Changing rainfall in the Palakkad plains of South India

P. P. N. RAJ and P. A. AZEEZ
Environmental Impact Assessment Division,
Sálim Ali Centre for Ornithology and Natural History (SACON)
Anaikatty (PO), Coimbatore-641108, India
Corresponding author: P. P. N. RAJ; e-mail: ppnraj@gmail.com

RESUMEN

El análisis de las tendencias generales de la precipitación es vital para entender sus características subyacentes con el propósito de pronosticar e identificar los cambios e impactos que son cruciales para una economía basada en la agricultura como la de la India. Las planicies de Palakkad, situadas al lado oeste de la brecha de Palakkad, comunican al estado de Kerala, en la India, con las planicies de Tamil Nadu y Deccan. Su ubicación geográfica resulta en un ambiente diferente del resto de Kerala. La investigación presente analiza la tendencia general de la precipitación en las planicies de Palakkad utilizando datos mensuales de precipitación, correspondientes a casi un siglo, tomados de la red de estaciones disponibles en el área. El patrón anual de precipitación en todas las estaciones muestra una tendencia significativa de declinación con el paso de los años. Los cambios en la precipitación pueden tener implicaciones en la ecología local así como en la productividad agrícola. El decremento de la precipitación podría ser reflejo de los cambios climáticos a nivel local ocasionados por varios factores antrópicos.

ABSTRACT

Analysis of the general rainfall trend is vital in understanding the underlying features, for the purpose of forecasting and in identifying the changes and impacts that are very crucial for an agro-based economy like the one of India. Situated on the western side of the Palakkad Gap, the Palakkad plains connect the state of Kerala in India to the plains of Tamil Nadu and Deccan. The geographical location results in an environmental realm in the Palakkad plains that is different from the rest of Kerala. The present study examines the general trend of rainfall in the Palakkad plains using monthly rainfall data, almost spanning a century, collected from four rain gauge stations available in the area. The annual rainfall pattern of all the stations showed a trend of significant decline, as the years proceed. Changes in the rainfall may have implications on local ecology as well as in agricultural productivity. The decrement in rainfall may reflect the actual regional level climate changes compounded by various anthropogenic factors.

Keywords: Trend analysis, rainfall patterns, Kerala, Indian monsoon.

1. Introduction

Understanding the regional level of rainfall trend from past data is of immense importance for agriculture based economies such as the one of India. Such data are crucial for the effective modeling of the local rainfall patterns, which can help in dealing with the vagaries and troubles from the inconsistencies in occurrence of the regional rainfall. Reichardt *et al*. (1995) show significant local variation in rainfall occurrence in humid tropical regions. Due to a dearth of infrastructure and scarcity of resources, the people in the tropics undergo such miseries severely.

Variation in occurrence of rainfall has been studied widely by several authors across the globe. Studies conducted by Burgueño *et al*. (2004) in Spain, Smith (2004) in Australia, Bidin and Chappel (2006) in

Malaysia, Shen *et al*. (2007) in China, Ashley *et al*. (2003) and Haylock *et al*. (2005) in USA, Fauchereau *et al*. (2003) in Africa, are some among them. The Indian monsoon rainfall on the other hand have been investigated by several authors; its events and predictability (Venketesan *et al*., 1997; Rajeevan, 2001; Pai and Rajeevan, 2006; Goswami and Gauda, 2007; Raju *et al*., 2007; Ratnam *et al*., 2007), its general characteristics (Rajeevan *et al*., 2006) and the inconsistencies in the occurrence (Goswami and Ramesh, 2007; Ramesh and Goswami, 2007; Francis and Gadgil, 2009) are some of the issues explored regarding Indian monsoon rainfall. It is reported that Indian monsoon rainfall is highly influenced by atmospheric factors such as regional pressure anomalies (Dugam and Kakade, 2003), cyclonal activities (Pattanaik and Rajeevan, 2007) and sea surface temperature variations (Goswami *et al*., 2006) thereby making monsoon rainfall less predictable (Mani *et al*., 2009).

Kerala, the southwestern strip of India (72.5-77.5º E; 8.5-15.5º N) is blessed with copious monsoonal rainfall. Kerala is known as the "Gate way of the summer monsoon" to India and the economy of the state is highly influenced by the monsoon rainfall. The principal rainy seasons in Kerala are the south-west monsoon (June-September) and north-east monsoon (October-November). The pre-monsoon months (March-May) account for several thunderstorm incidences in the state and the winter months (December-February) are characterized by minimum clouding and rainfall (Ananthakrishnan *et al*., 1979). Several authors have examined the rainfall pattern of Kerala state. Fasullo and Webster (2003), and Joseph *et al*. (2004) documented the general characteristics, arrival and distributional pattern of the monsoonal rainfall in the state. Kumar *et al*. (2004) studied the premonsoon rainfall of the state, while Guhathakurtha (2005) examined the Kerala monsoon using artificial neural networks. Krishnakumar *et al*. (2009) reported a significant decrease in the south west monsoon in the state and an increase in the north east monsoon rainfall. Simon and Mohankumar (2004) studied spatial variation in the occurrence of rainfall and found it significantly influenced by the general physiography of the state. Soman *et al*. (1998) have reported a fall in the annual rainfall in the southern part of Kerala. However, they could not find similar decrement in the northern part of the state. The present study examines the rainfall occurrence in the Palakkad plains of Kerala using historical data.

2. Study area and methodology

The study area, the Palakkad plain, is the east west tending plain to which the 30 km discontinuity, known as the Palakkad Gap, in the Western Ghats, spreads out on its west. The Palakkad Gap, the lowest mountain pass in the Western Ghats, is the chief corridor connecting Kerala to Tamil Nadu and other parts of India, which historically played a crucial role in cultural, political, linguistic and commercial integration of south India. The gap supports a network of brooks and rivulets forming the west flowing river Bharathapuzha, the second longest river in the state. The rains occurring in the Western Ghats of Palakkad and the Palakkad plains mainly feed the river Bharathapuzha, on which people of three districts of Kerala largely depend. The Palakkad Gap also plays a critical role in the climate of the state, especially that of the Palakkad plain. The gap shapes the moderate climate of Coimbatore and provides notable rainfall in the region than other parts of Tamil Nadu by allowing the moisture laden monsoon winds to pass through during the south-west monsoon season. On the other hand, the summer temperature of the Palakkad plain of Kerala is also greatly influenced by the gap.

The present study examines the general rainfall pattern in the Palakkad plains using the historical rainfall data available at four rain-gauge stations located at Palakkad, Malampuzha, Chittur and Mannarkkad. We procured available rainfall data (Fig. 1) from Mannarkkad, Palakkad (1916 to 2000), Chittur (1930-2000) and Malampuzha (1923-2000). The four rain-gauge stations fall within a 30 km radial distance, and are located in the upper catchment of the river Bharathapuzha. Our enquiries show that no data is available from 1945 to 1968 for the study area. Average rainfall data, taking all the stations together were used for the analysis to identify the trend in rainfall. The rationale behind taking the average rainfall for the four stations for the entire Palakkad plain was that the average inter-station distance among these stations is only 23.2 km. James *et al*. (1986), while proposing a rain-gauge network for the Bharathapuzha basin reports a high correlation between the rain gauges occurring at this level of inter-station distances.

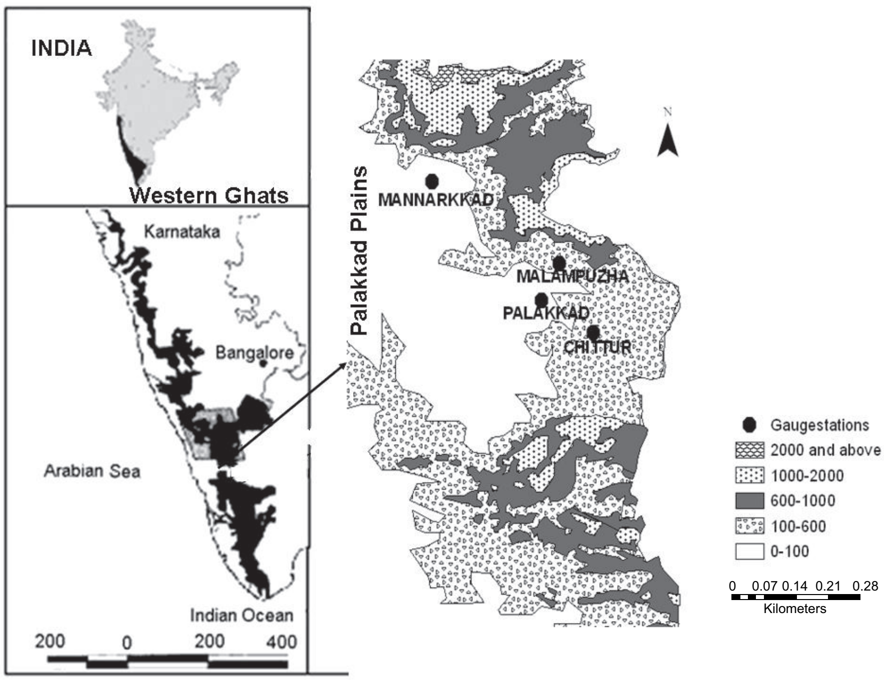

Fig. 1. Physiography of the Palakkad Plains showing the altitudinal differences and the location of the rain gauge stations.

The consolidated data were grouped into two classes on the basis of the variation found between two periods-events before 1945 and events after 1968. Spatial as well as temporal changes in the seasonal and annual rainfalls were analyzed using Man-Kendall rank correlation, since it is a suitable statistical test for a long period of data (Basistha *et al*., 2007; Krishnakumar *et al*., 2009). The value of t where used as the basis of a significant test by comparing it with

$$Tt = 0 \pm t_g \surd[4\,N + 10/9N\,(N - 1)]$$

Where, t_g is the desired probability point of the Gaussian normal distribution. In the present study t_g at 0.01 and 0.05 where considered as the points for significance. The trend line fitted to the data was analyzed using Student t test to verify the results obtained from Man-Kendall statistics. From the basic monthly mean rainfall data annual maximum and minimum, mean, standard deviation and coefficient of variation among the stations were computed. SPSS 10 Software package was used for carrying out the statistical analyses.

3. Results

3.1 General rainfall pattern

The average total annual rainfall in the Palakkad plains during the period of study was 2212 mm. The total rainfall during this period ranged from 1309 to 3668 mm. Rainfall in the plains is largely consistent in its range and pattern. The area receives a major share of rain (70 %) from the south-west monsoon. The north-east monsoon contributes 17%, of the total rainfall. Pre-monsoon showers contribute 11% of the total rainfall in the Palakkad plains, while only 2% of the total rainfall is received from the winter rains. The Man-Kendall rank correlation analysis shows a significant decline in annual rainfall across the two periods (prior to 1945 and after 1968, Table I). Variations in rainfall were found among the four stations. Among the stations, the average annual rainfall was found to be highest in Mannarkkad and the lowest in Chittur (Table II).

Table I. Spatio-temporal variation in rainfall Man-Kendall statistics.

Season	Palakkad	Malampuzha	Mannarkkad	Chittur	Whole study area
Annual	–0.189	–0.647**	–0.238*	–0.461**	–0.428**
Winter	–0.145	0.006	–0.044	–0.092	–0.263*
Premonsoon	–0.003	–0.038	–0.055	–0.298*	–0.076
SW monsoon	–0.138	–0.681**	–0.271**	–0.245	–0.469**
NE monsoon	–0.056	–0.266*	–0.054	–0.352**	0.054

**Significant at the 0.01 level and *significant at the 0.05 level.

4. Temporal variations in rainfall events

Temporal variation in the total rainfall received in the Palakkad plains is shown in Figure 2. The annual rainfall in the area shows a significant decline. The south-west monsoon and winter rainfalls also show a significant decrement. The pre-monsoon rain events in the plains on the other hand show a declining trend that is not statistically significant. However, the north-east monsoon rainfall showed a trend of increase, although it is not statistically significant. Among the stations, the south-west monsoon rainfall shows a decreasing trend in all the stations, which is found to be statistically significant only in the case of Malampuzha and Mannarkkad. The winter rainfall in all the stations shows a decreasing trend which however is not statistically significant, except in the case of Malampuzha (Table I).

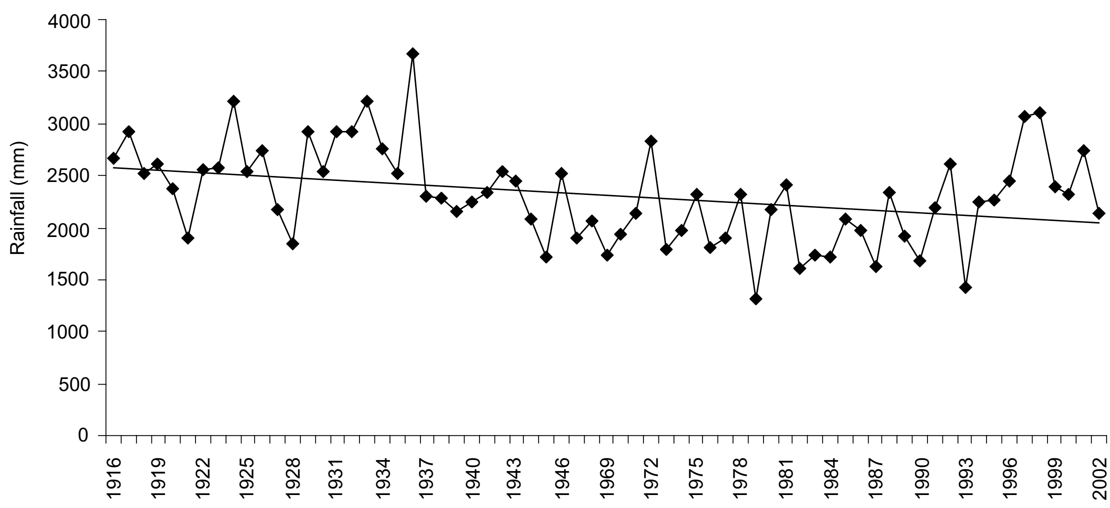

Fig. 2. Temporal variation in the rainfall in the Palakkad plains.

Table II. Station-wise annual rainfall statistics.

Stations	Minimum (mm)	Maximum (mm)	Mean (mm)	Std. deviation	Coefficient of variation (%)
Chittur	742.5	3621	1666.9	557.68	33.5
Malampuzha	1309	7048.5	2611.49	1160.28	44.4
Mannarkkad	496.4	5115.31	2629.03	738.07	28.1
Palakkad	1224	3204.21	2032.12	439.04	21.6

5. Discussion

The total annual rainfall of the Palakkad plains is lower than the total annual rainfall for the whole state of Kerala (2817 mm; Krishnakumar *et al*., 2009). Due to its specific geographical location, the climate of the Palakkad plains is highly influenced by the humid climate of Kerala as well as the more arid climate condition on the western side of the Western Ghats, the Coimbatore plains of Tamil Nadu. The decrement in the total rainfall in the region is found to be highly related with the decrease in the seasonal rainfalls. Raj and Azeez (2009) reported advancement in the first rain event in a Julian year towards winter in the Palakkad Gap of Western Ghats, contiguous to the area of the present study. The significant decrement in the south-west monsoon rainfall in the Palakkad plains observed in the present study is obviously due to the decline of the same in Malampuzha and Mannarkkad, receiving comparatively higher annual rainfall among the stations in the study area. This observation agrees with the findings of Soman *et al*. (1988). Contrary to the study by Krishnakumar *et al*. (2009) that reports an increasing trend in the winter rain events in the state, the present study over the Palakkad plains shows a significant decline in winter rainfall.

The rainfall in the Palakkad plains shows a degree of location specificity in rainfall, the stations differing from one another. The amount of rainfall in each of the stations was found to be related to their location relative to the Palakkad Gap. Chittur, which is located at the base of the Palakkad Gap received comparatively lower rainfall and Mannarkkad on the other hand, which is located at a relatively greater distance from the gap received the highest rainfall. However, there seems to be no correlation between the annual rainfall and altitude. The study conducted by Simon and Mohankumar (2004) also reports that altitude and the rainfall in Kerala are not correlated. On the other hand the study on rainfall in the Palakkad Gap in the Western Ghats by Raj and Azeez (2009) shows annual rainfall varying with altitude. The high annual rainfall at Mannarkkad and Malampuzha is possibly due to their specific location in the valleys amidst the rolling mountains and the surrounding rain forest patches. On the other hand, Chittur which is located in the Palakkad plains is comparatively deprived of forest cover and also happens to get the least rainfall among the stations. The studies conducted by various authors also report the influence of forest cover on the local rainfall (Ravindranath *et al*., 2006; Tiwari, 2006).

Meteorology is to a great extend related to the local physiography, particularly orography (Cerlini *et al*., 2005). These features act as major driving forces determining the amount of downpour in most of the cases. The location of stations such as Mannarkkad and Malampuzha in the windward direction during the south-west monsoon periods in the valleys in the Western Ghats (Fig. 1) provides higher rainfall events. On the other hand, although Chittur is located in the windward direction in the Palakkad Gap, it lacks hillocks or other similar structures to tap the clouds, which presumably results in low rainfall. During the north-east monsoon season a reversal of air circulation happens. However, the north-east monsoon contributes to only 15% of the total rainfall of the state (Krishnakumar *et al*., 2009).

Changes in land use pattern particularly related to deforestation in the highlands of the state during and after the 1950s (Meher-Homji V. M., 1991; Soman *et al*., 1998) as a result of having to accommodate 1.5×10^5 people (Chattopadhyay, 1985) moving in from the midlands and lowlands of the state, would have modified the state's landscape and local meteorology. The later years have seen a greater spread of human habitations and urban sprawl in the state due to various socio-economic reasons. The higher variation in the rainfall in Malampuzha may possibly be an after-effect of the installation of the Malampuzha hydroelectric project. A large portion of the area lost its forest cover when the project was built during the 1950s and resulted in a large reservoir of about 20 km^2. A majority of the forest lands of the area surrounding the Malampuzha hydroelectric project was transformed into largely monoculture plantations. Urbanization is also found to play a major role in rainfall (Liu *et al*., 2005). Palakkad, Chittur, Mannarkkad and Malampuzha are major urban growth centers in the Palakkad plains. It needs to be noted that during the last century, especially towards the second half, the Palakkad region underwent a wide range of changes associated with urbanization.

6. Conclusion

The present study examines the general rainfall pattern in the Palakkad plains, located in the western part of the Palakkad Gap in the Western Ghats, using available data from four rain gauge stations. Due to its geographical location, the climatic condition of the place is different from the rest of the state. The study revealed that the annual rainfall in the region is comparatively lesser than that of the entire state. A significant decrement in the annual rainfall, winter rainfall and the south-west monsoon rainfall was also observed. A level of spatial variation in the occurrence of rainfall was observed in the Palakkad plains. The average annual rainfall among the stations was found to be in the following decreasing order: Mannarkkad Malampuzha Palakkad Chittur. In three of the stations, the annual rainfall showed a decreasing trend. Therefore, it is suggested that the intensive deforestation and extensive urban development may also have an influence on the annual rainfall variation of the region.

Acknowledgement

We thank the Irrigation Department (Engineers Mrs. Anitha, Mr. Denny and Mr. Solin) Government of Kerala, Thrissure and the Librarian, Kerala Engineering Research Institute, Peechi, Thrissure, for their valuable helps. We are thankful to Prof. P. Ilangovan for language corrections and our colleagues Ms. Ranjini and Mr. Zaibin for their comments on the manuscript.

References

Ananthakrishnan R., B. Parthasarthy and J. M. Pathan, 1979. Meteorology of Kerala. Contributions to Marine Sciences. India, 123-125.

Ashley W. S., T. L. Mote, P. G. Dixon, S. L. Troti'er, E. J. Powell, J. D. Durkee and A. J. Grundstein, 2003. Distribution of mesoscale convective complex rainfall in the United States. *Mon. Wea. Rev*. **131**, 3003-3017.

Basistha A., N. K. Goel, D. S. Arya and S. K. Gangawar, 2007. Gangawar spatial pattern of trend in Indian sub-divisional rainfall. *Jalavigyan sameekha* **22**, 47-57.

Bidin K. and N. A. Chappell, 2006. Characteristics of rain events at an inland locality in northeastern Borneo, Malaysia. *Hydrol. Process*. **20**, 3835-3850.

Burgueño A., C. Serra and X. Lana, 2004. Monthly and annual statistical distributions of daily rainfall at the Fabra Observatory (Barcelona, NE Spain) for the years 1917-1999. *Theor. Appl. Climatol*. **77**, 57-75. DOI 10.1007/s00704-003-0020-9.

Cerlini P. B., K. A. Emanuel and E. Todini, 2005. Orographic effects on convective precipitation and space-time rainfall variability: preliminary results. *Hydrol. Earth Syst. Sc.* **9**, 285-299.

Chattopadhyay S., 1985. Deforestation in parts of Western Ghats region (Kerala), India. *J. Environ. Manage.* **20**, 219-230.

Dash S. K., R. K. Jenamani, S. R. Kalsi and S. K. Panda, 2007. Some evidence of climatic change in twentieth-century India. *Climatic Change* **85**, 299-321.

Dugam S. S and S. B. Kakade, 2003. Indian monsoon variability in relation to regional pressure index. *Proc. Indian Acad. Sci. (Earth Planet. Sci.)* **112**, 521-527.

Fasullo J. and P. J. Webster, 2003. A hydrological definition of Indian Monsoon onset and withdrawal, *J. Climate* **16**, 3200-3211.

Fauchereau N., S. Trzaska, M. Rouault and Y. Richard, 2003. Rainfall variability and changes in southern Africa during the 20th century in the global warming context. *Nat. Hazards* **29**, 139-154.

Francis P. A and S. Gadgil, 2009. The aberrant behaviour of the Indian monsoon in June 2009. *Curr. Sci.* India **97**, 1291-1295.

Goswami B. N., V. Venugopal, D. Sengupta, M. S. Madhusoodanan and P. K. Xavier, 2006. Increasing trend of extreme rain events over India in a warming environment. *Science* **314**, 1442-1445.

Goswami P. and K. C. Gouda, 2007. Objective determination of the date of onset of monsoon rainfall over India based on duration of persistence. CSIR Centre for Mathematical Modelling and Computer Simulation, Research Report RR CM 0711.

Goswami P. and K. V. Ramesh, 2007. Extreme rainfall events: Vulnerability analysis for disaster management and observation system design. CSIR Centre for Mathematical Modelling and Computer Simulation, Research Report RR CM 0703, Bangalore, India, 10 pp.

Guhathakurtha P., 2005. Long-range monsoon rainfall prediction of 2005 for the districts and subdivision Kerala with artificial neural network. *Curr. Sci. India* **90**, 773-779.

Haylock M. R., T. C. Peterson, L. M. Alves, T. Ambrizzi, Y. M. T. Anunciação, J. Baez, V. R. Barros, M. A. Berlato, M. Bidegain, G. Coronel, V. Corradi, V. J. García, A. M. Grimm, D. Karoly, J. A. Marengo, M. B. Marino, D. Moncunill, D. Nechet, J. Quintana, E. Rebello, M. Rusticucci, J. L. Santos, I. Trebejo and L. Vincent, 2005. A Trends in total and extreme South American rainfall in 1960-2000 and links with sea surface temperature. *J. Climate* **19**, 1490-1512.

James E. J., K. E. Sreedharan, G. Ranganna, I. V. Nayak and T. S. Prasad, 1986. Design of rain gauge network using spatial correlation for the Bharathapuzha basin on the Malabar coast of India. Integrated design on hydrological network. Proceedings of the Budapest symposium 1986, IAHS Publ. No.158.

Joseph P. V., A. Simon, V. G. Nair and A. Thomas, 2004. Intra-seasonal oscillation (ISO) of south Kerala rainfall during the summer monsoons of 1901-1995 *Proc. Indian Acad. Sci. (Earth Planet. Sci.)*, **113**, June, 139-150.

Krishnakumar K. N., G. S. L. H. V. P. Rao and C. S. Gopakumar, 2009 Rainfall trends in twentieth century over Kerala, India. *Atmos. Environ.* **43**, 1940-1944.

Kumar R. M. R, S. S. S. Shenoi and D. Shankar, 2004. Monsoon onset over Kerala and Premonsoon rainfall peak. http://drs.nioorg/drs/bitstream/2264/1183/2/ProcMETOC2004_305.

Liu W. T., X. Xie and W. Tang, 2005. Proceedings of the First International Symposium in Cloud-prone and Rainy Areas Remote Sensing (CARRS), Chinese University of Hong Kong http://airsea-www.jpl.basa.gov, downloaded on 17/09/08, www.geo.uni.lodz.pl.

Mani N. J., E. Suhas and B. N. Goswami, 2009. Can global warming make Indian monsoon weather less predictable? *Geophys. Res. Lett.* **36**, L08811, doi:10.1029/2009GL037989.

Meher-Homji V. M., 1991. Probable impact of deforestation on hydrological processes. *Climatic Change* **19**, 163-73.

Pai D. S. and M. Rajeevan, 2006. Empirical prediction of Indian summer monsoon rainfall with different lead periods based on global SST anomalies. *Meteorol. Atmos. Phys.* **92**, 33-43.

Pattanaik D. R. and M. Rajeevan, 2007. Northwest Pacific tropical cyclone activity and July rainfall over India, *Meteorol. Atmos. Phys.* **95**, 63-72.

Raj N. and P. A. Azeez, 2009. Historical analysis of the first rain event and the number of rain days in the western part of Palakkad gap, south India. In: Climate Change: Global Risks, Challenges and Decisions IOP Conferences Series: Earth and Environmental Science. 6, 072046. Coimbatore, India. doi:10.1088/1755-1307/6/7/072046.

Rajeevan M., 2001. Prediction of Indian summer monsoon: Status, problems and prospects. *Curr. Sci. India* **81**, 1451-1457.

Rajeevan M., J. Bhate, J. D. Kale and B. Lal, 2006. High resolution daily gridded rainfall data for the Indian region: Analysis of break and active monsoon spells. *Curr. Sci. India* **91**, 296-306.

Raju P. V., S. Raju, U. C. Mohanty and R. Bhatla, 2007. Interannual variability of onset of the summer monsoon over India and its prediction. *Nat. Hazards* **42**, 287-300.

Ramesh K. V. and P. Goswami, 2007. The Shrinking Indian summer monsoon. CSIR Centre for Mathematical Modelling and Computer Simulation, Research Report RR CM 0709.

Ratnam J. V., D. R. Sikka, A. Kaginalkar, N. Amitkesarkar, S. Jyothi and S. Banerjee, 2007. Experimental seasonal forecast of monsoon 2005 using T170L42 AGCM on PARAM Padma. *Pure Appl. Geophys*. **164**, 1641-1665.

Ravindranath N. H., N. V. Joshi, R. Sukumar and A. Saxena, 2006. Impact of climate change on forests in India, *Curr. Sci. India* **90**, 1-8.

Reichardt K., L. R. Angelocci, O. O. S. Bacchi and J. E. Pilotto, 1995. Daily rainfall variability at a local scale (1,000 ha), in Piracicaba, S.P., Brazil and its implication on soil water recharge. *Sci. Agric. (Piracicaba)*, **52**,43-49.

Shen C., W. C. Wang, Z. Hao and W. Gong, 2007. Characteristics of anomalous precipitation events over eastern China during the past five centuries. *Clim. Dynam.* Doi 10.1007/s00382-007-0323.

Simon A. and K. Mohankumar, 2004. Spatial variability and rainfall characteristics of Kerala. *Proc. Indian Acad. Sci. (Earth Planet. Sci.)*, **113**, 211-221.

Smith I., 2004. An assessment of recent trends in Australian rainfall. *Aust. Met. Mag*. **53**, 163-173.

Soman M. K., K..K Kumar and N. Singh, 1998. Decreasing trend in the rainfall of Kerala. *Curr. Sci. India* **57**, 7-12.

Tiwari R. C., 2006. Analytical study on variation of climatic parameters at Aizawl, Mizoram (India). *Bulletin of Arunachal Forest Research* **22**, 33-39.

Venketesan C., S. D. Raskar, S. S. Tambe, B. D. Kulkarni and R. N. Keshavamurty, 1997. Prediction of all India summer monsoon rainfall using error- back-propagation neural networks. *Meteorol. Atmos. Phys.* **62**, 225-240.