Chapter 10

Summary and Conclusions

Kerala is situated in the southern tip of India between 8° 15’ N and 12°50’ N latitude and 74°50’ E and 77°30’ E longitude. It is popularly known as “Gods own country”. It is the “Gateway of monsoon” to the country as it is the entry point of monsoon to the Indian subcontinent. It is also one of the wettest places in the humid tropics. The annual rainfall of Kerala is about 2.7 times the national average, receiving about 3000 mm as against 1150 mm of the national average. The State is bestowed with 44 rivers and a number of backwaters, streams, canals and other inland water bodies and has rich biodiversity and the tropical rainforests spread in 13 agro-ecological zones. The Indian Ocean in the South, the Arabian Sea in the West, and the Western Ghats in the East surround the State. Due to the presence of North-South orientation of the Western Ghats, the State is blessed with copious rainfall during the southwest monsoon season (orographic effect). Though Kerala is identified as a plantation State, the major staple food is rice.

Though, more or less assured amount of rainfall is being received almost every year over the State, the inter-annual and intra-seasonal variability has been increasing in recent decades. Increasing uncertainties in rainfall are also being experienced as the State received deficit monsoon consecutively for more number of years during the current decade. Droughts during summer and floods during rainy season are not uncommon in Kerala. Weather related disasters like cloudbursts and landslides/mudslides are not uncommon across Kerala. Even sunburns were noticed in the border of
Thrissur and Palakkad districts in March 2010. The State's economy, to a great extent, is dependent on production of plantation crops, which is very much influenced by weather factors. Therefore, one of the objectives of the study was to update the knowledge on regional climate change/variability across the country. The study also aimed at understanding the climate change / variability zone-wise within the State of Kerala and to understand the vulnerable zones to climate change / variability. It also envisaged to understand the impact of climate variability / change on plantation crops and food security under the projected climate change scenario of Kerala. The results that emerged from the study are presented here:

The increase in annual mean temperature was 0.49°C over a period of 103 years (1901-2003. The increase in annual maximum temperature over the country was 0.76°C and 0.22°C in the case of minimum temperature resulting in an increase of 0.54°C in the annual temperature range. All the months showed warming trends though the trend in night temperature declined in half of the months (Jan, May, June, July, August and September). Increase in mean temperature was relatively high in post monsoon (0.0085°C per year), followed by winter (0.007°C per year) during 1901-2003. Among various zones in the country, increase in maximum (0.012°C per year), mean (0.0071°C per year) and range of temperature (0.0098°C per year) was relatively high across the West Coast of India when compared to that of other zones. It was not so in the case of minimum temperature as the Western Himalayas of India recorded a larger increase in minimum temperature when compared to that of other zones across the country.
The projected annual maximum temperature on tri-decadal basis from the base period of 1961-90 will be 0.9°C, 1.9°C and 2.8°C by 2020, 2050 and 2080 AD, respectively at the current rate of increase in India. It would be 0.7°C, 1.4°C and 2.1°C in the case of minimum temperature by 2020, 2050 and 2080 AD, respectively. The rate of increase in mean temperature is similar to that of minimum temperature (0.7°C, 1.4°C and 2.1°C, by 2020, 2050 and 2080 AD, respectively). Of course, the rate of increase in ensuing decades may vary depending upon the emission of greenhouse gases, in particular the emission of CO₂ as it accounts for about 70-75% of increase in atmospheric temperature.

The annual rainfall over the country showed a marginally increasing significant trend during the study period of 1813 to 2006. It was evident in 1871-1900 and 1931-60. An increasing trend in rainfall was noticed in all the seasons viz., southwest monsoon, post monsoon and winter except in summer during which there was a marginal decline in annual rainfall. At the same time, rainfall was increasing in recent decades during post monsoon season. The monthly rainfall also indicated a decline in June and an increase in July, August and September during the monsoon season, indicating a shift in rainfall in some zones.

On a regional scale, the maximum, minimum, mean temperatures and temperature ranges over Kerala showed an increasing trend during the study period from 1956 to 2009 and were significant since 1981 onwards. The increase in maximum temperature, minimum temperature, mean temperature
and temperature range across the State was 0.72°C, 0.22°C, 0.48°C and 0.51°C, respectively over a period of 54 years.

The rise in maximum temperature was high (1.46°C) across the high ranges, followed by the coastal belt (1.09°C) of Kerala while the increase was relatively marginal (0.25°C) across the midlands. Therefore, the high ranges and coastal belt in Kerala are more vulnerable in terms of the rate of increase in temperature due to global warming. The added disadvantage for the coastal belt due to climate change was a possible rise in sea level.

At the current rate of tri-decadal increase in maximum temperature of 0.4°C during the study period, the increase in maximum temperature across Kerala is likely to be between 1.2°C and 1.6°C by 2051-80 and 2081-2100, respectively. It would be between 0.3°C and 0.4°C in the case of minimum temperature during the above periods. The increase in mean temperature is likely to be between 0.59°C and 0.76°C by 2051-80 and 2081-2100, respectively. In the case of temperature range, the increase is likely to be between 0.89°C and 1.14°C by 2051-80 and 2081-2100, respectively.

The trend in onset of monsoon revolves around 1<sup>st</sup> June +/- 7 days. It indicated that monsoon onset is likely to be before 1<sup>st</sup> June rather than after 1<sup>st</sup> June during the ensuing years.

A decline in monsoon rainfall and an increase in post monsoon rainfall were the trends obtained for the State of Kerala as a whole with the cyclic trends of 40-60 years. The contribution of southwest monsoon rainfall to the annual value is declining while the post monsoon contribution is increasing. It was also evident that rainfall during June and July is declining and that of
August and September is increasing within the monsoon period. The moisture index across the State of Kerala was moving from B4 to B3 humid, indicating that the State was moving from wetness to dryness within the humid climate. The intensity of summer droughts was also increasing across the State of Kerala though it falls under the heavy rainfall zone due to unimodal rainfall. The recent decades also witnessed more number of droughts.

The rate of increase in Indian foodgrains production was below the normal of 12.5% since last 15 years due to frequent occurrence of weather abnormalities like floods, droughts, heat and cold waves. While area and production of paddy was declining in Kerala, the productivity was increasing during the study period. The decline in paddy production varied between 2 to 17.6 per cent due to heavy rainfall. On an average, the effect of heavy rainfall on paddy production was 8.5 per cent. In the case of paddy productivity also, the effect of heavy rainfall during *kharif* varied between 2.2 and 14.9 per cent. Erratic behaviour of monsoon, extended post monsoon rainfall with intermittent dryspell during post monsoon and unusual summer rains are detrimental to paddy production in the State as noticed in recent years. Under the projected climate change scenario, the frequency of such instances is likely to be more and hence it is a threat to paddy production in the State.

The paddy productivity in Kerala is unlikely to decline due to long term climate change such as increase in temperature, but bound to decline to
some extent through the abrupt short term changes as noticed in 2008, 2009 and 2010 in the form of monsoon uncertainties like long dry spell and floods. In fact, the paddy productivity can be increased further at the current rate of increase in temperature during kharif through better crop improvement and management techniques, for which R&D initiatives need to be taken up on priority basis as a part of food security under the projected climate change scenario.

High rainfall during the monsoon period, followed by a prolonged dry spell from November to May is detrimental to all the selected plantation crops under the study. However, cashew and black pepper perform relatively better under the prolonged dry spell conditions during the summer. In the case of black pepper, mortality rate was high in young pepper vines under prolonged dry spell/drought conditions during summer. Coffee and black pepper respond differently to summer rainfall because it is good in the case of coffee as it requires blossom and backing showers between February/March and March/April while it is not so in the case of black pepper as it needs dry spell. Therefore, in sub mountainous regions of Wayanad district, coffee and pepper are planted as a mixed farming system. That is why, when one crop (coffee) is benefited with good yield on receipt of summer showers, the other crop (black pepper) yield will be adversely affected. Therefore, farmers practice mixed farming of black pepper and coffee in order to get assured returns from unit cropped area. However, both the crops responded negatively to high annual rainfall.

The decline in cashew production was evident due to decline in cashew area since last two decades. A significant decline was also noticed in
the case of cashew productivity. It can be attributed to various factors. However, the inter-annual variability in cashew yield could be explained due to weather aberrations like extended monsoon and increase in night temperature with less dew nights.

Increase in temperature, aridity and droughts with a simultaneous decline in rainfall and moisture index are the climate change indicators noticed in Kerala. Climate variability, in the form of extended monsoon rainfall with erratic distribution, dry spells in post monsoon, unusual summer showers and prolonged dry spells from November to May if pre-monsoon showers fail, adversely affect the crops in Kerala. It is a threat to agricultural production in the State of Kerala in the ensuing decades since the frequency of such weather extremes is likely to be more under projected climate change scenario. Therefore, there is a need for pro-active measures as a part of climate change adaptation for sustenance of agricultural production in the State of Kerala.

CONCLUSIONS AND RECOMMENDATIONS

The study revealed that southwest monsoon rainfall in Kerala has been declining while increasing in post monsoon season. The annual rainfall exhibits a cyclic trend of 40-60 years, with a significant decline in recent decades. The intensity of climatological droughts was increasing across the State of Kerala through it falls under heavy rainfall zone due to unimodal rainfall pattern. The moisture index across the State of Kerala was moving from B4 to B3 humid, indicating that the State was moving from wetness to dryness within the humid climate.
The study confirms that a warming Kerala is real as maximum, minimum and mean temperatures and temperature ranges are increasing. The rate of increase in maximum temperature was high (1.46°C) across the high ranges, followed by the coastal belt (1.09°C) of Kerala while the rate of increase was relatively marginal (0.25°C) across the midlands. The rate of increase in temperature across the high ranges is probably high because of deforestation. It indicates that the highranges and coastal belts in Kerala are vulnerable to global warming and climate change when compared to midlands.

Interestingly, the trend in annual rainfall is increasing at Pampadumpara (Idukki), while declining at Ambalavayal across the highranges. In the case of maximum temperature, it was showing increasing trend at Pampadumpara while declining trend at Ambalavayal. In the case of minimum temperature it is declining at Pampadumpara while increasing in Ambalavayal.

The paddy productivity in Kerala during kharif/virippu is unlikely to decline due to increasing temperature on the basis of long term climate change, but likely to decline to a considerable extent due to prolonged monsoon season, followed by unusual summer rains as noticed in 2007-08 and 2010-11.

All the plantation crops under study are vulnerable to climate variability such as floods and droughts rather than long term changes in temperature and rainfall.
Recommendations/suggestions for future line of work

- Network of meteorological observatories should be increased. Presently, the network of temperature stations under IMD across the State is scarce, though it has a good number of rain gauge stations. Hence, there is urgent need to record surface air temperature across the State. This will provide a better picture of temperature variability over the State under the projected climate change scenario. This still holds good across the highranges.

- Climate projections for smaller locations/regions are not available. Hence, there is a need to incorporate downscaling techniques in the GCM models for smaller geographical regions as well. It is true in the case of observational data.

- Crop species-specific and location-specific crop weather relationships are to be worked out based on long period experimental data.

- As crops are more vulnerable to short terms variabilities rather than long term climate changes, the impact of climate variability on crops has to be documented. Detailed investigations are the need of the hour to understand the short and long term effects of climate change in the case of plantation crops through crop-simulation models. To understand the impact of climate change on crops, simulation models need to be developed/revalidated.

- R & D initiatives are needed in climate change adaptation for sustenance of agricultural production in the State of Kerala.

- There is a need to train skilled personnel in the field of climate change adaptation and mitigation.