Chapter 2
Climate Change Variability in Coastal Karnataka, India

R.B. Singh, Anju Singh, and Ashok Kumar

Abstract Climate change is one of the biggest environmental threats to food production, water availability, forest biodiversity and livelihoods. It is widely believed that developing countries such as India will be impacted more severely than developed countries. Global warming and Climate Change is projected to increase the number of extreme temperature and rainfall events, and hence climate variability is expected to show an upward trend. It is very important to understand the past trends and variability in rainfall, minimum and maximum temperature in Karnataka since the knowledge on the past could provide guidance for the future. The Arabian Sea and the North Kanara coast belong to the "Indo-Australian Marine Bio-geographic Region" considered to be the richest in the world for biodiversity. The coastal backwaters, estuaries, river-mouths are well known for their productivity. Some of them like the Aghanashini, Kali and Sharavati river backwaters, are even today so. The rivers from the Western Ghats carry great quantity of forest organic matter and deposit the same in the coastal waters including the sea. The current climate variability in Karnataka has been analyzed using the IMD daily rainfall data for the period of 1971–2005 and CRU data for the temperature for the period 1901–2002. The Costal Karnataka districts have an average rainfall of >25 mm/day. Decrease in precipitation trend has been observed in Coastal Karnataka. Rainfall has decreased by 17.69, 1.87 and 22.38 mm/day/100 year in Mangalore, North Kanara and Udupi respectively. The Increase in minimum

R.B. Singh (✉) • A. Kumar
Department of Geography, Delhi School of Economics, University of Delhi, Delhi 110007, India
e-mail: rbsgeo@hotmail.com

A. Singh
Department of Geography, Aditi College, University of Delhi, Delhi 110007, India

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temperature is 0.141, 0.146 and 0.111°C/100 year, whereas increase in maximum temperature is observed as 0.148, 0.146 and 0.113°C/100 year in districts of Mangalore, North Kanara and Udupi respectively.

Keywords Climate change • Climate variability • Coastal ecosystem • Environmental threats • India • Kanara coast

2.1 Introduction

The global climate is continuing to change at unprecedented rate in recent human history. The vulnerability of climate change and extreme climatic events such as drought and flood has dramatic impacts on economy and natural systems (Thornton 2006). Coastal regions are among the most vulnerable systems as it lies on boundary of terrestrial and marine ecosystems, which makes the climatic and environmental conditions in coastal areas very dynamic and sensitive too. The resilience and adaptive capacity of traditional networks and land use systems to cope with climate variability/extremes are weakening, while frequency and magnitude of climate variability and land use intensity are in rise.

Climatic variability is a complex concept including several issues of climate as temperature, rainfall, humidity and cloud conditions (Sen Roy and Singh 2002). A change in the variability of the climate is also considered as climate change even if average weather conditions could be as normal. India is known as one of the highly affected and vulnerable country to climate change owing to its large population depending on ecosystem services. Like other developing countries in India mostly population is actively engaged in activities which are more vulnerable, like agriculture, forestry, livestock and many more. People has lack of infrastructure, due to this even simple natural climatic variables turns in a severe climatic scenario. Further the means and capacity in developing countries adapt to changes in climate are scarce due to low level human and economic development and a considerable high proportion of poor population in the society (Downing et al. 1997).

The impact of climate change on the basic sectors decides the future food security of human being on the earth surface. The dimensions of the climate change and ecosystems are changing continuously. During the earlier times, ecosystem was considered to bear the bad impact of climate change (Sen Roy et al. 2011). The climatic sensitivity of coastal zone is not certain because of variability in rainfall, temperature and other climatic phenomena. The inter-annual variation in these factors of climate is increasing. Weather predictions of either short time or long time go out wrong and due to wrong predictions the economic loss used to increase (IPCC 2001; Sahu et al. 2012, 2013).

Coastal zones have certain aesthetic and practical advantages and this has resulted in the concentration of residential, recreational and industrial areas in this zone. Nearly two thirds of the World's population live in these areas which are often only one or two meters above the mean sea level. Most of these coastal areas are geologically young and are still being shaped by nature. People have chosen to live close to the water front either ignorant of or ignoring deliberately the vulnerability involved, the vulnerability that this boundary is not stable and not clearly defined, Water gives and takes and a state of dynamic equilibrium exists, More often the fluctuations that are part of this dynamic equilibrium are underestimated leading inevitably to disaster, loss of life and loss of property. This fragile dynamic equilibrium can often be upset by human interference, it becomes necessary that this coastal zone is managed and developed in a way that respects its natural and social significance, which ultimately lead to change in coastal climate and problems for livelihood.

The coastal zone of Kanara is one of the highly urbanised and better-developed geographical areas of the State with high degree of economic development and density of population. The settlements in the coastal region consist of 22 urban agglomerations. The occupational pressure by these urban areas can be attributed to fish landing and processing, port maintenance, mining for lime shell, bauxite and silica sand and coir retting. The occupational pressure is likely to be increased in the urban areas of Mangalore and Udupi regions, which will lead to further growth of urban population and thereby increasing the vulnerability posed by climate change. Therefore the present paper aims to assess the spatio-temporal extent and magnitude of climate variability in the coastal zone of Kanara.

2.2 Study Area

Kanara coast is located between 12°27′ to 15°32′N latitude and 74°05′ to 75°45′E longitude, its geographic area is 18,732 km^2, the coast stretches for 320 km along the three districts of South Kanara, Udupi and North Kanara. Of these North Kanara has 160 km long coastline while 98 km are in Udupi district and the rest in South Kanara. There are three distinct agro-climatic zones ranging from coastal flatlands in the west with undulating hills and valleys in the middle and high hill ranges in the east that separates from the peninsula. There is a narrow strip of coastal plains with varying width between the mountain and the Arabian Sea, the average width being about 20 km. The average height of the hinterland is 70–75 m, but in some places it can be as high as 150 m. Fourteen rivers drain their waters into the shore waters of Kanara coast (Singh 1997).

The three districts consist of 19 Talukas of which 8 are coastal talukas. In which 5 are in North Kanara, 2 are in Udupi and 1 is in South Kanara district. Kannada, Konkani and Tulu are the major Regional Language spoken. As per 2001 Census, the total population of coastal districts is 4,363,617,with average density of 278 km^2 (Census of India 2011) (Table 2.1). There are about 90 beaches with varying aesthetic potential that are suitable for beach tourism.

Table 2.1 Socio-Economic Profile of Kanara Coast

Geographic area	18,732 km^2	Adult literacy rate	62.41 %
Total population	4,359,196	Life expectancy at birth (both sexes together)	67 years
Proportion of female population	47 %	Life expectancy at birth of females	70 years
GDP per capita income	9,742	Total infant mortality	49/1,000
Population below poverty line	25 %	Mean age at marriage of females	20.89
Households without civic amenities (Drinking water, electricity and toilets)	33.5 %	Sex ratio	970/1,000

Source: Human Development in Karnataka 2005

2.3 Research Methodology

Both primary as well as secondary data sources are used in the present study. The temporal and spatial analysis has been done by using following techniques:

2.3.1 Moving Average (Five Years)

This tool is used to find out the trend of temperature and rainfall variation over the years.

2.3.2 Water Balance (FAO and Thornthwaite and Mather)

In this study whenever the monthly rainfall crosses 50 % Potential Evapotranspiration (PET), the length of growing period starts and the season gets terminated when the monthly rainfall is lesser than 50 % PET. The comparison between this water balance and previous one is helpful in determining the change.

2.3.3 Thornthwaite's Moisture Index and Climatic Classification

The classification of the climate is the appropriate way of analyzing climatic conditions of a region. Temperature and rainfall are the two main aspects of climatic classification. Thornthwaite's 1948 climatic classification was based on the evapotranspiration and vegetation index. Evaporation is the total amount of

Table 2.2 Thornthwaite's humidity provinces based on moisture index

Moisture index	Humidity provinces
100 and Above	Pre-humid (A)
80–100	Humid (B4)
60–80	Humid (B3)
40–60	Humid (B2)
20–40	Humid (B1)
0–20	Moist Sub-humid (C2)
−33.3–0	Dry Sub-humid (CI)
−66.7 to −33.3	Semiarid (D)
−100 to −66.7	Arid (E)

moisture which is evaporated from water bodies and transferred to atmosphere with amount of transpiration from living organisms. It is very difficult to call a climate, moist or dry, only by measuring level of precipitation; rather it is essential to know whether the precipitation is more or less than the water needed for evaporation and transpiration (Thornthwaite 1948). The potential evapotranspiration is calculated through mean monthly temperature (°C) with corrections for day length for a 30 day month.

$$\mathrm{PE(cm)} = 1.6(10\mathrm{t}/\mathrm{I})^{\mathrm{a}}$$

where I is the sum of 12 months of $(t/5)^{1.51\ 4}$; a is the Further complex function of I.

The monthly water surplus (S) or deficit (D) is calculated a moisture budget assessment including stored soil moisture. A moisture index is given by the following formula is as:

$$\mathrm{IM(100S\text{-}60\ D)\ PE\ or\ 100(P\text{-}PE)/PE}$$

The most important feature of this classification is that the temperature efficiency is calculated from PE value which is function of temperature. Using computed indices of moisture and heat, Thornthwaite defined the humidity provinces based on the moisture index (Table 2.2).

2.4 Results and Discussion

2.4.1 Temperature Variability

The wind direction over the Arabian Sea shows dramatic changes in temperature. The months of June and September, a time generally referred to as the summer monsoon, the general direction of winds over north of the equator is south-westerly and its strength is significantly larger than that during the rest of the year.

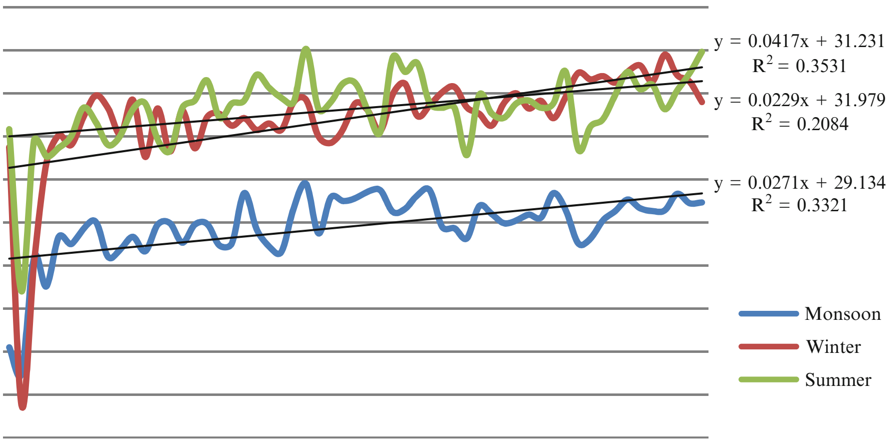

Fig. 2.1 Trend of Mean maximum temperature during 1953–2010 in Udupi district

During November to March, referred to as the winter monsoon, winds over the same region have overall north easterly direction. October and April–May are times of transition between the two monsoons causes variations in temperature too (Shetye et al. 1985).

2.4.1.1 Mean Maximum Temperature

The climate of coastal region is mainly influenced by land and sea breeze. The spatial variations in climate are also influenced by topography of the region. Out of the three study districts, North Kanara is having highest area under hills. The districts of Udupi and South Kanara are mostly coastal plain. The phenomenon of climate change is also observed in the region and variations are found in extent and magnitude of phenomenon. The change in mean maximum temperature is found to be highest in summer month (0.03°C per year) in Udupi district during the period of 1953–2010, with a coefficient of variation of 10 % (Fig. 2.1). The overall annual maximum change in mean maximum temperature is observed for the North Kanara station (Fig. 2.2). The minimum variations have been observed in South Kanara district for the month of monsoon (0.016°C per year) (Table 2.3).

2.4.1.2 Mean Minimum Temperature

The temperature dips to the lowest in morning around 3 o'clock. The mean minimum temperature has a considerable impact of cloud cover also. In the region the maximum change in minimum temperature is observed in the North Kanara district for the summer month (0.28°C per year) due to its

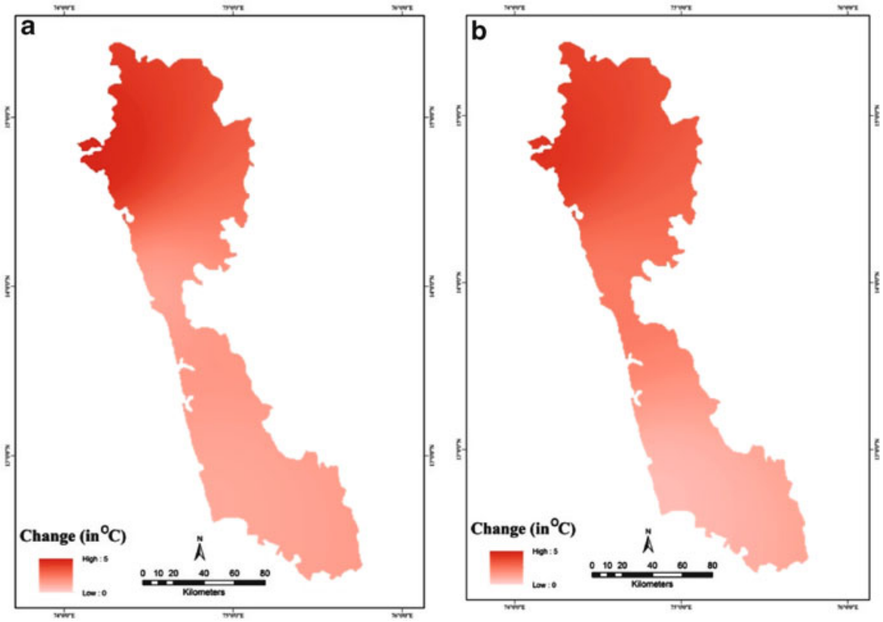

Fig. 2.2 Spatial pattern of change in mean maximum temperature during (**a**) summer season and (**b**) winter season

Table 2.3 Season wise variations in mean maximum temperature at three stations

	Monsoon (June–Oct)	Winter (Nov–Feb)	Summer (March–May)
North Kanara			
Average	29.480	31.945	32.172
Standard deviation	0.870	2.356	3.000
Coefficient of variation	2.951	7.375	9.327
Udupi			
Average	29.919	32.441	32.643
Standard deviation	0.779	1.165	0.833
Coefficient of variation	2.604	3.592	2.552
South Kanara			
Average	29.344	32.682	33.656
Standard deviation	0.844	0.745	0.583
Coefficient of Variation	2.878	2.281	1.734

undulating topography and proximity to Goa urban and industrial area (Fig. 2.3). The minimum change is noticed in Udupi station for monsoon month (0.05°C per year). The coefficient of variation is highest for the summer month in North Kanara station (Table 2.4).

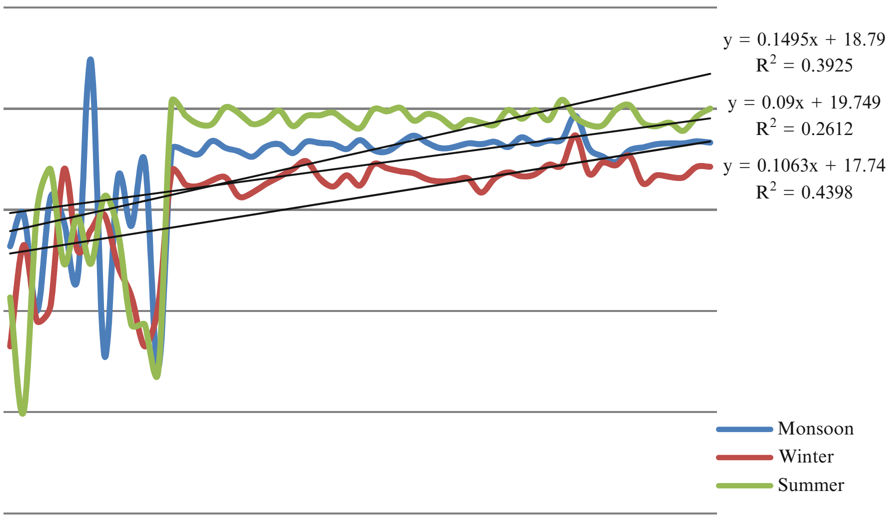

Fig. 2.3 Increase in mean minimum temperature at South Kanara station

Table 2.4 Season wise variations in mean minimum temperature at three stations

	Monsoon (June–Oct)	Winter (Nov–Feb)	Summer (March–May)
North Kanara			
Average	23.314	18.938	20.846
Standard deviation	5.425	3.457	6.694
Coefficient of variation	23.270	18.255	32.114
Udupi			
Average	23.134	20.000	21.350
Standard deviation	7.067	2.965	5.566
Coefficient of variation	30.547	14.826	26.073
South Kanara			
Average	22.177	20.610	22.827
Standard deviation	2.718	2.475	3.685
Coefficient of variation	12.258	12.011	16.146

2.4.2 Rainfall Variability

The study area lies west to the Western Ghats having per-humid climate according to Thornthwaite's climatic classification. About 90 % rainfall occurs in monsoon season. Maximum rainfall in monsoon season occurs at Udupi station (693 mm). In summer season maximum rainfall has been observed in South Kanara station (72 mm) (Fig. 2.4). The influence of climate change on rainfall has been maximum

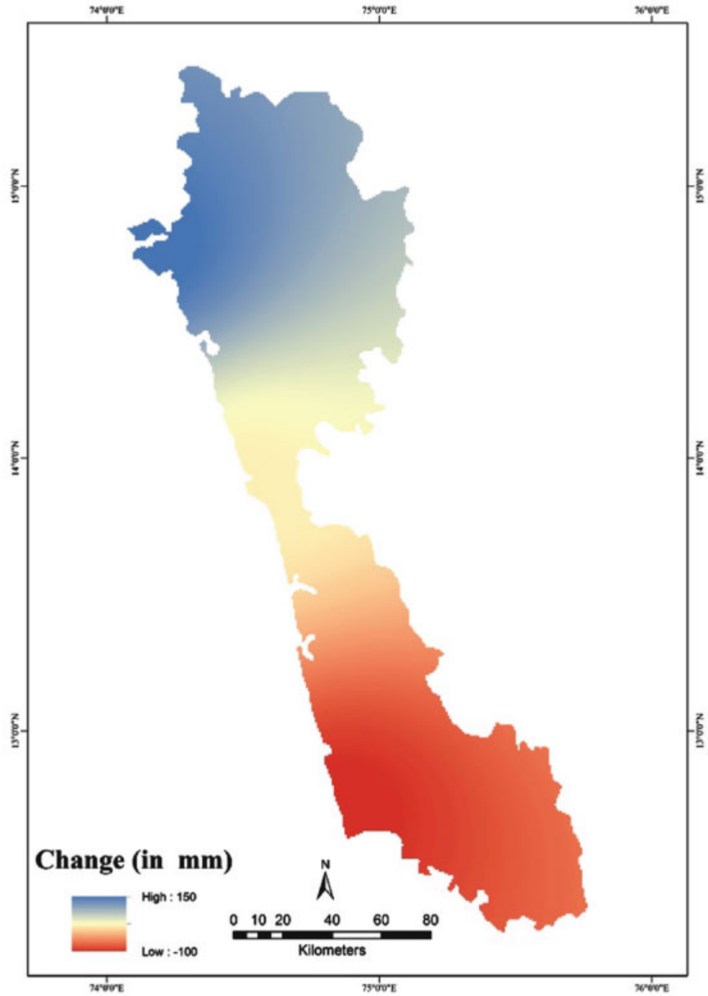

Fig. 2.4 Spatial pattern of change in average rainfall during monsoon season between 1953 and 2010

in South Kanara district. The rainfall in South Kanara district has reduced at the rate of 1.62 mm/year (Fig. 2.5). The other two stations have experienced an increase in rainfall during 1953–2010. The variation in rainfall is maximum for North Kanara district in winter season, the value of coefficient of variation is 149 %. The minimum variation is found in Udupi district for monsoon month with only 14 % coefficient of variation (Table 2.5).

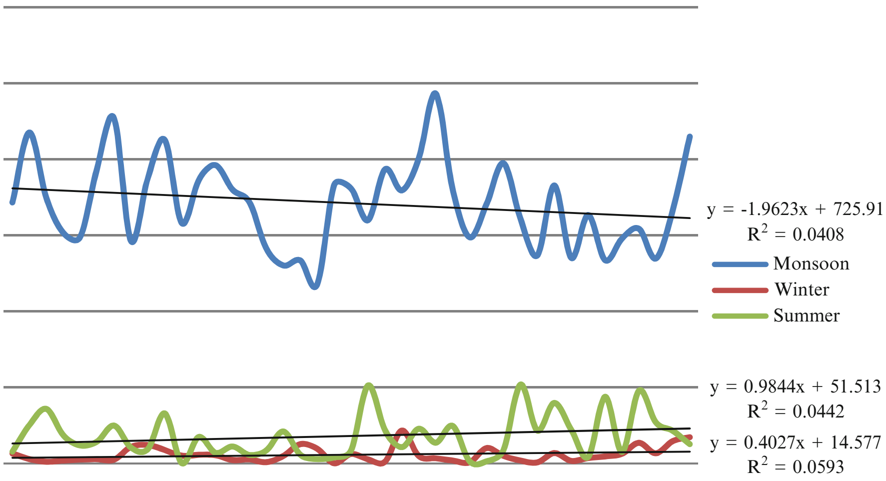

Fig. 2.5 Change in rainfall pattern in South Kanara district

Table 2.5 Season wise variations in average rainfall at three stations

	Monsoon (June–Oct)	Winter (Nov–Feb)	Summer (March–May)
North Kanara			
Average	588.495	12.460	45.804
Standard deviation	127.527	18.597	55.141
Coefficient of variation	21.670	149.248	120.385
Udupi			
Average	692.693	14.684	47.788
Standard deviation	102.386	17.381	46.986
Coefficient of variation	14.780	118.362	98.321
South Kanara			
Average	684.696	23.033	72.185
Standard deviation	116.318	19.802	56.074
Coefficient of variation	16.988	85.972	77.680

2.4.3 Change in Moisture Index

The trend of increasing temperature and changing precipitation scenario caused the shift in humidity provinces in coastal region of Karnataka. The analysis of correlation matrix indicates that the change in potential evapotranspiration which further causes the change in humidity provinces are caused by change in maximum temperature. Though there are significant changes in humidity indices throughout the coastal region of Karnataka but North Kanara district has observed maximum decrease in moisture index. By applying the Thornwaite's method of identifying and classifying regions into appropriate climatic category it is found

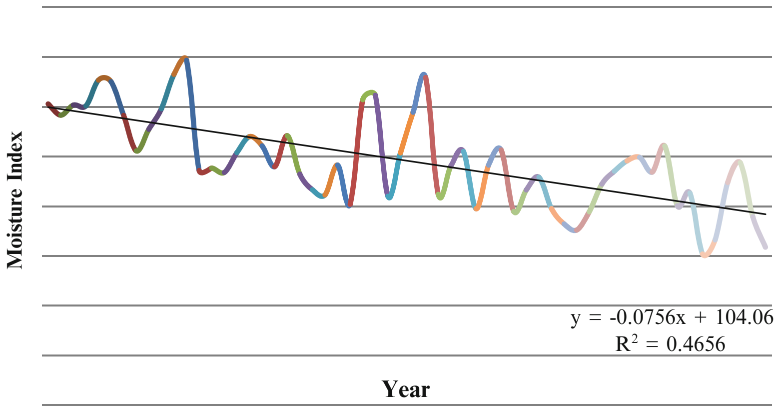

Fig. 2.6 Change in Thornthwaite's moisture index during 1953–2010

the coastal region of Karnataka has been transformed from per-humid to humid category due to combined effect of expansion of urban and industrial area. The moisture index has decreased from average value of 104 in 1953 to 98 in 2010 (Fig. 2.6).

2.5 Conclusion

Climatic variability is the most significant phenomenon affecting almost all economy sectors of the region. Variability also poses problems before fishermen and farmers to adopt certain measures as they may become useless after one cycle of variability. As spatial variability there is also temporal variability in climatic parameters. Rainfall in coastal region is concentrated in only 4 months of rainy season and variability leads to the fishermen and farmers to take wrong measures. To cope with the problem, it is essential to assess in advance the trend of future climatic variability based on past experiences.

The variability in the average temperature for all three seasons of summer, winter and monsoon is diverse in the region. In summer season the region is experiencing more temperature rise while in monsoon season less temperature rise is experienced. The precipitation has a decreasing trend in Udupi district whereas other two districts have experienced increase in precipitation. Number of wet days has also decreased over the years and the season of monsoon rainfall has been shrinking.

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