Research Article

doi:10.19071/jpc.2015.v43.i3.2856
Journal of Plantation Crops, 2015, 43(3): 218-224

Occurrence of extreme temperature events – A probable risk on natural rubber cultivation

K.K. Jayasooryan*, P.R. Satheesh, R. Krishnakumar and James Jacob

Rubber Research Institute of India, Rubber Board, Kottayam-686009, Kerala, India

(Manuscript Received:03-09-2015, Revised:18-10-2015, Accepted:30-10-2015)

Abstract

Climate change and occurrence of extreme temperature events were studied in Kottayam, a major rubber growing district in Kerala state. Occurrence of extreme temperature events can affect the livelihood of rubber growers apart from the ecological impact. The present study was conducted by analysing the occurrence of extreme temperature events in the past 40 years (1970-2010) using the RClimDex package developed by the Expert Team on Climate Change Detection Monitoring and Indices (ETCCDMI), Canada. Temporal variations in trends of occurrence of extreme temperature events were tested with Mann-Kendall trend analysis. The 5-year diurnal temperature range (DTR, difference between monthly mean maximum and minimum temperatures) increased from 7.8 (during 1970-1974) to 9.2 ^{0}C (during 2006-2010). The monthly mean maximum temperature increased by 0.035 ^{0}C per year. Frequency of occurrence of hot days increased at a rate of 0.56 per cent per year and the highest temperature recorded in a month showed an increase of 0.038 ^{0}C per year. As observed, the increasing trends in the occurrence of extreme temperature events may eventually lead to the warming up of the region in future. The study indicates that the projected warming tendency in the traditional rubber growing regions of India may affect the rubber cultivation adversely.

Keywords: Climate change, extreme weather events, natural rubber, RClimDex, weather indices

Introduction

Temperature extremes, characterized by daily temperature level exceeding tolerance limits and their frequency, are of great interest in terms of impacts. The frequency of extreme events may have a greater environmental and public health impact as compared to long term climatic changes (Insaf *et al*., 2012). Outbreak of epidemics, flood, drought, biodiversity loss and ecosystem damages, heavy loss in agriculture, dam breakup, landslides, traffic problem, economic loss *etc*., are some of the possible impacts of extreme weather events. Extreme temperatures, both maximum and minimum temperature events, have particular importance due to relationship with biodiversity and human thermal comfort and their use in climate change impact assessment in sectors such as agriculture, water resources, and energy demand (Xiao *et al.,* 2013; Garcia-Cueto *et al.,* 2013).

Very few studies have come out from India regarding the extreme weather events and most of them are on rainfall events. Guhathakurta *et al*. (2011) studied the occurrence of extreme rainfall events and associated flood risks in India and its relation to the climate change in different geographical regions of India. According to Joshi and Rajeevan (2006), the extreme precipitation events show a positive trend in peninsular India. Khaladkar *et al*. (2009) also supported this findings based on the analysis of rainfall data from 165 stations across India. All these studies, based on the analysis of long term data, support increasing trend of occurrence of extreme weather events over India. Studies are scarce regarding the occurrence of extreme temperature events at regional or large scale in Indian context. The studies on extreme temperature events are highly relevant at regional scale since the impacts of events are more visible and severe at regional level. The present study

**Corresponding Author: jayasooryan@rubberboard.org.in*

analyses the occurrence of extreme temperature events in Kottayam district of Kerala, a traditional rubber growing region in India.

Materials and methods

Daily maximum temperature (Tmax, represented by TX), daily minimum temperature (Tmin, represented by TN) and precipitation for a period of 40 years (1970 to 2010) were collected from the weather station located at Rubber Research Institute of India (9^0 34' 44.44" N, 74^0 36' 16.98" E) Kottayam, Kerala.

The data was analysed using RClimDex software package developed by Expert Team on Climate Change Detection Monitoring and Indices (ETCCDMI) at the climate research branch of the meteorological service of Canada (Wang *et al*., 2013; Ning *et al.,* 2012; Insaf *et al.,* 2013; Renom *et al*., 2011; Marofi *et al.,* 2011; Sohrabi, *et al.,* 2013). The package is able to generate 27 extreme indices including 11 precipitation indices and 16 temperature indices. The 16 extreme temperature indices selected in this study are shown in Table 1.

The trend analysis for detecting the changes during 1970 to 2013 was done using Mann-Kendall trend analysis using EXCEL STAT. Significance of trend was not analysed for CSDI and WSDI, since it was not observed during the initial decades, instead, the frequency of occurrence is plotted directly against year.

Table 2. Results of Mann-Kendall trend test for different indices from 1970 to 2010

Sl. No.	Parameter	Trend
1	DTR	Increasing
2	SU 32	Increasing
3	Tmax mean	Increasing
4	Tmin mean	No trend
5	TN 10P	No trend
6	TN 90P	No trend
7	TNn	No trend
8	TNx	No trend
9	TR 20	No trend
10	TR 25	No trend
11	TX 10P	Decreasing
12	TX 90P	Increasing
13	TXn	No trend
14	TXx	Increasing

Table 1. List of indices selected for the study

No.	Indicator name	Index ID	Definition	Units
1	Tmax mean	Tmax mean	Monthly mean of Tmax	^{0}C
2	Tmin mean	Tmin mean	Monthly mean of Tmin	^{0}C
3	Hot days	SU 32	Annual count when TX >32 ^{0}C	days
4	Diurnal temperature range	DTR	Monthly mean difference between TX and TN	^{0}C
5	Hot day frequency	TX90p	Percentage of days when TX>90th percentile	%
6	Cool day frequency	TX10p	Percentage of days when TX<10th percentile	%
7	Hottest day	TXx	Annual average of Monthly highest TX	^{0}C
8	Warm spell duration index	WSDI	Annual count of days with at least 6 consecutive days when TX>90th percentile	days
9	Hot night frequency	TN90p	Percentage of days when TN>90th percentile	%
10	Cool night frequency	TN10p	Percentage of days when TN<10th percentile	%
11	Coolest night	TNn	Monthly lowest TN	^{0}C
12	Hottest night	TNx	Monthly highest TN	^{0}C
13	Warm nights	TR 20	Annual count of days when TN>20 ^{0}C	days
14	Warm night	TR 25	Annual count of days when TN> 25 ^{0}C	days
15	Coolest day	TXn	Monthly lowest TX	^{0}C
16	Cold spell duration index	CSDI	Annual count of days with at least 6 consecutive days when TN<10th percentile.	days

Results and discussion

The study shows clear trends in the temperature events from 1970 to 2010 in the South-West coast of India. The trend in percentile based temperature indices and absolute temperature indices during the 1970 to 2010 are given in Table 2. Analysis of long term temperature data showed clear indication of warming trend which can be attributed to climate change. An increasing trend was noticed in the occurrence of high temperature events such as diurnal temperature range, Tmax mean, TX 90 P, TXx *etc.,* but no significant trend was observed for low temperature events.

Mann-Kendall trend analysis showed an increasing trend of days with maximum temperature greater than 32 ^{0}C during 1970 to 2010 (Fig. 1), indicating the warming up of this region possibly due to urbanisation and heat island phenomenon as

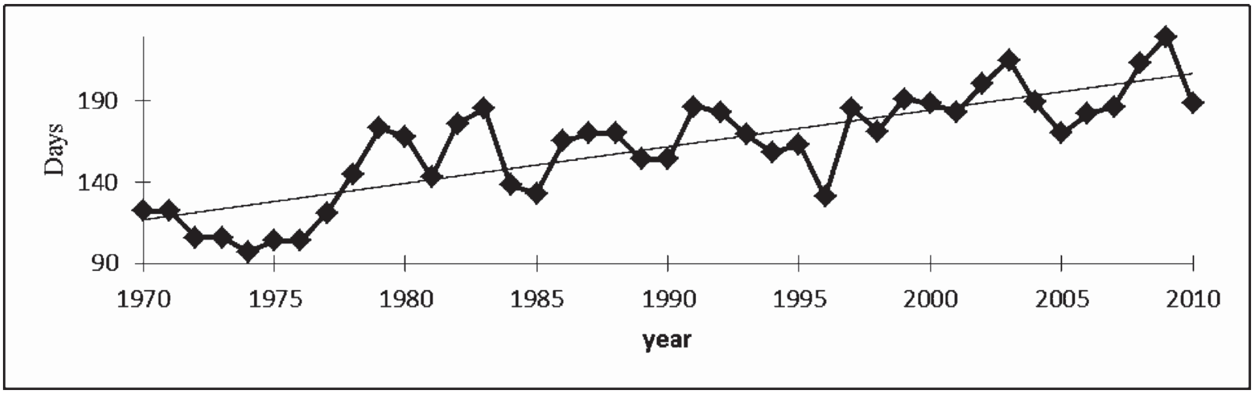

Fig. 1. Variation in number of hot days (SU 32) from 1970 to 2010

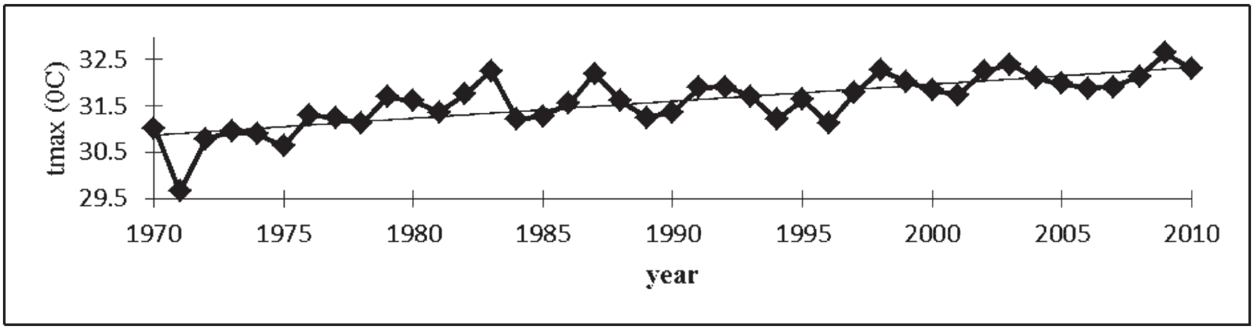

Fig. 2. Variation in monthly mean of Tmax (Tmax mean) from 1970 to 2010

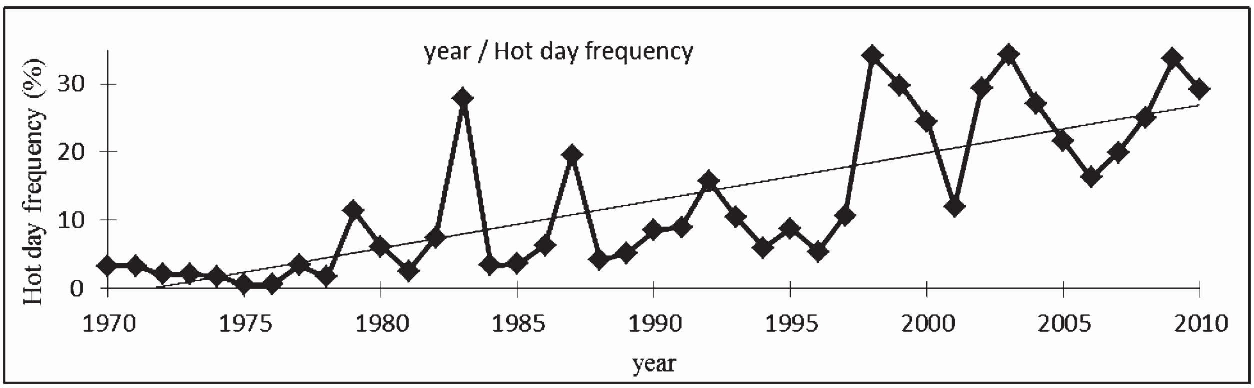

Fig. 3. Variation in hot day frequency (TX90P) from 1970 to 2010

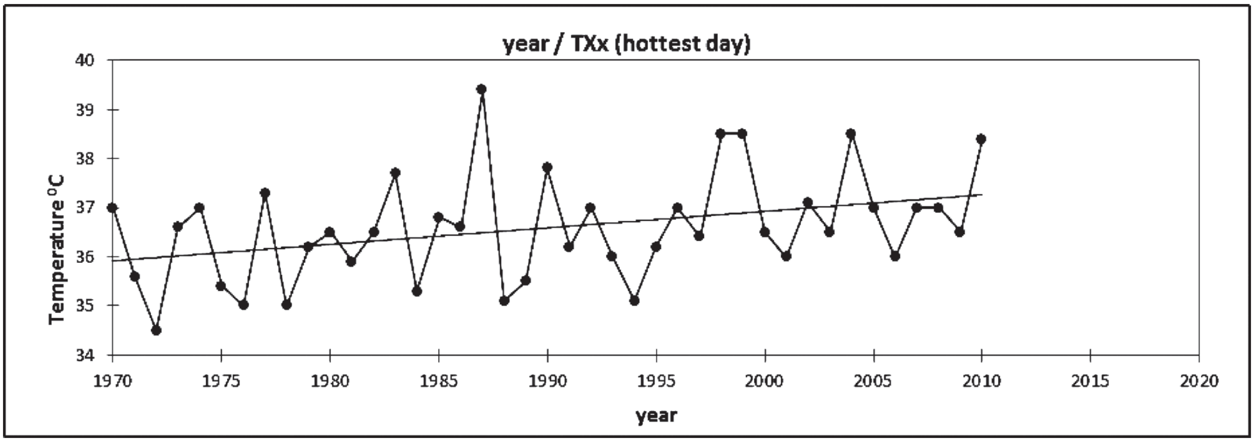

Fig. 4. Variation in TXx. (hottest day) from 1970 to 2010

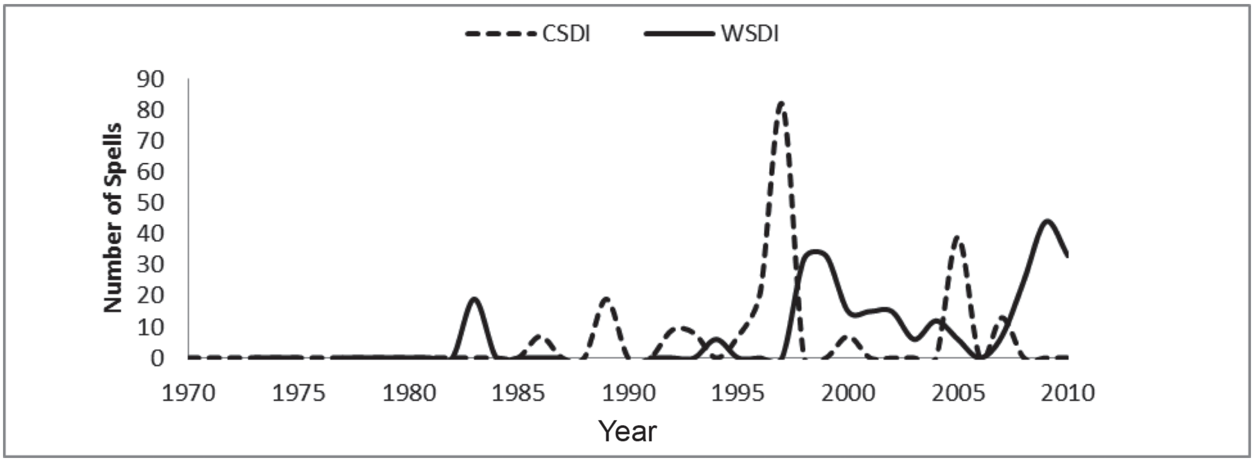

Fig. 5. Frequency of occurrence of CSDI and WSDI from 1970 to 2010

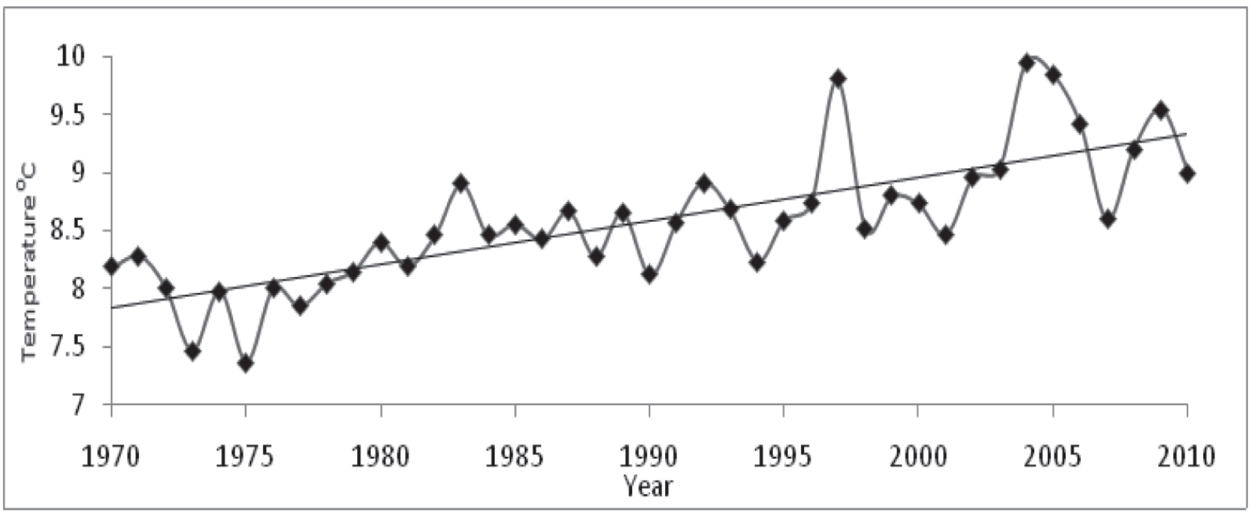

Fig. 6. Variation in diurnal temperature range (DTR) from 1970 to 2010

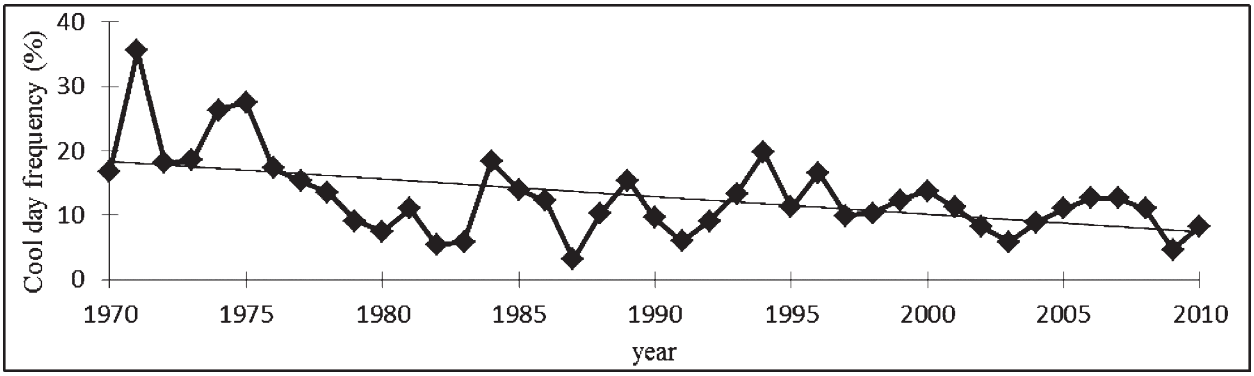

Fig. 7. Variation in cool day frequency (TX10p) from 1970 to 2010

earlier reported by Jain and Kumar (2012) from the southern peninsula of India. Tmax mean showed a steady increase during the last 40 years with an annual increase of 0.034 ^{0}C (Fig. 2) and hot day frequency was increasing at a rate of 0.56 per cent per year during the period of analysis (Fig. 3). Hottest day (TXx), the highest temperature recorded in a month, showed a significant increase from 1970 to 2010 with an increase of a 0.035 ^{0}C per year (Fig. 4). The increase in Tmax mean is highly significant reflecting the global warming trend associated with the climate change. Revadekar *et al.* (2012) reported widespread warming through increase in intensity and frequency of hot events and also decrease in frequency of cold events in 121 stations across India. The present study supports these findings, based on the weather data from an economically important agro-climatic location situated between west coast planes and ghat regions of Kerala.

CSDI and WSDI appeared more frequently after 1995 (Fig. 5). The increase in the frequency of warm spells indicated the persistent warming phenomenon. Average DTR increased from 7.8 ^{0}C during 1970-1974 to 9.2 ^{0}C during 2006-2010, indicating a sharp hike in the atmospheric temperature (Fig. 6). A decreasing trend in the cool day frequency was also observed during the analysis (Fig. 7) which is also an indicator of warming trend in the region. Various studies (Raj *et al*., 2005; Caprio *et al.,* 2008; Sheppard *et al*., 2012) showed that extreme temperature events can cause potential negative impacts on plants. Since rubber is the dominant crop in the study area, survival of young rubber plants in the initial period of field establishment, subsequent growth and yield in the mature phase may be affected by the extreme weather events. This may lead to serious socio-economic and ecological impacts in the area. Satheesh and Jacob (2011) reported 9 to16 per cent reduction in natural rubber productivity in Kerala with 1 ^{0}C rise in both daily Tmax and Tmin. The risk will be much higher if extreme conditions persist, since long spells of extreme condition will reduce the restoration potential of plants due to the damages caused by extreme weather events. According to Guhathakurta *et al.* (2011) the increasing trends of extreme precipitation events reported in the southern Indian peninsula was closely related with the global warming and climate change. Pattanaik and Rajeevan (2010) reported that high vapour content generated by warming effect may be the reason for extreme precipitation. The high intensity of instant summer rains in the southern peninsula of India may be related to the increasing temperature events evidenced in the present study.

The changing trend in the occurrence of extreme temperature events were reported along different climatic zones such as Mexico (Cueto *et al.,* 2013), Iran (Marofi *et al*., 2011), China (Wang *et al*., 2013), Mediterranean and Middle East regions (Lelieveld *et al*., 2013), Uruguay (Renom *et al.,* 2011) and USA (Sohrabi *et al.,* 2013). Studies on the reasons of occurrence of extreme temperature events and its relationship to urbanisation, land use pattern and global climatic change provided positive relationship to heat islands, urbanisation and changing temperature (Jain and Kumar, 2012). An inconsistent relationship with the above parameters was reported by Dhorde *et al.* (2009). According to

Almazroui *et al.* (2013) and Bartolini *et al.* (2012), increasing temperature was independent of population growth and urbanization, but may be related to large scale circulations and global climate change. Uncertainties in the existing literature demand more studies to understand the reasons and extend of impacts of extreme weather events.

Based on the results, the present study indicates the need of caution for possible impacts of extreme weather events in the region. Management measures such as compensation for agricultural production loss and crop damage, epidemic control precautions, natural disaster mitigation strategies *etc*., need to be considered in the region as a part of risk management of extreme weather events under the changing scenario of climate.

Conclusion

The results showed an increasing trend in the high temperature events from 1970 to 2010. The varying trend in extreme weather events at regional scale, as observed over many regions of the world, may be attributed to the global climate change, urbanisation and changes in land use pattern. Such events may cause potential impacts on crop productivity, ecological and human health status, socio-economic sustainability *etc*. Thus proper resilient measures may be adopted at community and ecosystems levels in the study area for the sustainable crop production in rubber.

Acknowledgement

Authors express sincere thanks to Dr. Jayasree Revadekar, (IITM, Pune), Dr. Xuebin Zhang and Dr. Feng Yang, (Climate Research Branch, Meteorological Service, Canada) for providing software packages and technical advices for the study.

References

Almazroui, M., Islam, M.N. and Jones, P.D. 2013. Urbanization effects on the air temperature rise in Saudi Arabia. *Climatic Change* **120**(1-2): 109-122.

Bartolini, G., Stefano. V., Maracchi, G. and Orlandini, S. 2012. Mediterranean warming is especially due to summer season. *Theoretical and Applied Climatology* **107**(1-2): 279-295.

Caprio, J.M., Quamme, H.A. and Redmond, K.T. 2008. A statistical procedure to determine recent climate change of extreme daily meteorological data as applied at two locations in North Western North America. *Climatic Change* **92**(1-2): 65-81.

Dhorde, A., Dhorde, A. and Gadgil, A.S. 2009. Long-term temperature trends at four largest cities of India during the twentieth Century. *Journal of Indian Geophysical Union* **13**(2): 85-97.

Garcia-Cueto, O.R., Cavazos, M.T., de-Grau, P. and Santillán-Soto, N. 2014. Analysis and modelling of extreme temperatures in several cities in north western Mexico under climate change conditions. *Theoretical and Applied Climatology* **116**(1): 211-225.

Guhathakurta, P., Sreejith, O.P. and Menon, P.A. 2011. Impact of climate change on extreme rainfall events and flood risk in India. *Journal of Earth System Science* **120**(3): 359-373.

Insaf, T.Z., Lin, S. and Sheridan, S.C. 2012. Climate trends in indices for temperature and precipitation across New York State, 1948–2008. *Air Quality, Atmosphere and Health* **6**(1): 247-257.

Jain, S.K. and Kumar, V. 2012. Trend analysis of rainfall and temperature data for India. *Current Science* **102**(2): 37-49.

Joshy, V.R. and Rajeevan, M. 2006. Trends in precipitation extremes over India. National Climate Centre- *Research Report Number 3/2006*. Indian Meteorological Department, Pune.

Khaladkar, R.M., Mahajan, P.N. and Kulkarni, J.R. 2009. Alarming rise in the number and intensity of extreme point rainfall events over the Indian Region under climate change scenario. *Research Report No. RR-125*. Indian Institute of Tropical Meteorology. Pune.

Lelieveld, J., Hadjinicolaou, P., Kostopoulou, E., Giannakopoulos, C., Pozzer, A., Tanarhte, M., and Tyrlis, E. 2014. Model projected heat extremes and air pollution in the eastern Mediterranean and Middle East in the twenty-first century. *Regional Environmental Change* **14**: 1937-1949.

Marofi, S., Sohrabi, M.M., Mohammadi, K., Sabziparvar, A.A. and Abyaneh, H.Z. 2011. Investigation of meteorological extreme events over coastal regions of Iran. *Theoretical and Applied Climatology* **103**(3-4): 401-412.

Ning, B., Yang, X. and Chang, L. 2012. Changes of temperature and precipitation extremes in Hengduan Mountains, Qinghai-Tibet Plateau in 1961–2008. *Chinese Geographical Science* **22**(4): 422-436.

Pattanaik, D.R. and Rajeevan, M. 2010. Variability of extreme rainfall events over India during southwest monsoon season. *Meteorological Applications* **17**: 88-104.

Raj, S., Das, G., Pothen, J. and Dey, S.K. 2005. Relationship between latex yield of *Hevea brasiliensis* and antecedent environmental parameters. *International Journal of Biometeorology* **49**: 189-196.

Renom, M., Rusticucci, M. and Barreiro, M. 2011. Multi decadal changes in the relationship between extreme temperature events in Uruguay and the general atmospheric circulation. *Climate Dynamics* **37**(11-12): 2471-2480.

Revadekar, J.V., Kothawale, D.R., Patwardhan, S.K., Pant, G.B. and Rupa Kumar, K. 2012. About the observed and future changes in temperature extremes over India, *Natural Hazards* **60**(3): 1133-1155.

Satheesh, P.R. and Jacob, J. 2011. Impact of climate warming on natural rubber productivity in different agro -climatic regions of India. *Natural Rubber Research* **24**(1): 1-9.

Sheppard, C.S., Alexander, J.M. and Billeter. R. 2012. The invasion of plant communities following extreme weather events under ambient and elevated temperature. *Plant Ecology* **213**(8): 1289-1301.

Sohrabi, M.M., Ryu, J.H., Abatzoglou, J. and Tracy, J. 2013. Climate extreme and its linkage to regional drought over Idaho, USA. *Natural Hazards* **65**(1): 653-681.

Wang, H., Chen, Y., Xun, S., Lai, D., Fan, Y. and Li, Z. 2013. Changes in daily climate extremes in the arid area of North Western China. *Theoretical and Applied Climatology* **112**(1-2): 15-28.

Xiao, H., Tian, H., Lin, X., Gao, L., Dai, X., Zhang, X. and Xu, J. 2013. Influence of extreme weather and meteorological anomalies on outbreaks of influenza A (H1N1). *Chinese Science Bulletin* **58**(7): 741-749.