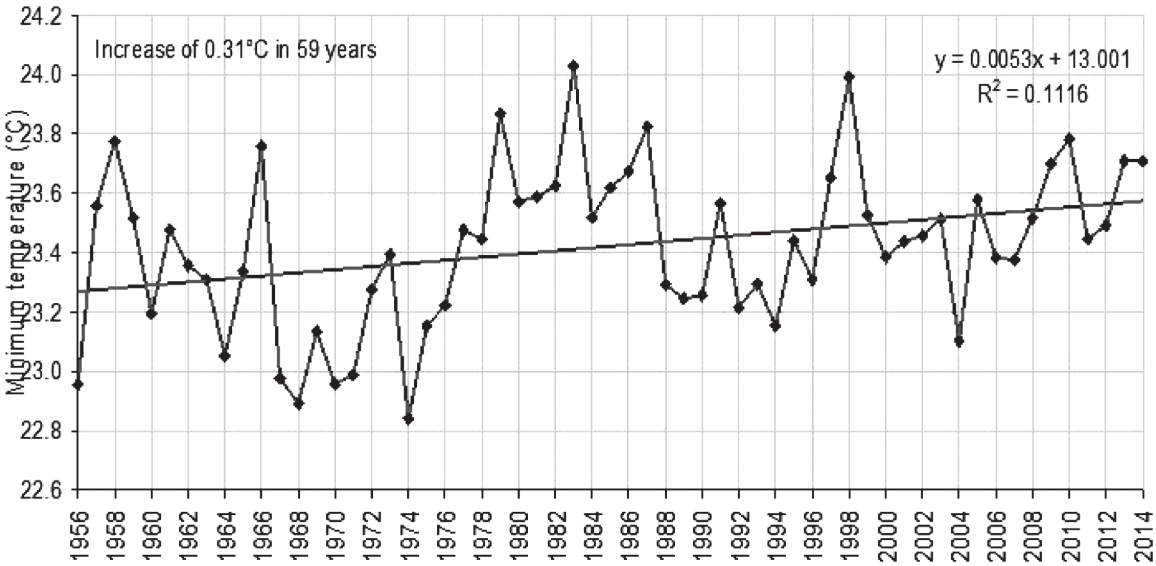

Fig. 6. Trend in min. temperature over Kerala from 1956-2014

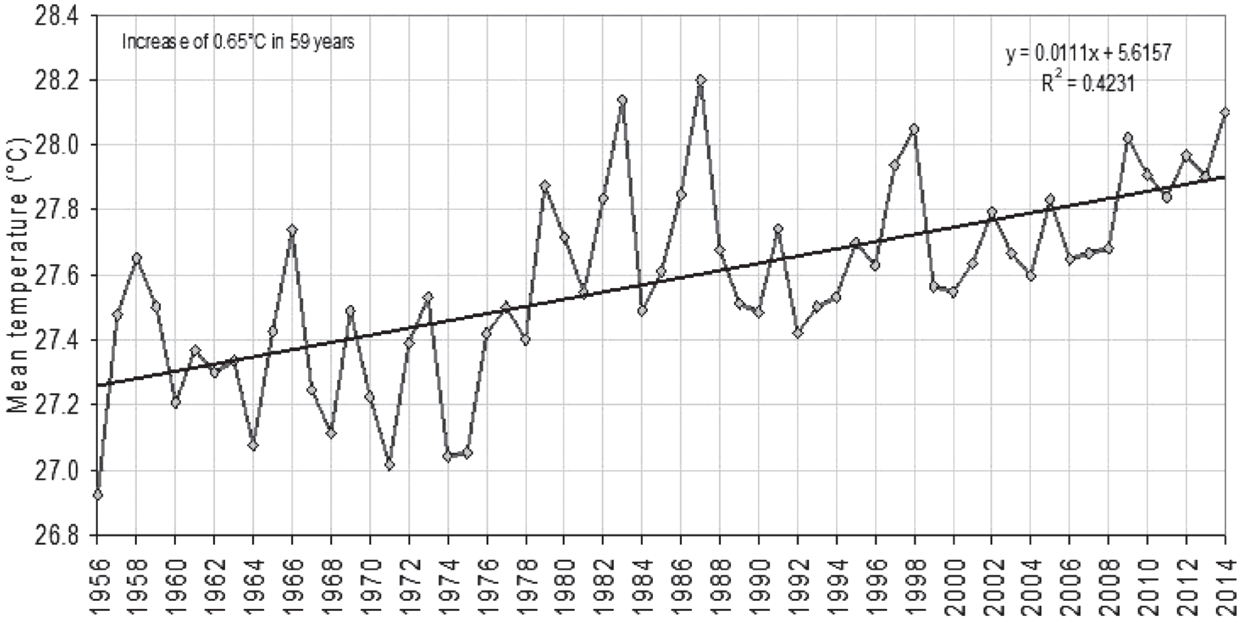

Fig. 7. Trend in mean temperature over Kerala from 1956-2014

cultivation in the Idukki district was only 181 thousand hectares during 1982-83, which has escalated to 6620 thousand hectares during 2018-19. The area increase was 1734 per cent. A significant increase in area was seen in coffee (161%), mango (228%), cocoa (383%), jack (656%), pineapple (333%) and rubber (41%), while the area under tea, the major beverage crop in Idukki, showed a meagre increase of 8 per cent. Paddy cultivable area has declined by 92 per cent during the study period in the high ranges of Idukki. The area under cashew, papaya and tapioca was declining in Idukki high ranges. There was a shift in the cropping system as the index of non-food grain crops was increasing while it was declining in foodgrain crops, which might pose a challenge to the state's food security. In tune with the changing climate, cropping patterns across the state and the high ranges are likely to change to adapt to the future climate change scenario. Unlike seasonal crops, the impact of climate change on plantation crops like rubber, arecanut and cashew on a long-term basis in terms of global warming may not be seen as they are grown under tolerable limits of surface air temperature across the state.

The effect of floods, as noticed in 2007, 2013, 2018 and 2019, and prolonged summer droughts, as noticed during the summers of 2004, 2012 and 2016, is likely to recur under the predicted global warming and climate change scenario in the ensuing decades. The disastrous summer drought of 2016 was a rare event in the state's history, recording a total failure of post-monsoon. There was a deficit of 63 per cent in post-monsoon rainfall across the state. Coupled with deficit monsoon and the failure of post-monsoon, almost all the surface water resources across the state dried up during summer due to the absence of summer showers. This situation led to a

Table 1. Percentage changes in the area of major plantation crops from 1952-53 to 2018-19 in Kerala

Sl. No.	Crops	1952-53 area (000 Ha)	2018-19 area (000 Ha)	% change in area
1.	Coconut	409.40	760.90	85.86
2.	Cashew	35.41	38.78	9.52
3.	Cardamom	25.54	38.88	52.23
4.	Coffee	409.40	849.70	107.55
5.	Tea	44.98	36.47	-18.92
6.	Arecanut	50.99	95.74	87.76
7.	Banana	31.00	52.90	70.65
8.	Black pepper	78.80	82.60	5.03
9.	Paddy	742.16	202.20	-72.76
10.	Rubber	133.10	551.10	314.05

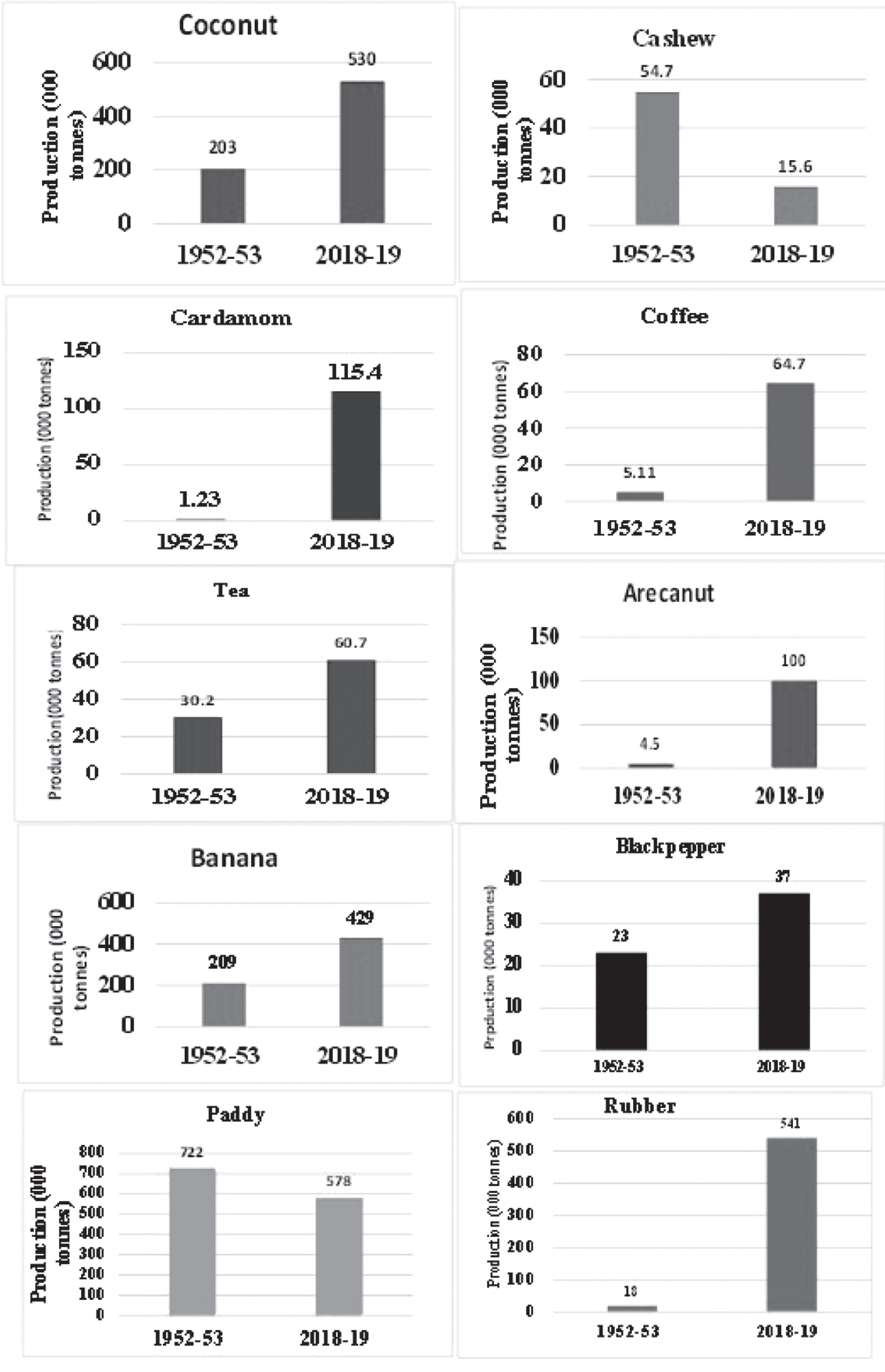

Fig. 8. Percentage change in production from 1952-53 to 2018-19 of major plantation crops in Kerala

severe water shortage. Even the drinking water supply was adversely affected. Many reservoirs dried up and leading to hydrological drought. The over-exploitation of groundwater across the high ranges for irrigation aggravated the situation.

Unprecedented summer showers received during 2008 devastated paddy crops in the state. The quality and quantity of black pepper were also affected. The total coconut production of the state during the decade of 1981-90 was observed to be

Table 2. Percentage changes in the area of major plantation crops in Idukki district from 1984-85 to 2018-19

Sl. No.	Crops	1984-85 area (000 Ha)	2018-19 area (000 Ha)	% change in area
1.	Cashew	1189.0	944.6	-20.6
2.	Coconut	15036	14513.6	-3.5
3.	Tea	23804	25588	7.5
4.	Coffee	4875	12717	160.9
5.	Rubber	28749	40600	41.0
6.	Cocoa	1936	9342	382.5
7	Mango	1663	5450.8	227.8
8	Jack	2214	16732.7	655.8
9	Banana	181	3319.8	1734.1
10	Pineapple	301	1302.3	332.7
11	Pappaya	626	917.1	46.5
12	Paddy	8475	688.3	-91.9

lower compared to that of other decades due to the occurrence of drought during summer in the state. The summer droughts that occurred in 1983, 1989, 2004, 2012 and 2016 severely affected the total coconut production to a greater extent during the following years in the state. The cocoa yield was also affected whenever the summer temperature escalated by 1-3 °C, as noticed in 2004, 2012 and 2016. A similar trend was observed in cardamom also. As the temperature range is likely to increase and deforestation is alarming, crops like cardamom, coffee and tea need attention as these crops are grown under the influence of typical forest-agro-ecosystems. It reveals that crop losses or gains are subjected to climate variability. Crop simulation models predict the decline in yield across the country due to increased temperature and atmospheric carbon dioxide levels. In the case of coconut, the trend was not seen over Kerala; however, the coconut gardens in nontraditional areas (Karnataka, Tamil Nadu and Andhra Pradesh) are likely to suffer due to global warming. Similar may be the case of rubber and arecanut. The paddy crop of *Kole lands* of Thrissur district and *Kuttanad* area were devastated due to the unusual summer showers received during March 2008. But, this rain was beneficial to coconut, cardamom and arecanut.

Over the past three decades, starting from 1990-91 (78.72 kg ha^{-1}), there was a productivity increase of almost five times in cardamom and a

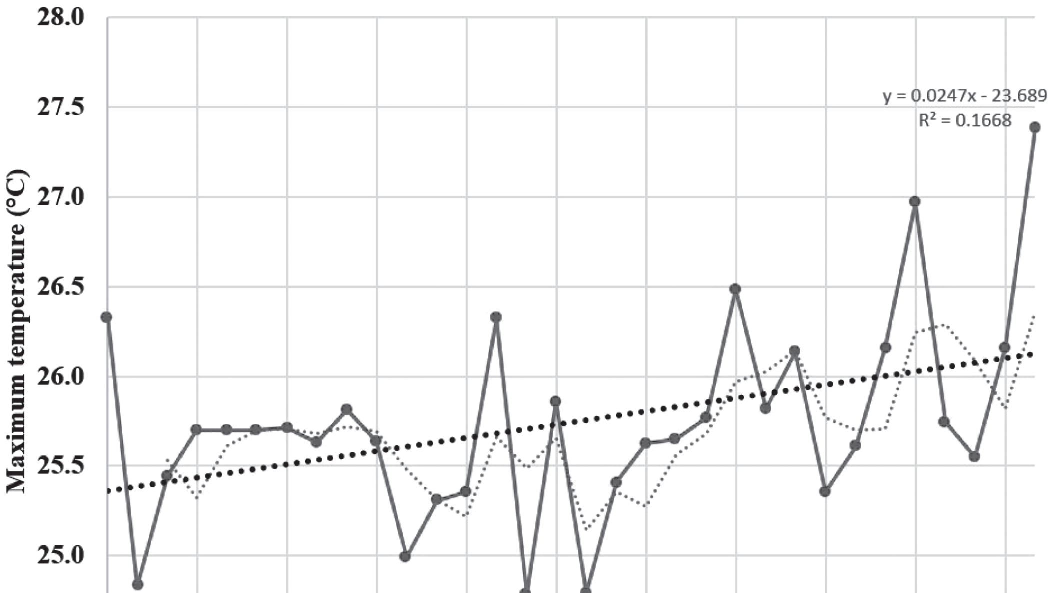

Fig. 9. Trend in max. temperature in Idukki district from 1989 to 2019

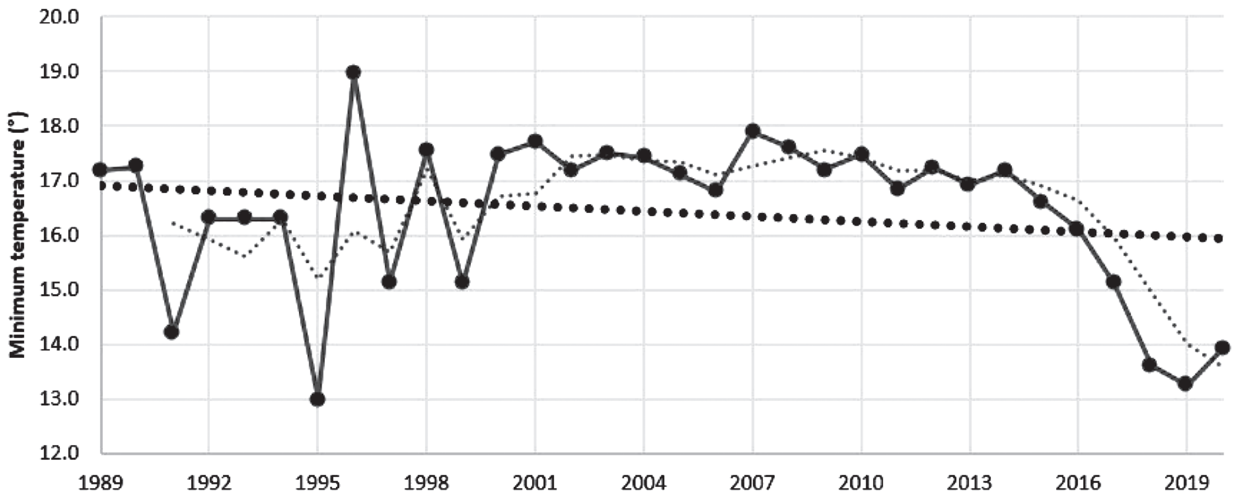

Fig. 10. Trend in min. temperature in Idukki district from 1989 to 2019

9.42 percentage decline in the area. However, the agronomic constraints resulting from climate change led to a substantial increase in the cost of cultivation (Thomas *et al.*, 2010). An increase in temperature range across the Idukki district may pose a threat to thermo-sensitive crops like cocoa, black pepper, cardamom, coffee and tea (Figs. 9-11). Similarly, the untimely heavy winter precipitation during January 2021 caused massive crop losses in the Idukki district. Vegetable tracts of Vattavada and Marayur sugarcane were the worst affected areas. The state received an unusually heavy rainfall of 105.5 mm during January 2021 as against the normal of 11.0 mm during January (Fig. 12). The above cases clearly show that crop losses or gains are subjected to climate variability rather than climate change. However, crop simulation models indicate a decline in yield across the country due to increased temperature and atmospheric carbon dioxide levels. From time to time, all crop simulation model projections must be tested and revalidated to obtain realistic crop projections in the climate change scenario.

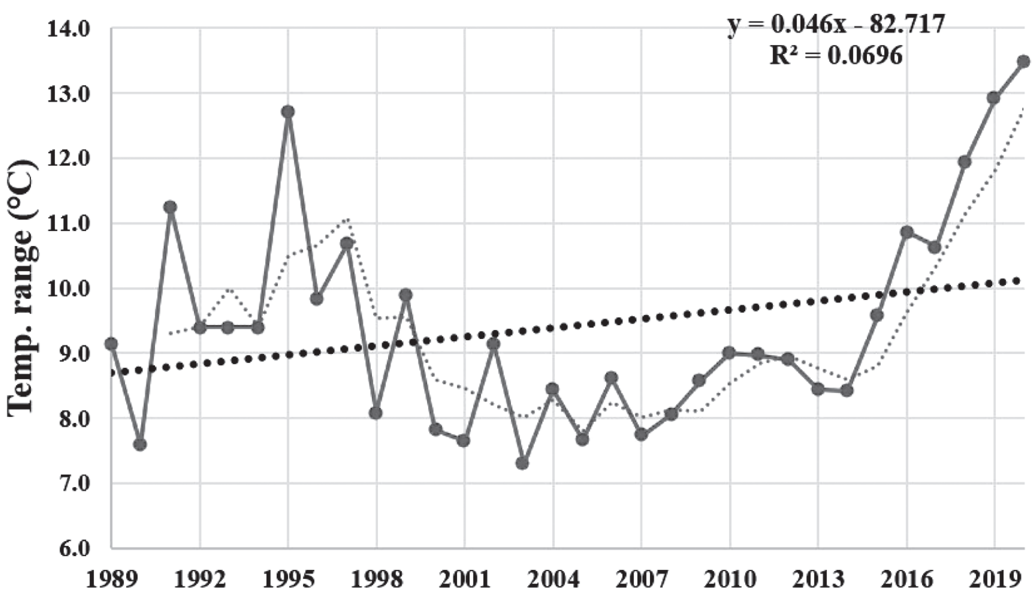

Fig. 11. Trend in temperature range in Idukki district from 1989 to 2019

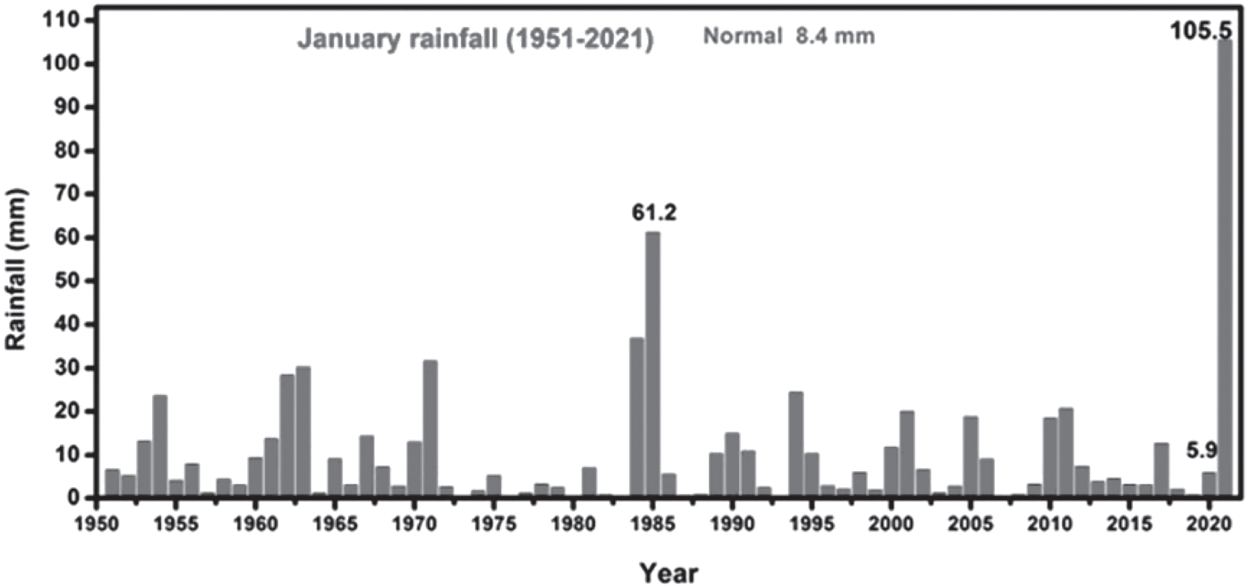

Fig. 12. Rainfall received during January from 1950 to 2021 over Kerala

As model output always overestimates, an intensive field test is required for confirmation. The need of the hour is to generate a database through research efforts to understand climate change and its relationships with cropping systems, especially in the spices and plantation sector.

Conclusion

During the study period (1950-2018), the annual and southwest monsoon rainfall over the state has been found to decline. Within the humid tropical climate, the climate of Kerala exhibited a propensity to move from wetness to dryness during the study period. This trend may be disturbed in the events of continuous high rainfall. The impact of climate change on crops like coconut, rubber, arecanut and cashew in terms of global warming on a long-term basis may not be seen as in the case of seasonal crops because they are grown under tolerable limits of surface air temperature across the state. The thermo-sensitive crops like cocoa, black pepper, cardamom, coffee and tea may be under threat as the temperature range across the Idukki district is increasing. In the high ranges of Idukki, the maximum temperature was found to be rising, and the minimum temperature was found to be diminishing, resulting in a widening of the temperature range. This may adversely affect the thermosensitive crops, which may need urgent attention as these crops are grown in the forest-agro-ecosystems.

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