Chapter 2

Rainfall Pattern Analysis over India in Relation to the State of Kerala

Shajimon K John

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.72870

Abstract

Rainfall over a region across the earth is the prima face reason of its uniqueness. Different regions over the earth having different rainfall pattern in turn is directly related to the regions uniqueness, it is referred as ecosystem. India is one of the ancient regions having different rainfall pattern which has developed into places with its own unique ecosystem prevailing over its different states. Kerala the southernmost tip of this sub-continent has almost clear green top throughout the year in comparison to various other states in the country. This work mainly concentrates on the variation of rainfall over the state of Kerala in comparison with other states which are its neighbours. Rainfall data over the last century is being analysed for finding out whether the rainfall pattern over the state of Kerala has any relation with the rainfall pattern across the country. Solar activity and the number of sun spots and how these activities effect the rainfall pattern also a major area to be investigated.

Keywords: rainfall, monsoon, solar activity, Kerala, India

1. Introduction

Rain is the most beautiful activity in nature which supports the healthy living. Rain is defined as the liquid water in the form of droplets that have condensed from atmospheric water vapour and becomes heavy enough to fall under gravity in every scientific write-up. It is the most significant means of keeping the fresh water level in the earth to its normal level. Rain occurs when the water droplets or moisture are moving across the multi-dimensional temperature moisture profile [1]. We, as human being should be very much indebted to this natural phenomenon. Unfortunately, over the years due to many stated and unstated reasons the rainfall pattern has a change in its pattern as well as the amount of rainfall. Rainfall occurs when moisture contained air rises above the earth's surface and cools to form clouds which in turn precipitate to fall as rain. This precipitation can reach earth's surface as rain, snow, sleet or hail depends on the pressure variations across the region [2, 3]. Maximum rainfall occurs near the earth's equator because these regions having very high direct sunlight impact with very high temperature which creates high level of vertical uplift or air. The presence of mountains in this region increases the uplift of air. The opposite happens in Polar Regions, where the air is very cold and contains high amount of water level which enable only low level of vertical uplift. This forces the air to descend down preventing from any cloud formation.

Rainfall study is mainly known as climatology which includes process of measuring, understanding, and predicting rainfall pattern across the earth surface [4, 5]. The major factors which have direct impact on the amount of rain received over a region are humidity, air pressure, region's topography and the type of cloud formed over the region. Based on the amount of rain received over a specific period is used an instrument to classify the climatic regions over the earth known as Köppen classification [4–6]. According to Köppen classification, five primary types named as tropical, dry, mild mid latitude, cold mid latitude and polar. These primary classifications are again subdivided into rain forest, having the maximum rainfall, monsoon, tropical savannah, humid sub-tropical, humid continental, oceanic climate, steppe, subarctic climate, tundra, polar ice cap and desert [4, 5].

2. Study area

The study area is India, in the Asian continent. The study area has much uniqueness with respect to rainfall pattern as well as the climatic characteristics. India is one of the oldest civilizations with a wide cultural heritage. One of the major driving force towards this wide cultural heritage is the difference in climatic characteristics prolongs through the area. The region covers snow covered Himalayas in the north to tropical rain forests in the south. The types of mountains, rivers and sea shores make India a distinct geographical entity in Asia. It is bound by the Himalayas in the north to tapper between Indian Ocean in south, Bay of Bengal in the east and Arabian Sea in the south. The region lies entirely in the northern hemisphere (https://www.mapsofindia.com/geography/). The mainland extends between latitudes 8° 4′ and 37° 6′ north, longitudes 68° 7′ and 97° 25′ east and measures about 3214 km from north to south between the extreme latitudes and about 2933 km from east to west between the extreme longitudes. The climate of the subcontinent is mainly depending on its altitude, latitude, monsoon winds and tropical cyclones [7, 8]. The presence of Tropic of Cancer through the middle of the region keeps the climate near tropic and sub tropic style. The presence of high altitude Himalayas in the north keeps the winter temperature milder than the rest of the central Asia regions. The monsoon winds flows from the southern tip from Bay of Bengal and Arabian Sea have a significant effect on the rainfall across the country. Most of the regions are also under the effect of cyclones from Bay of Bengal.

The climate within India can be mainly classified into four major categories: tropical dry, tropical wet, sub-tropical humid and mountain climate. The elevated regions in the Himalayas experience snow during the winter season. At the same time Thar Desert experience tropical dry climate. The Himalayas and the Thar Desert influences the climate over the Indian sub-continent a

http://dx.doi.org/10.5772/intechopen.72870

lot. The Himalayas act as a barrier against katabatic winds which blow from Central Asia [8–10]. Overall the country's climate inclined more towards tropical since the Tropic of Cancer passes through the middle of the country. The tropical wet climatic regions within the country can be sub divided into; tropical monsoon climate and savannah climate. The major areas which fall in tropical monsoon region are Lakshadweep, Andaman and Nicobar Islands, southern Assam, the Western Ghats and Malabar Coast. These areas experience moderate to high temperature along with high rainfall during monsoon season; from June to November. The high amount of rain received in these regions keeps these regions green throughout the year [11, 12]. The savannah climate is the most commonly prevailing climate in the country. Almost all inland areas experience the savannah (tropical wet and dry) climate, with extremely high temperature during summer and moderate to heavy rainfall during monsoon which normally occurs during June to September [13, 14].

The tropical dry climate is again sub divided into three mainly; sub-tropical arid (steppe) climate, tropical semi-arid (steppe) climate, and sub-tropical arid (desert) climate. Regions around Karnataka, Central Maharashtra, Andra Pradesh and some parts of Tamil Nadu experiences Tropical semi-arid climate experience with hot and dry summers during March to May and almost very unreliable and erratic rainfall. Western Rajasthan regions of Thar Desert fall into the sub-tropical arid (desert) climatic region. The region where the desert extends like parts of Punjab, and Haryana comes under sub-tropical semi-arid climate regions. These regions experience high temperature during summer and rain normally occurs during summer monsoon only. Sub-tropical humid climate experienced in most of the North and Northeast regions. In these regions summers are hot to very hot while during winter season the temperature may dip to 0°C [15, 16]. These regions also experience rainfall during summer with sporadic rain or snowfall during winter. The summer occurs during May to July while the winter occurs during December and January. The mountain climate mainly happens in the Himalayas region with an average temperature fall of almost 0.5°C with every 100 meters rise in height.

The effect of these different climatic styles on the country is that it has mainly four different seasons; winter, summer, rainy season and autumn. The months of December, January and February are generally considered as winter months in most of the north and north eastern regions. The average temperature may vary around 10° to 15°C in the northern region while the southern regions has an average temperature between 20° to 23° centigrade [17, 18]. Some parts like western Himalayas and Kerala experiences rain during this season also. The pre monsoon season or summer or hot weather conditions occur during March to June with an average temperature rises up 35° centigrade. The central and northern and north western regions near to Thar Desert the temperature may reach up to 45° to 48°C. While the coastal areas record moderate temperature due to the influence of sea breeze. Some parts of north eastern and eastern areas witness thunderstorms also during these months. The areas near to Thar Desert witness hot and dry winds along with sand/dust storms. Around 75% of the total rain received across the country falls during the South West monsoon [19, 20]. The start of South West monsoon happens during last week of May or the first week of June and this season extends up to September. The extent of this season varies from region to region as the southern state of Kerala almost four to four and half months under this season while the western state of Rajasthan having less than two months. The monsoon arrives in the Indian

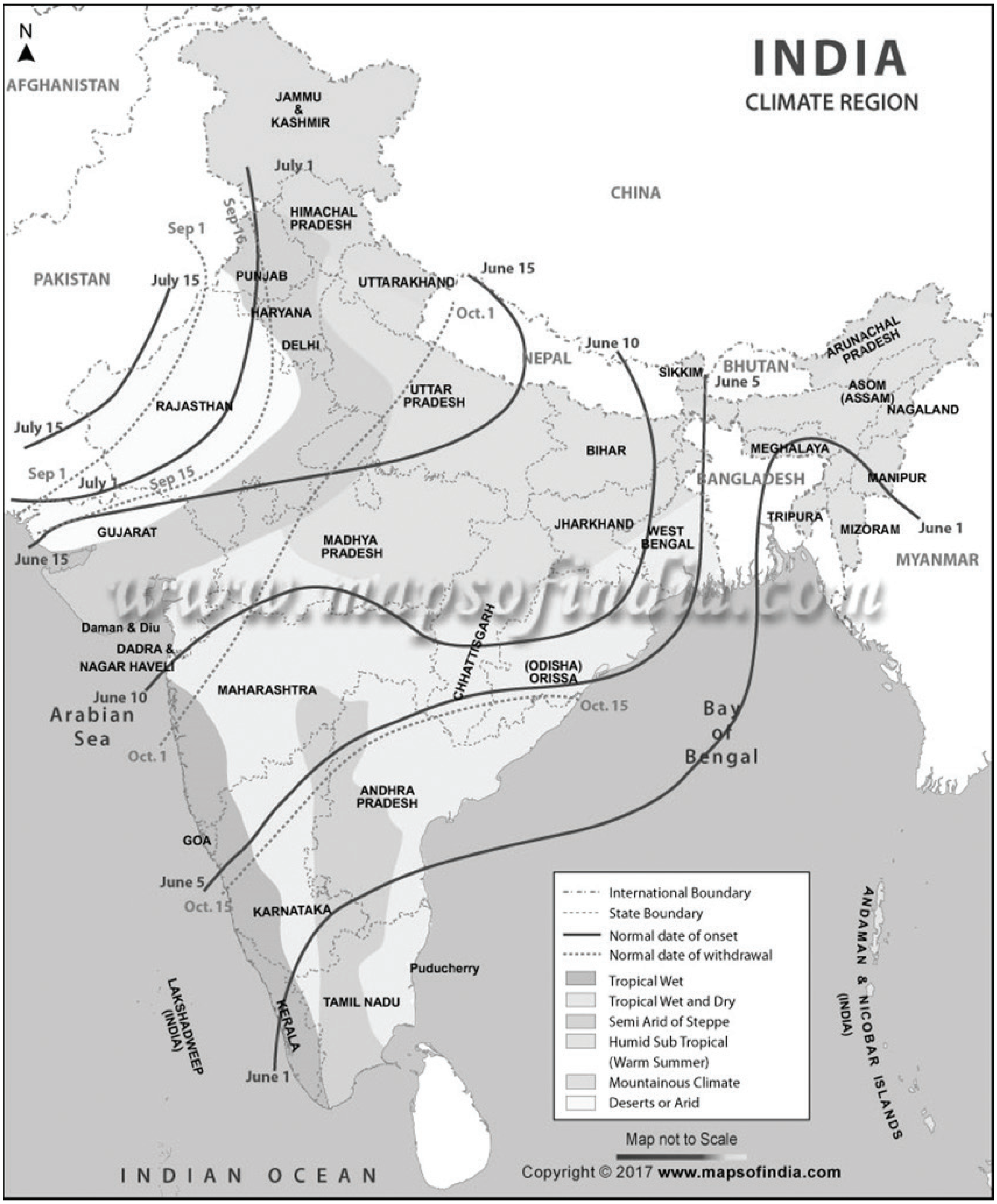

Figure 1. The climatic regions over Indian subcontinent. (courtesy: Maps of India, https://www.mapsofindia.com/maps/india/climaticregions.htm).

subcontinent through Bay of Bengal and Arabian Sea. The effect of monsoon through Arabian Sea is almost three times stronger than the effect of Bay of Bengal with the monsoon through Arabian Sea extends its presence into the Thar Desert region. The greenery and the agriculture

http://dx.doi.org/10.5772/intechopen.72870

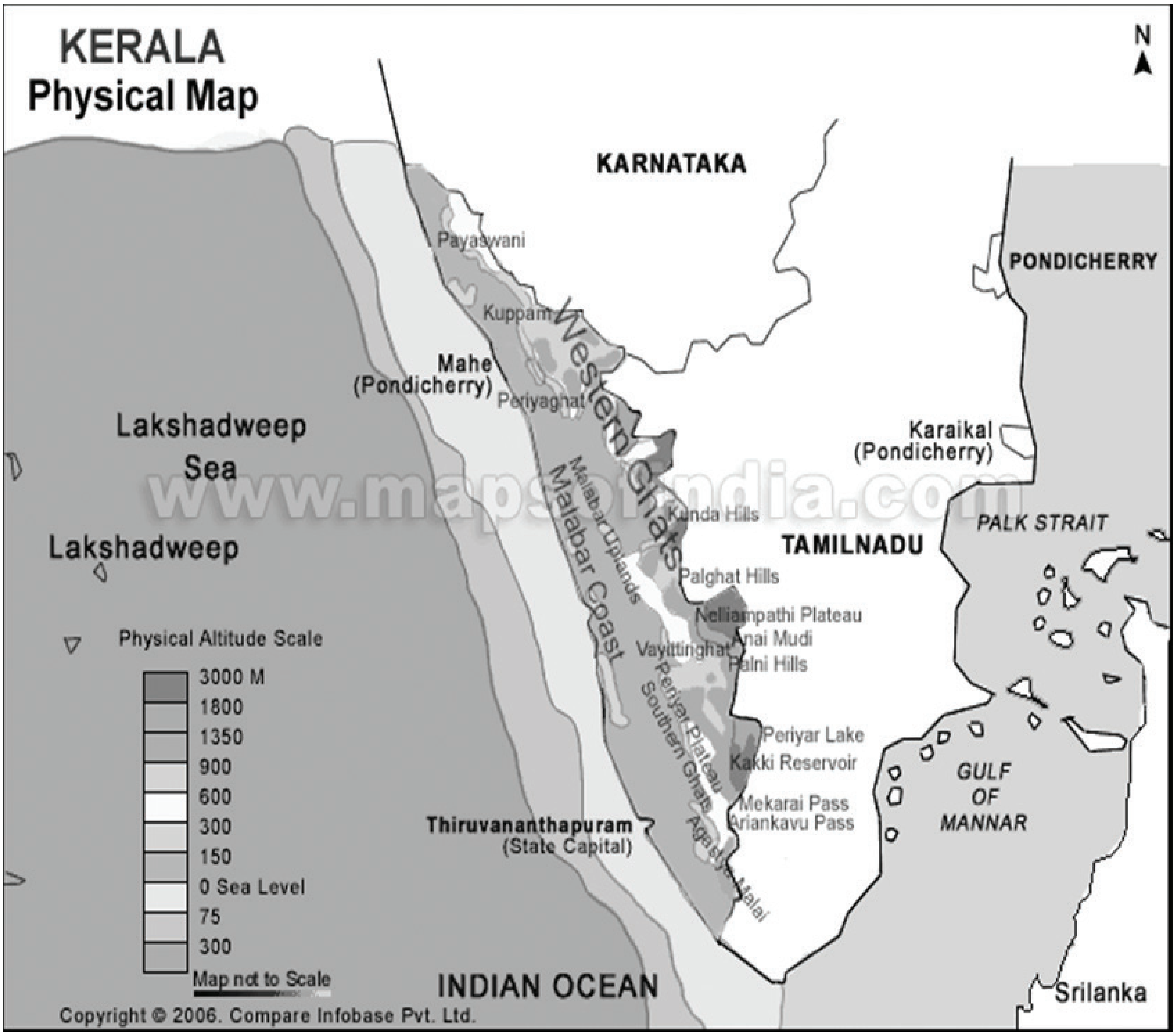

Figure 2. Physical map of Kerala (courtesy: Maps of India, https://www.mapsofindia.com/maps/kerala/keralaphysical.htm).

of the country depend mainly on this South West monsoon. There are many stated reasons which have direct impact on the monsoon like; sea surface temperature, snow cover and El Nino [20].

The post monsoon season or the Northeast monsoon occurs for nearly two months, October and November across the country. This season is mainly treated as the retreating of rainy season the country [21, 22]. Most of the Southern states of the country like Kerala, Tamil Nadu and Karnataka receive almost 30% of their annual rainfall during these months. This period also experiences decrease in temperate from an average around 35–28°C. Another highlight during this season is that the humidity level decreases across the country with clear to very clear sky throughout the day [23, 24]. **Figure 1** shows how various climatic regions discussed above are mapped across the Indian subcontinent. Depending upon the latitude and longitude of the region along with its proximity to the Bay of Bengal or Arabian Sea and the presence of mountainous regions determines the regions climatic style.

Kerala even with its closeness to equator when compared to other states in the country, has a composed and pleasing climate with temperature lies between 28–35°C throughout the year. The presence of sea in its west side and Western Ghats in the west side are the major reason for this pleasing climate. Kerala lies between north latitudes 8°.17′.30″ N and 12°. 47′.40″ N and east longitudes 74°.27′47″ E and 77°.37′.12″ E. The climate is mainly tropical wet due the presence heavy monsoon which starts from June and extends till September (https://www.mapsofindia.com/maps/kerala/geography-and-history/). **Figure 2** shows the physical map of Kerala.

Kerala can be divided into three climatically distant regions namely, hot and wet coastal areas along the west, central midlands and eastern highlands. The region lies in the centre of Indian tectonic plate with gradual increase in altitude from coastal areas to western highlands. Kerala experiences mainly three seasons; south west Monsoon, north east Monsoon and summer [25, 26]. The south west monsoon is the most prominent source of rainfall across the region with almost 65% of the total rain received during this season. The southwest monsoon, which is known as "Edavapathi" in the colloquial language, means mid of Malayalam month Edavam, start during the end of May or first of June with support of southwest monsoon wind [27–29]. Across the state 42 rivers flow from Eastern Ghats to the Arabian Sea which are fed by these rains. Northeast monsoon, known as "Thualavarsham", occurs during the retarding of southwest monsoon. This occurs during October and November. The main characteristics of this rainy season are the prudential rains with lighting and thunder. Summer starts towards the start of March with reaching higher temperature around 40°C at certain places [30–33].

3. Analysis of rainfall pattern

The rainfall pattern over the study areas were analysed with data received from the metrological department of India (http://www.imd.gov.in). The analysis is done for the data between years 1951 and 2014. The monthly rainfall over Kerala, and weighted average rainfall across India were analysis to find the relationship between the rainfall over the state Kerala and Indian subcontinent. **Figure 3** shows the comparison of rainfall over Kerala with the weighted average rainfall across India. While **Figure 3(b, c)** corresponds the histogram of rainfall occurred during 1951–2014. It is clear from the histogram that out of 64 years used for study every year having rainfall more than 2000 cm overall across Kerala while more than 90% of years having rainfall over 1000 cm on weighted average scale across India. Hence it is evident that the overall rain pattern over the Indian subcontinent almost kept the same.

Figures 4–**7** shows the rainfall comparison of Kerala and weighted average across India for the four seasons that predominantly occurs across the subcontinent; namely summer, winter, rainy season and autumn. Major finding is that overall changes in the rain pattern are not visible along the study duration. From **Figure 4** it is clear that during summer season only traces of rain across the country occurs in all parts of India. These summer rains do not follow a specific pattern also across India as well as Kerala state too.

Upon analysing **Figures 5**–**7** it is clear that state of Kerala is getting more rainfall when compared to the weighted average across India. Another interesting fact is that if the rainfall across is less in certain years then the overall weighted average across India is also in the

http://dx.doi.org/10.5772/intechopen.72870

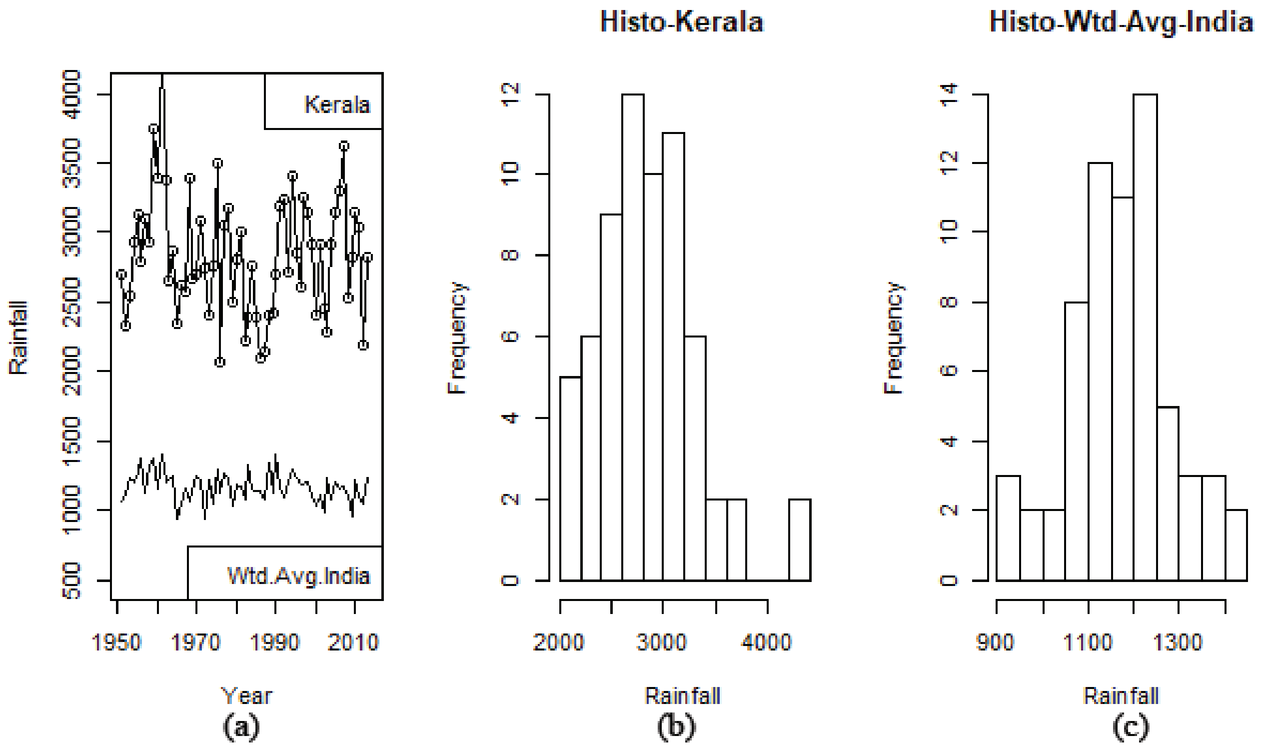

Figure 3. (a) Yearly rainfall comparison 1951–2014, (b, c) histogram.

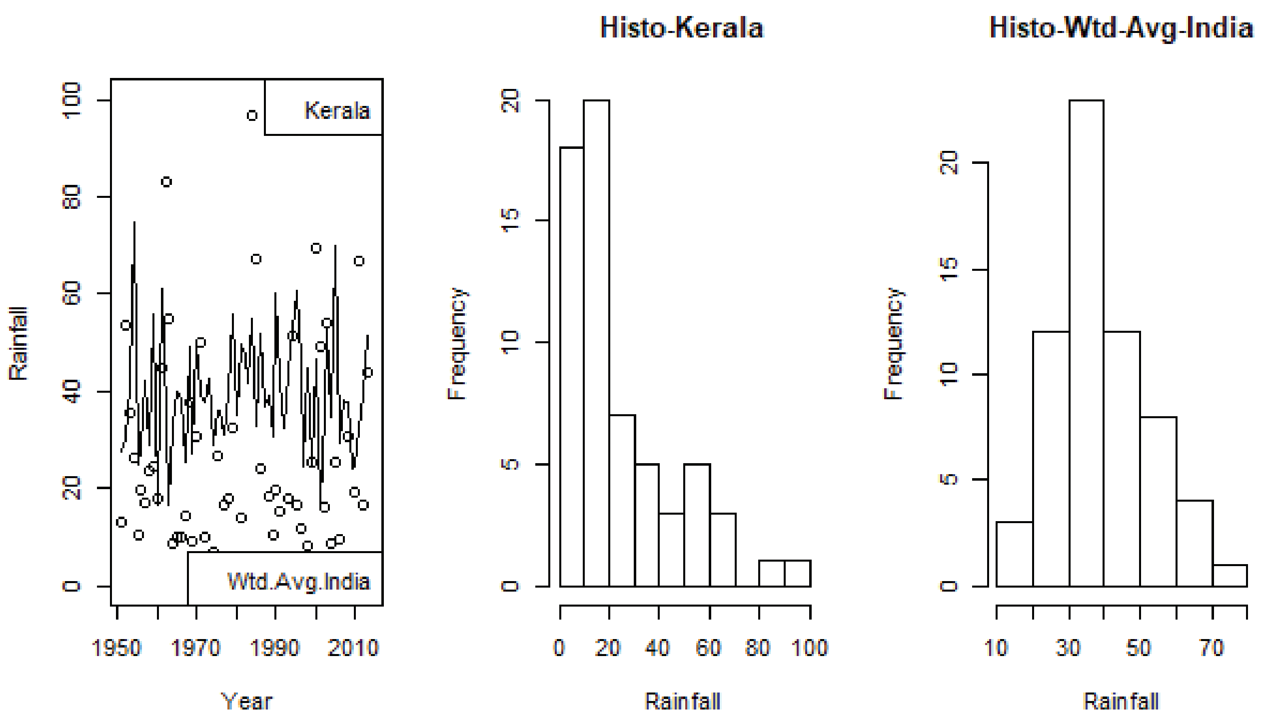

Figure 4. Rainfall comparison during summer season.

reduced level. The detailed study using histogram it is clear that even during summer Indian subcontinent receives some amount of rain at least some parts or some traces of rain in other parts, which is a common trait of along any region which lies along the equator.

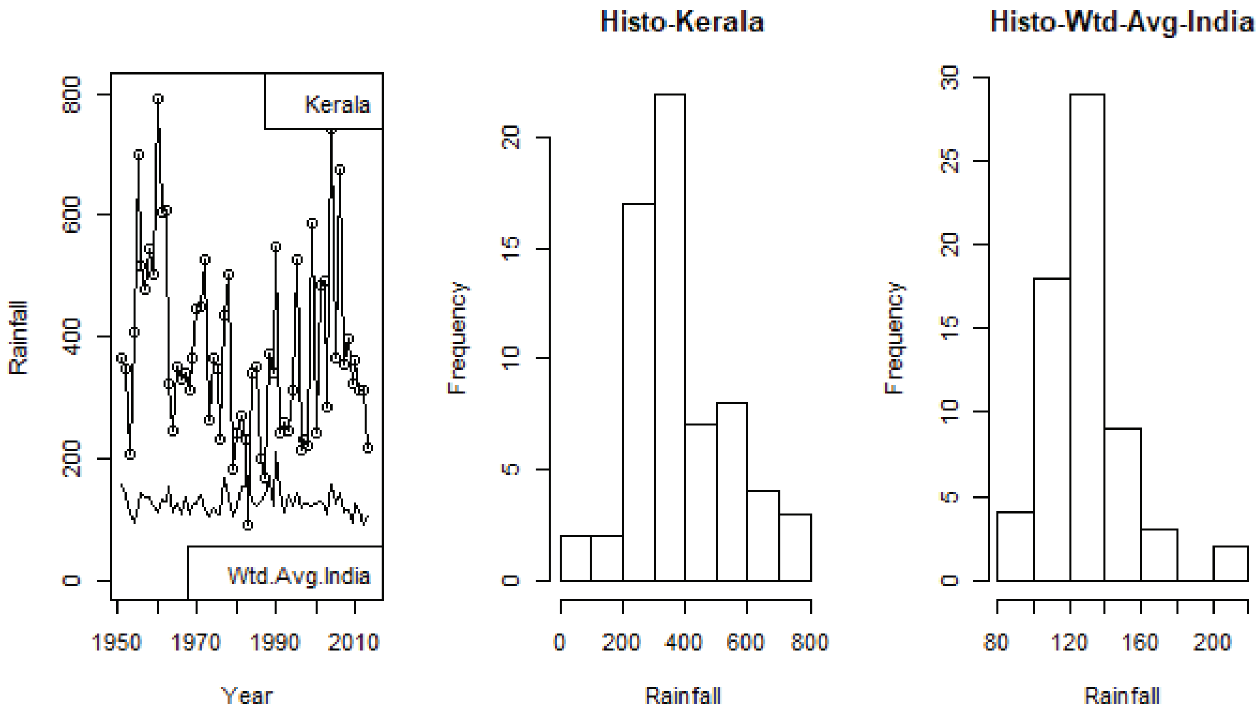

Figure 5. Rainfall comparison during autumn season.

3.1. Effect of solar cycle over rainfall

Solar cycle is the most significant activity of Sun over earth which changes the solar radiation levels. Solar irradiance is the power per unit area received from the Sun in the form of electromagnetic radiation in the wavelength range of the measuring instrument. Irradiance

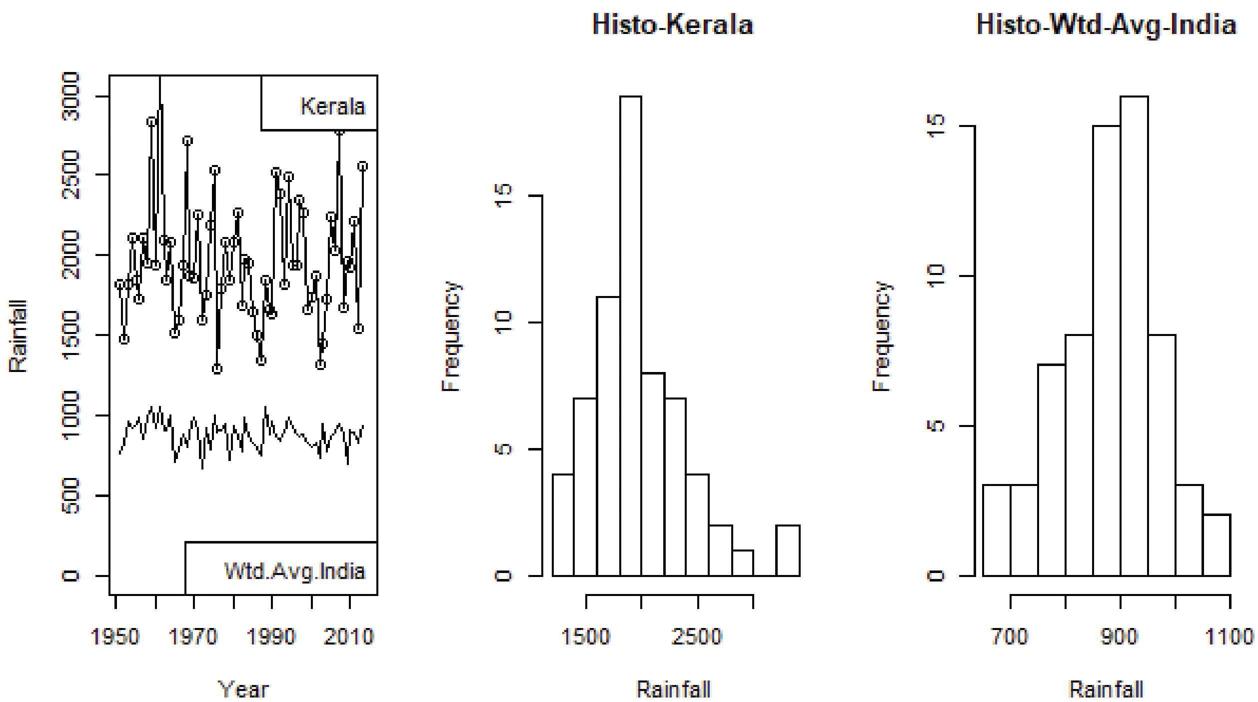

Figure 6. Rainfall comparison during rainy season.

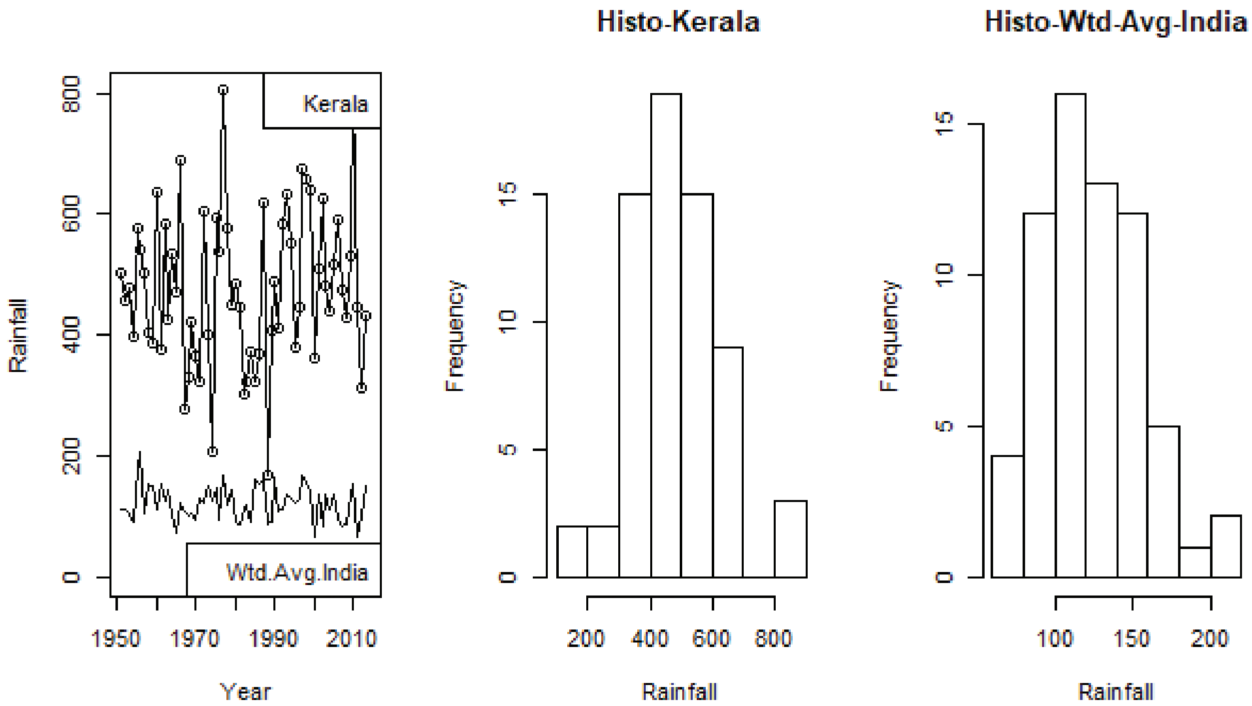

Figure 7. Rainfall comparison during winter season.

is measured in space or at the Earth's surface after atmospheric absorption and scattering. It is measured perpendicular to the incoming sunlight), ejection of solar materials along with the Sun's appearance (changes in number and size of sun spots). The changes occurred in the Sun forces changes in the atmosphere, space and earth's surface. The solar cycle mostly is of 11 years' duration. The solar cycle has its maximum activity and minimum activity period based on the number of sunspots occurrence. Sun spots are developed over the sun's surface when Sun's magnetic field welling up to the photosphere of the sun which creates powerful active regions on the Sun. This sun spots form over duration of few days extends up to months. Sun spot number is used to measure this solar activity which in turn a major cause for variations in earth's climate, satellite failures, etc. Sun spot number counted by counting individual sun spots and sun spots groups. Mathematically sun spot number is the sum of individual sun spots and ten times the sun spot groups. **Table 1** shows the details of solar cycle over the study time. This table describes solar cycles occurred during the phase of our study [32–34].

Solar cycle No.	Starting time	Finished time	Duration (yrs.)
Solar cycle 18	Jan 1944	Feb 1954	10.2
Solar cycle 19	Feb 1954	Oct 1964	10.5
Solar cycle 20	Oct 1964	May 1976	11.7
Solar cycle 21	May 1976	March 1986	10.3
Solar cycle 22	March 1986	June 1996	9.7
Solar cycle 23	June 1996	Jan 2008	11.7
Solar cycle 24	Jan 2008	Still going	

Table 1. Solar cycle between 1951 to 2014.

Every solar cycle has its maximum activity period and minimum activity period. It depends on the number of sun spots occurrence during a specific time. Sun spots are dark patches over the photosphere of sun, which forms due to the reduction of surface temperature which is due to concentration of magnetic flux because of convection. These sun spots usually appear in pairs of opposite magnetic polarity and may be active for a few days to over a month period with varying sizes. The study has recorded the rainfall over these solar cycles and analysed for identifying any similarity or dissimilarity occurs over the solar cycle. **Table 1** shows the details of Solar cycles 18 to 24. Solar cycle 24 is currently running. All solar cycles have a time duration of around 11 years. The study tabulated and analysed the rainfall received across Indian subcontinent and state of Kerala for solar cycles 18 to 23. The data was analysed for all the four seasons namely; winter, summer, rainy and autumn. The data analysed on the overall rainfall across Kerala and also the weighted average rainfall across India respectively. **Tables 2** and **3** shows the maximum and minimum values of both weighted average of rainfall across India and rainfall over Kerala these for each solar cycle with respect to each season.

The above data was analysed based upon the four seasons; summer, winter, rainy and autumn and its variation among the solar cycles 19 to 23. Based on the solar cycles, the available data was fitted into solar cycles 19 to 23. Solar cycle 19 started in February 1954 and solar cycle 23 ended in January 2008. **Figures 8–11** shows the graphical representation of rainfall across Kerala and the weighted average across India over these solar cycles. These graphs state that over the period of solar cycle these areas receive almost the same quality of rain.

The third set of analysis is done with respect to the rainfall received in maximum sun spot activity year with the overall average rainfall received between the years 1951 and 2014 for the four different seasons. The maximum sun spot occurred in years 1958, 1968, 1979, 1989 and 2001 during the solar cycles 19 to 23 respectively.

Figure 12a shows the average of maximum rainfall occurred during the four seasons in the above said years, **Figure 12b** shows the average rainfall received in years 1951 to 2014. On comparison it is clear that there is no specific impact on the maximum rainfall received with respect to the above stated years. **Figure 12c** and **d** shows the minimum rainfall received during the above two cases. There also no significant change was identified.

Solar cycle	Minimum rainfall				Maximum rainfall			
	Season 1	Season 2	Season 3	Season 4	Season 1	Season 2	Season 3	Season 4
19	8.9	245.3	1720	377.6	83.1	791	3229	637.6
20	0.3	263.7	1509	206.7	50.1	526	2711	688.2
21	0.8	90	1297	302.7	96.8	502.1	2274	805.4
22	1.4	169.8	1347	166.6	51.4	548.3	2516	631.2
23	3.6	213	1322	361.4	69.5	741.8	2786	675.7

Table 2. Maximum and minimum rainfall over Kerala.

Solar cycle	Minimum rainfall				Maximum rainfall			
	Season 1	Season 2	Season 3	Season 4	Season 1	Season 2	Season 3	Season 4
19	16.5	791	3229	91.3	74.9	153.1	1052	206.1
20	25.3	526	2711	74.4	50.5	138.6	1003.4	151.2
21	31.2	502.1	2274	86.6	55.9	170.5	727.6	167.4
22	30.7	548.3	2515.6	87.7	60.7	210.7	1049.6	165.3
23	16.1	741.8	2786.2	66.4	69.9	159.2	947.9	167

Table 3. Weighted average maximum and minimum across India.

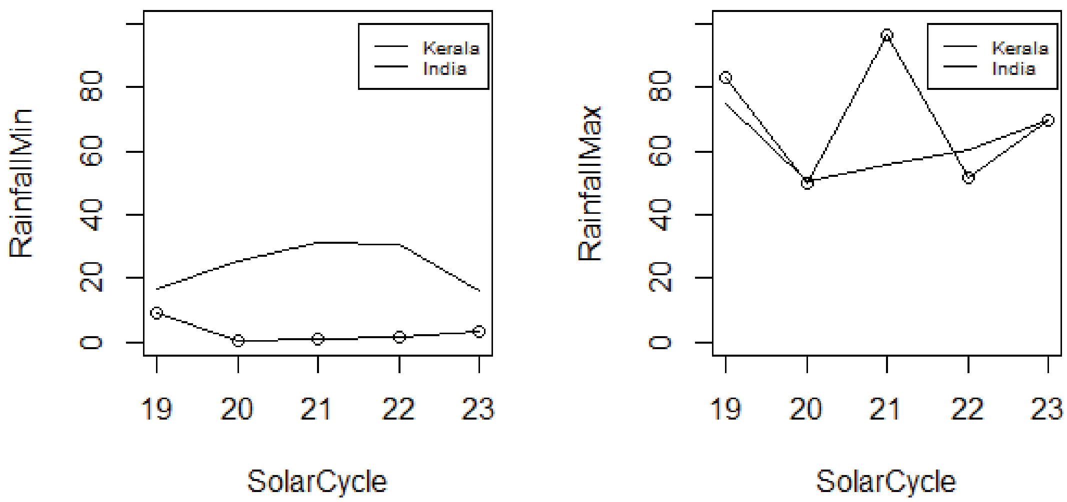

Figure 8. Rainfall during summer season across solar cycles.

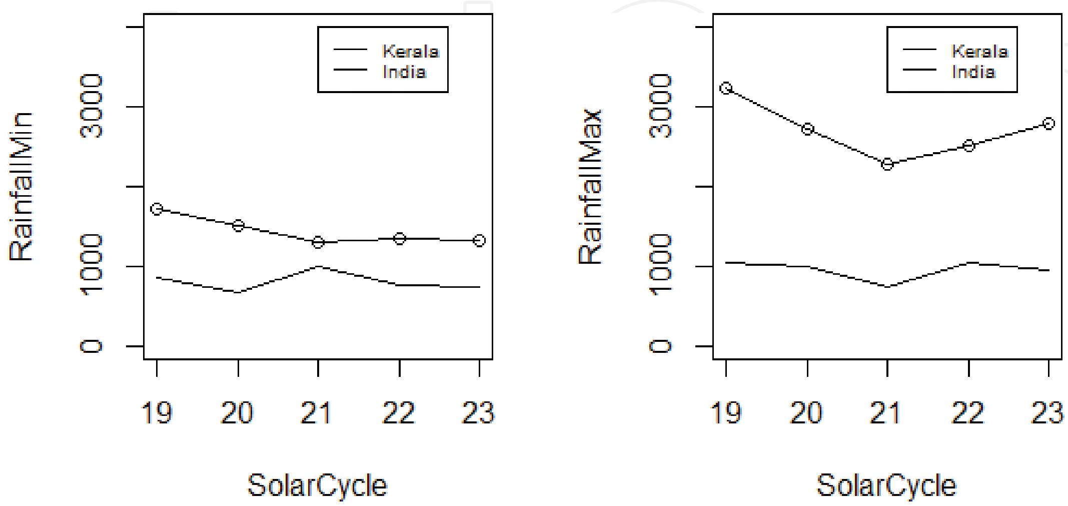

Figure 9. Rainfall during rainy season across solar cycle.

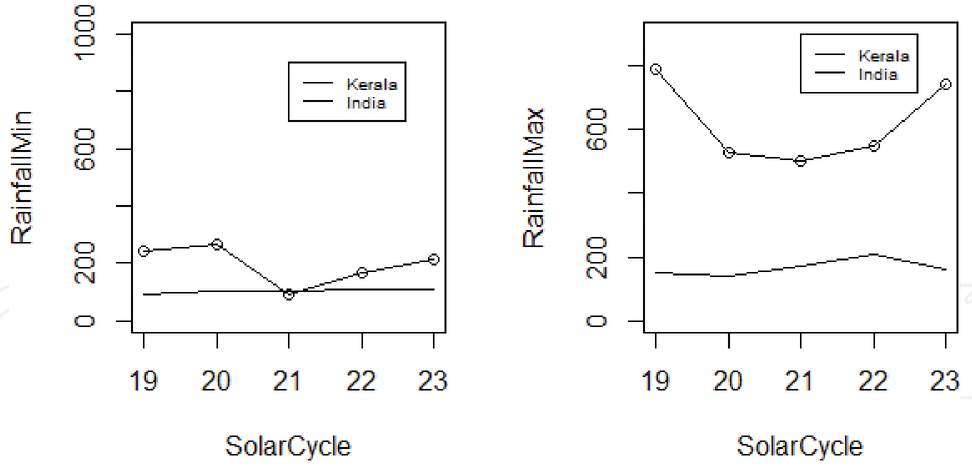

Figure 10. Rainfall during winter season across solar cycle.

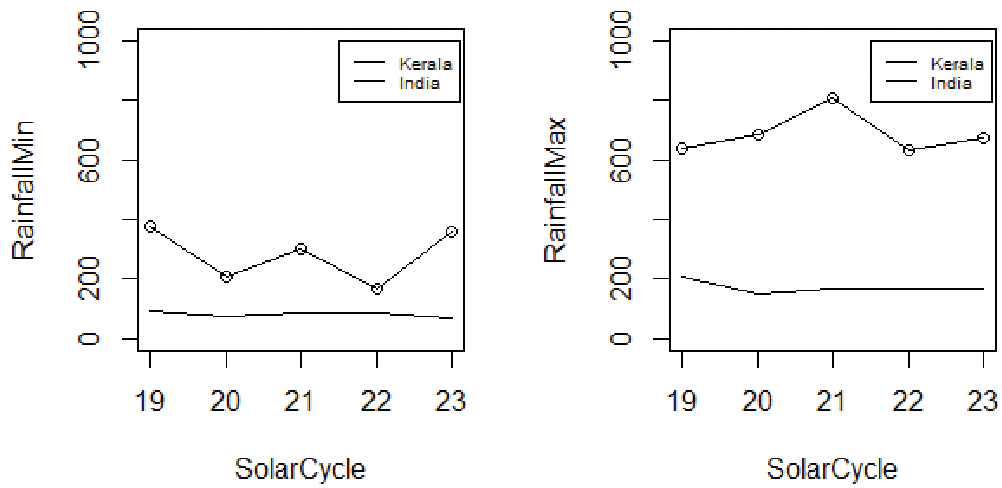

Figure 11. Rainfall during autumn season across solar cycle.

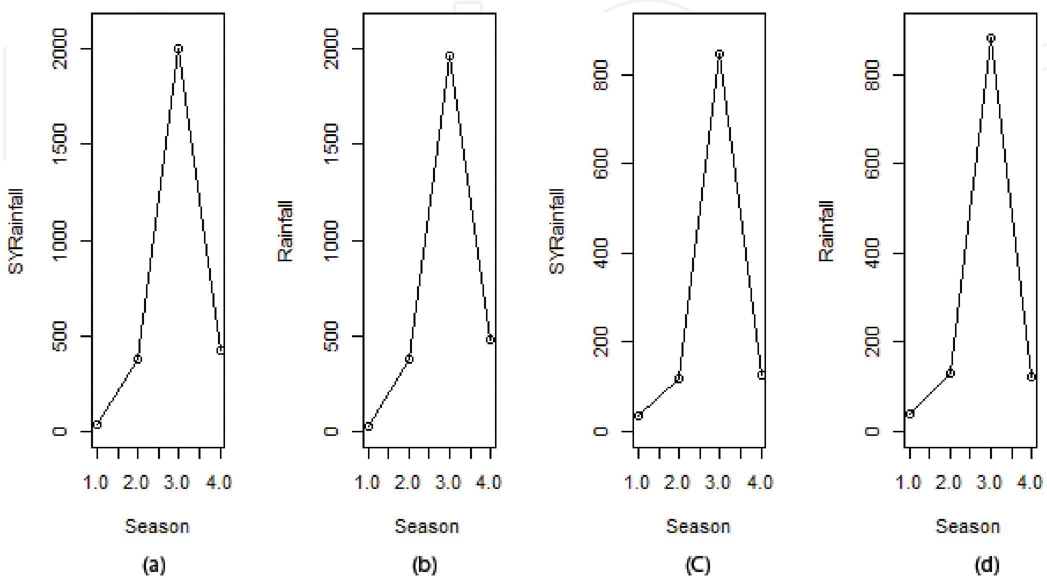

Figure 12. Comparison chart.

4. Conclusion

The study was mainly done on comparing the rainfall received across the Indian subcontinent to the specific state of India named Kerala. It has found that the amount of rain received across the state of Kerala has a direct impact on the overall rain received across subcontinent. The rainfall pattern was also analysed for the four predominant climatic patterns prevailing over India. It was also found that except the summer season, all three other seasons of the subcontinent follows the same pattern that prevails over the state of Kerala. Summer rainfall does not follow any specific pattern. Another interesting conclusion is that the overall rainfall does not show any significant change during the study duration. The second part of study was done with respect to the solar cycles. Based on the available data the solar cycles 19 to 23 were mapped based on the based criteria to verify significant changes if any. But there also no major changes identified. The last work was on comparing the maximum and minimum rainfall received during the maximum sun spot years to the average rainfall received between the years 1951 to 2014. This study also concludes that both average correlates very highly. This study points to the fact that the overall rainfall pattern across Indian subcontinent has not change much for the last 60 years or so and also that the solar activities like sun spots do not affect the rainfall pattern at all.

Author details

Shajimon K John

Address all correspondence to: shajimonkalayil@gmail.com

Saintgits College of Engineering, Kottayam, Kerala, India

References

[1] Chowdhury's guide to planet earth. In: The Water Cycle. USA: WestEd; 2005

[2] Timothy Liu W, XiaosuXie, Tang W. Monsoon, orography, and human influence on Asian rainfall (PDF). In: Proceedings of the First International Symposium in Cloud-Prone & Rainy Areas Remote Sensing (CARRS). National Aeronautic and Space Administration Jet Propulsion Laboratory: Chinese University of Hong Kong; 2006

[3] Meehl GA, Stocker TF, Collins WD, Friedlingstein P, Gaye AT, Gregory JM, Kitoh A, Knutti R, Murphy JM, Noda A, Raper SCB, Watterson IG, Weaver AJ, Zhao Z-C. Precipitation and Surface Water, Global Climate Projections. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. UK: Cambridge University Press; 2007

[4] Peel MC, Finlayson BL, McMahon TA. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences. 2007;**11**:1633-1644. DOI: 10.5194/hess-11-1633-2007 ISSN 1027-5606

[5] Rubel F, Kottek M. Comments on: 'The thermal zones of the Earth' by Wladimir Köppen (1884). MeteorologischeZeitschrift. 2011;**20**(3):361-365

[6] "Koppen climate classification | climatology". Encyclopedia Britannica

[7] https://www.mapsofindia.com/geography/

[8] Sivakumar MVK, Das HP, Brunini O. Impacts of present and future climate variability and change on agriculture and forestry in the arid and semi-arid tropics. Climatic Change. 2005;**70**:31

[9] Dhiman RC, Adak T, Subbarao SK. Impact of climate change on malaria in India with emphasis on selected sites. In: Gosain AK, Sharma SK, Bhattacharya S, Amit G, Rao S, editors. Proceedings of the Workshop on Vulnerability Assessment and Adaptation Due to Climate Change on Indian Water Resources, Coastal Zones and Human Health, 27-28 June, Indian Institute of Technology, Delhi, and Ministry of Environment and Forests. New Delhi: Government of India; 2004. pp. 127-133

[10] Cruz RV, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, Honda Y, Jafari M, Li C, Huu Ninh N. Asia. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2007. pp. 469-506

[11] Dash SK, Jenamani RK, Kalsi RS, Panda SK. Some evidence of climate change in twentieth-century India. Climatic Change. 2007;**85**:299-321

[12] Dash SK, Kulkarni MA, Mohanty UC, Prasad K. Changes in the characteristics of rain events in India. Journal of Geophysical Research. 2009;**114**:D10109

[13] Goswami BN, Venugopal V, Sengupta D, Madhusoodanan MS, Prince KX. Increasing trend of extreme rain events over India in a warming environment. Science. 2006;**314**: 1442-1445

[14] Guiteras R. The Impact of Climate Change on Indian Agriculture. College Park, Maryland: Manuscript, Department of Economics, University of Maryland; 2009

[15] Kothawale R, Rupa Kumar K, Mooley DA, Munot AA, Parthasarathy B, Sontakke NA. India Regional/Subdivisional Monthly Rainfall Data Set. Maharashtra: Indian Institute of Tropical Meteorology; 2006

[16] Kripalani RH, JH O, Kulkarni AS, Sabade S, Chaudhari HS. South Asian summer monsoon precipitation variability: Coupled climate model simulations and projections under IPCC AR4. Theoretical and Applied Climatology. 2007;**90**:133-159

[17] Krishna Kumar K, Rupa Kumar K, Ashrit RG, Deshpande NR, Hansen JW. Climate impacts on Indian agriculture. International Journal of Climatology. 2004;**24**:1375-1393

[18] Ramesh KV, Goswami P. Reduction in temporal and spatial extent of the Indian summer monsoon. Geophysical Research Letters. 2007;**34**:L23704

[19] Parthasarathy B, Kumar KR, Munot AA. Homogeneous Indian monsoon rainfall: Variability and prediction. Proceedings of Indian Academic Science (Earth Planet Science). 1993;**102**:121

[20] Selvaraju R. Impact of el Niño-southern oscillation on Indian foodgrain production. International Journal of Climatology. 2003;**23**:187-206

[21] Rajeevan M, Pai DS, Anil Kumar R, et al. New statistical models for long-range forecasting of southwest monsoon rainfall over India. Climate Dynamics. 2007;**28**:813

[22] Delsole T, Shukla J. Linear prediction of the Indian monsoon rainfall. Centre for Ocean–Land–Atmosphere Studies (COLA). Technical report CTR 114-58. 2002

[23] Webster PJ, Magana VO, Palmer TN, Shukla J, Tomas RA, Yanai M, Yasuna T. Monsoons: Processes, predictability, and the prospects for prediction. Journal of Geophysical Research. 1998;**103**:14451-14510

[24] Jagannathan P. Seasonal Forecasting in India: A Review. 1-80, India Meteorological Department, Pune, India: FMU; 1960

[25] Goswami BN. The Asian monsoon: Interdecadal variability. In: Chang CP, Wang B, Lau NC, editors. Global Monsoon System: Research and Forecast. Geneva: World Meteorological Organization; 2005. p. 455

[26] IndiaSingh N, Kumar KK, Soman MK. Some features of the periods contributing specified percentages of rainfall to annual total in Kerala. Theoretical and Applied Climatology. 1989;**39**:160

[27] Srinivasan V, Mukherji S, Ramamurthy R. Southwest monsoon-typical situations over Kerala and Arabian sea islands. Forecasting Manual Part III FMU Rep. No. III-3.8, India Meteorological Department, Poona-5. 1972

[28] Soman MK, Krishna Kumar K, Singh N. Decreasing trend in the rainfall of Kerala. Current Science. 1988;**57**:7-12

[29] India Meteorological Department, 1986: Climate of Kerala. Report No. PDGM-115 N/250-1986 (DSK-II), Division of Climatology and Geophysics, Pune 5

[30] Singh N. On the duration of the rainy season over different parts of India. Theoretical and Applied Climatology. 1986;**37**:51-62

[31] Raghavan K. Influence of the western Ghats on the monsoon rainfall at the coastal boundary of peninsula India. Indian Journal of Meteorology & Geophysics. 1964;**15**:617-620

[32] https://www.thesuntoday.org/the-sun/solar-activity/

[33] https://www.nasa.gov/content/goddard/what-is-solar-activity

[34] Zi-Niu XIAO, De-Lin LI, Li-Min ZHOU, Liang ZHAO & Wen-Juan HUO. Interdisciplinary studies of solar activity and climate change. Atmospheric and Oceanic Science Letters. 10;**4**:325-328. DOI: 10.1080/16742834.2017.1321951

IntechOpen