

LETTERS

633: 551.581.23 (540.11)

ANALYSIS OF RAINFALL AND DROUGHT CLIMATOLOGY FOR CROP PLANNING IN SUBTROPICAL PLAINS OF CHATHA, JAMMU

1. Although the subject area of climate change is vast, the changing pattern of rainfall is a topic within this field that deserves urgent and systematic attention, since it affects both the availability of freshwater and food production (Dore, 2005). Climate change is one of the key global challenges in the present era. It refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period typically decades or long (World Meteorological Organization). According to Fourth Assessment Report of Intergovernmental Panel on Climate Change, the world indeed has become more drought prone with higher frequencies of extreme events.

India is a country that gambles with monsoon because of the dependability of rainfall for crop production. India receives 80% of annual rainfall from southwest monsoon, which is imperative for the whole country, especially for the low rainfall belts like J&K state. Any drought will affect the economy in large. Drought can be referred as a normal recurring feature of earth's climate, it has a peculiar slow onset and disastrous, long lasting impacts; it affects more people than any other form of natural disaster. Drought is a recurrent, yet sporadic feature of climate, known to occur under all climatic regimes and is usually characterized by variability in terms of its spatial expanse, intensity and duration. (Drought Manual; Govt. of India, 2016). Generally rainfall deficiencies over a long time period leads to severe droughts events (Wilhite and Knutson, 2008). Mainly four types of droughts are mostly observed, meteorological (lack of precipitation), agricultural (lack of root zone soil moisture), hydrological (drying of surface water storage), socio-economic drought (lack of water supply for socio-economic purpose) and these drought types are generally interlinked with each other (Sigdel and Ikeda, 2010). Some clear instances around the world can be noticed, like changing trends of monsoonal rainfall over India due to climate change (Naidu *et al.*, 2009) increase in drought events in UK (Arnell, 2007) and over Indian subcontinent (Sivakumar, 2011) describing the impacts of climate change. Higher or lower rainfall, or changes in its spatial and seasonal distribution would influence the spatial and temporal distribution of runoff, soil moisture and groundwater reserves, and would affect the frequency of droughts and floods. Further, temporal

change in precipitation distribution will affect cropping patterns and productivity.

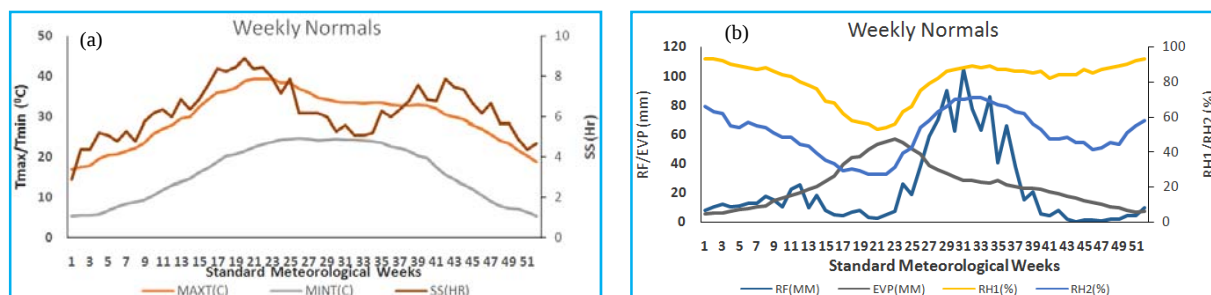
Climatological data of a location is of utmost important in order to assess the drought to minimize production risk (Vairavan *et al.*, 2002). In this context, the concept of estimating probabilities with respect to a given amount of rainfall is extremely useful for planning appropriate agricultural operations/activities. For agricultural planning and complex hydrological problems, knowledge of the characteristics of rainfall is a must. Long term averages of annual, monthly, and weekly rainfall are quite useful and have widespread applications in regions/years of normal rainfall. But in regions of uncertain precipitation, like Jammu and Kashmir, or in an arid/semiarid climate, one cannot fully depend on averages. The Markov chain model has been extensively used to study the probabilities of rainfall occurrence (Kar, 2002; Singh *et al.*, 2008). In a given crop growing season, many a times, decisions have to be taken based on the probability of receiving certain amount of rainfall during a given week. Hence, there is a felt need for effective monitoring of agricultural drought - its onset, progression and impact on crops to minimize the damages. The present study is based on analysis of rainfall and drought events, based on 29 years of climatological data of subtropical Chatha region of J&K for efficient crop planning.

2. Chatha region of Jammu and Kashmir falls in low latitude Subtropical zone encompassing 32.40° N Lat. and 74.53° E Long. with an elevation of about 349 m above mean sea level. The main agricultural crops grown in this region are rice, wheat, maize, oilseeds and pulses. In the present study, we have made an attempt to analyse rainfall and drought climatology for past 29 years (1987-2015) from the daily dataset provided by Central research Institute for Dryland Agriculture (CRIDA) Hyderabad.

3. Daily weather parameters and rainfall data was obtained from Central research Institute for Dryland Agriculture (CRIDA) Hyderabad for a period of 29 years (1987-2015). The data were collected and processed on Excel sheets and Weather Cock Software according to the requirements to obtain critical results of the study area.

(a) Rainfall parameters and Climatology

(i) Rainfall trend and total rainfall received during different seasons (Winter, Pre-monsoon, Monsoon and Post monsoon season),



Figs. 1(a&b). Weekly normal for maximum temperature, minimum temperature, Bright sunshine hour, RH1, RH2, Rainfall and evaporation)

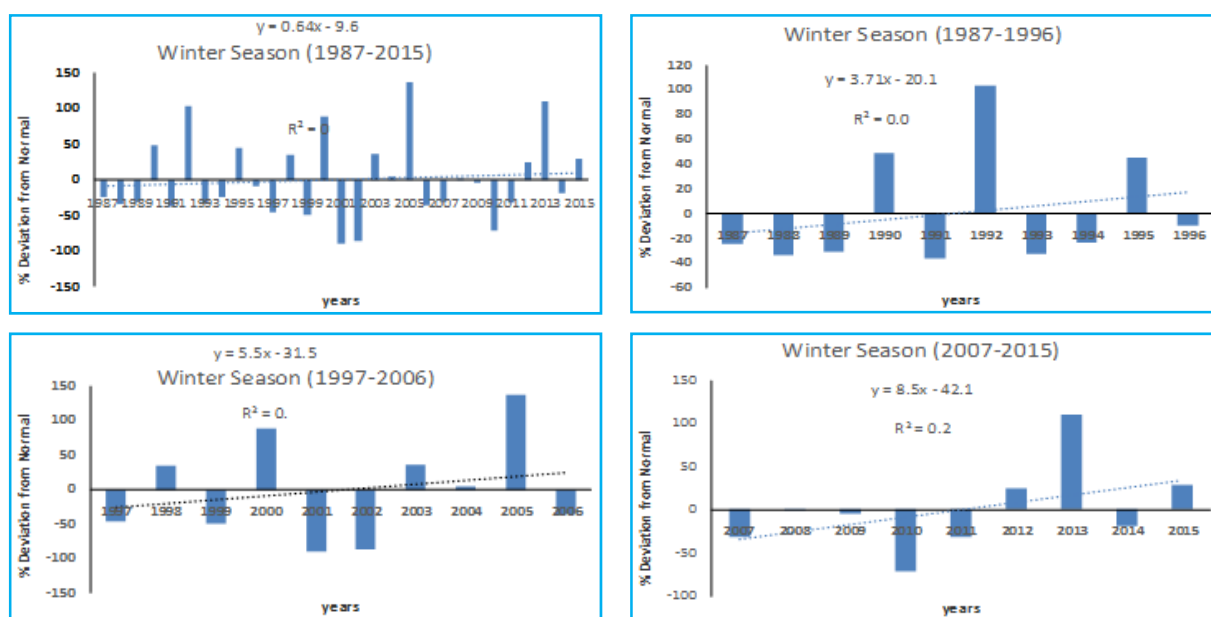


Fig. 2. Rainfall trend during winter season

- (ii) Total rainy days under different seasons
- (iii) Maximum heavy rainfall events in 29 years of study period and
- (iv) Computation of assured rainfall at different probability levels (10-90%).

(b) Drought Climatology

- (i) Agricultural drought and
- (ii) Meteorological drought.

4. Maximum and minimum temperature for the study area was analyzed for standard meteorological weeks and results revealed that mean maximum temperature (39.3 °C) was highest during pre-monsoon period (17-25 standard meteorological weeks) and lowest during winter (18.9 °C). Similarly highest mean minimum

temperature (24.6 °C) was observed during monsoon period (23-35 standard meteorological weeks) and lowest during winter (5.5 °C). Similarly the bright sunshine hours was highest during pre-monsoon (8.9 hours) and post monsoon period (7.9 hours) and lowest during winter (2.9 hours) and monsoon period (5.1 hours) [Fig. 1(a)].

The analysis for RH1 (morning humidity %), RH2 (evening humidity %), rainfall (mm) and pan evaporation was also done for all standard meteorological weeks. The RH1 and RH2 values were highest during winter followed by monsoon period and lowest during pre-monsoon period. Similarly highest rainfall values were observed during monsoon period and lowest during post-monsoon period. The pan evaporimeter values were considerably higher during pre-monsoon period and lowest during winter. Hence it shows that atmospheric demand for evaporation is highest during higher mean maximum temperature values and bright sunshine hour and relatively dry period during pre-monsoon season [Fig. 1(b)].

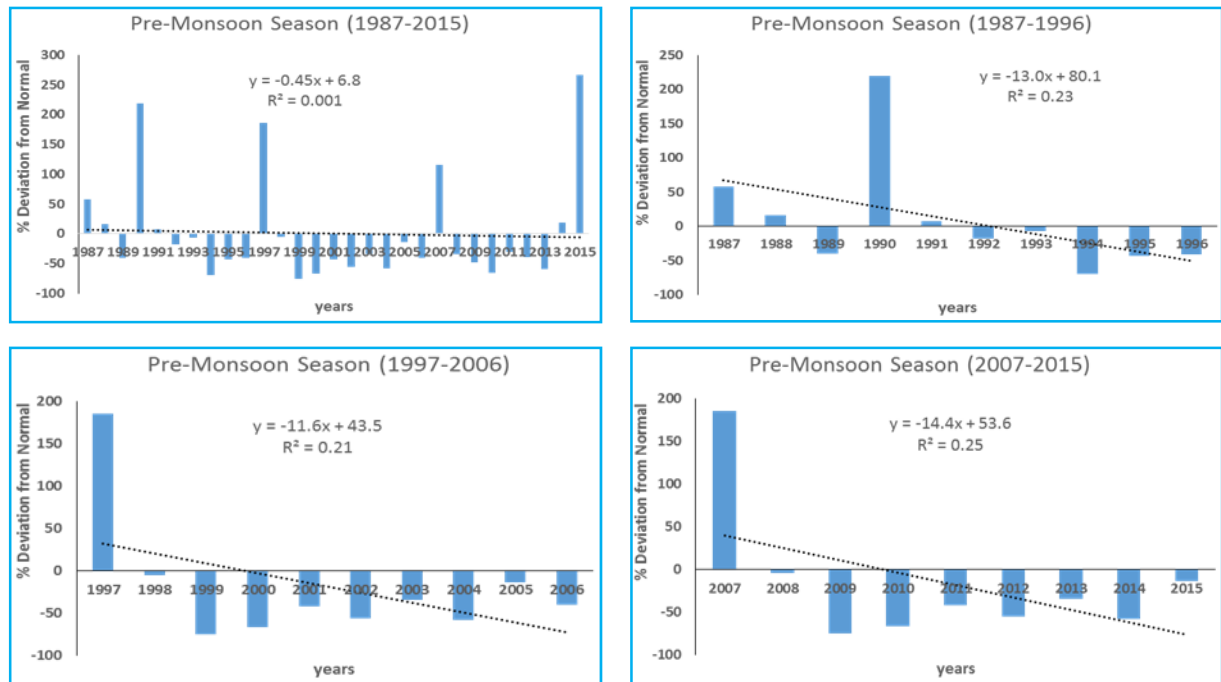


Fig. 3. Rainfall trend during pre-monsoon season

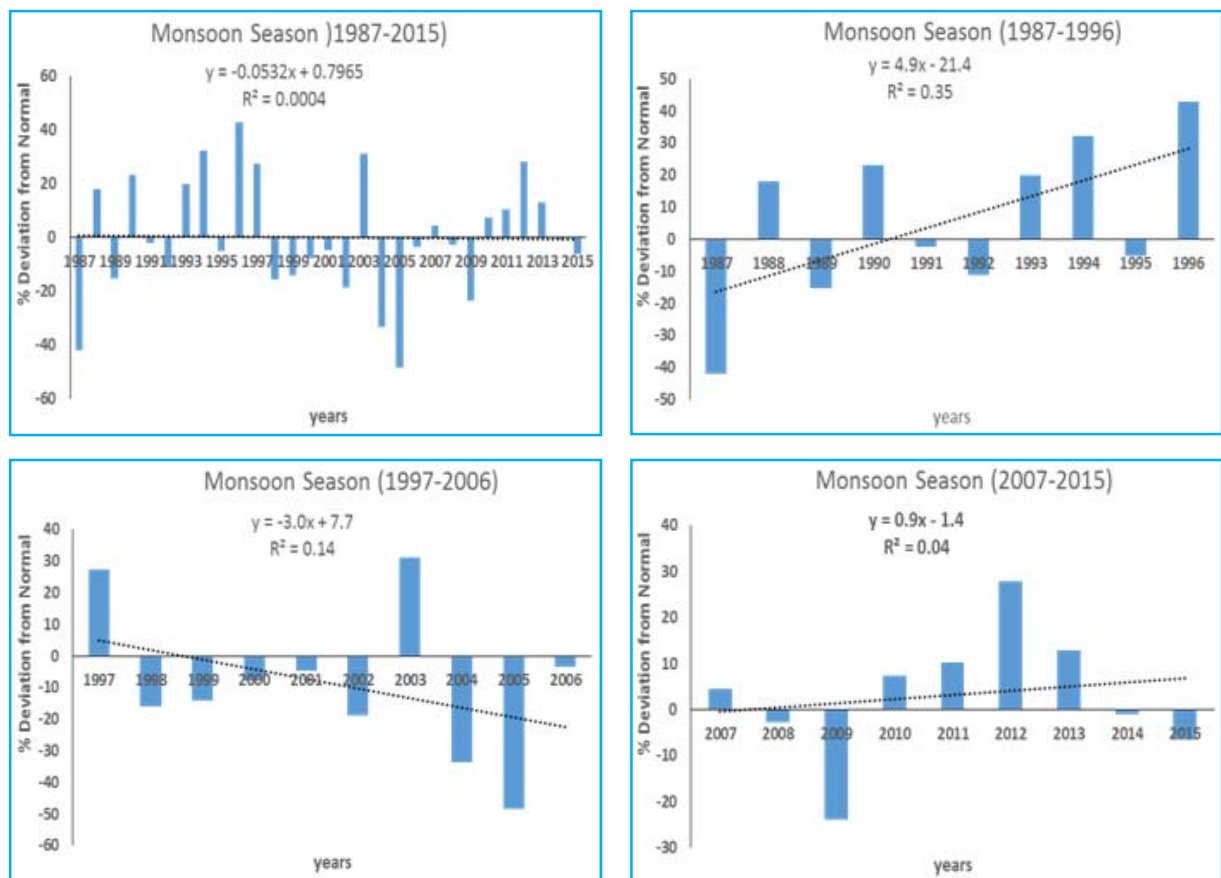


Fig. 4. Rainfall trend during monsoon season

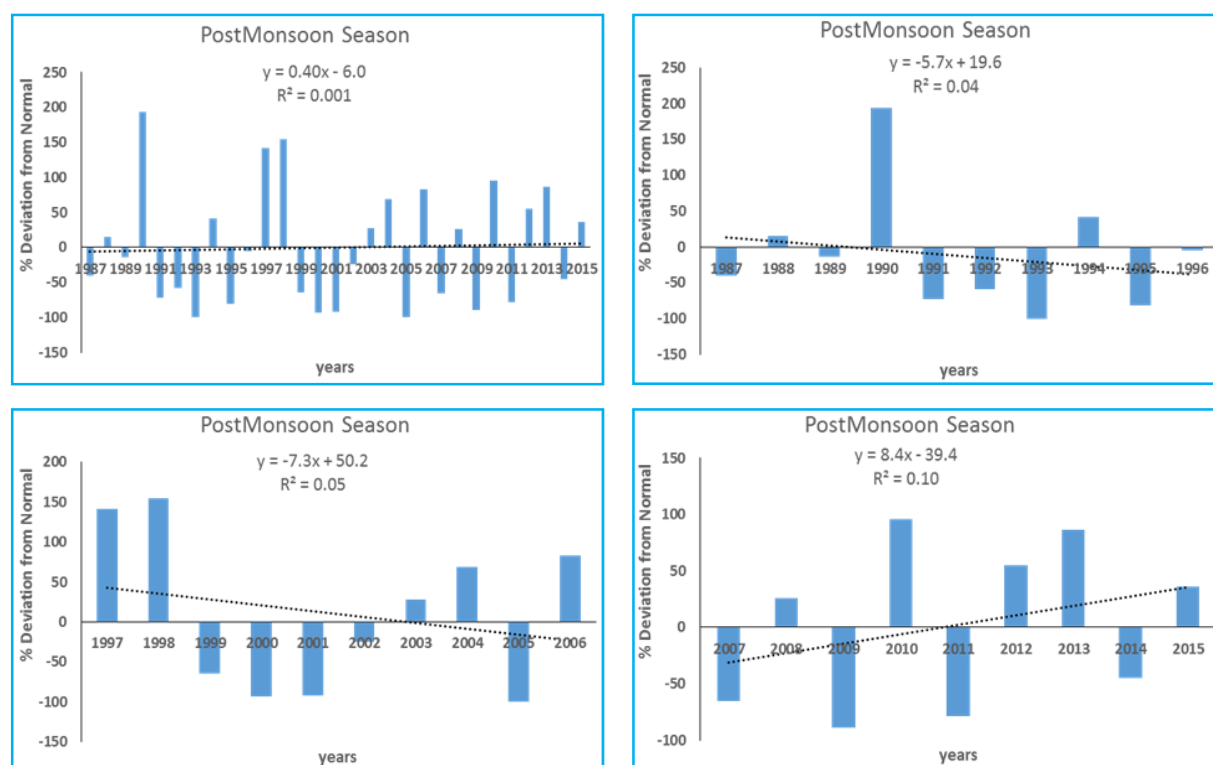


Fig. 5. Rainfall trend during post-monsoon season

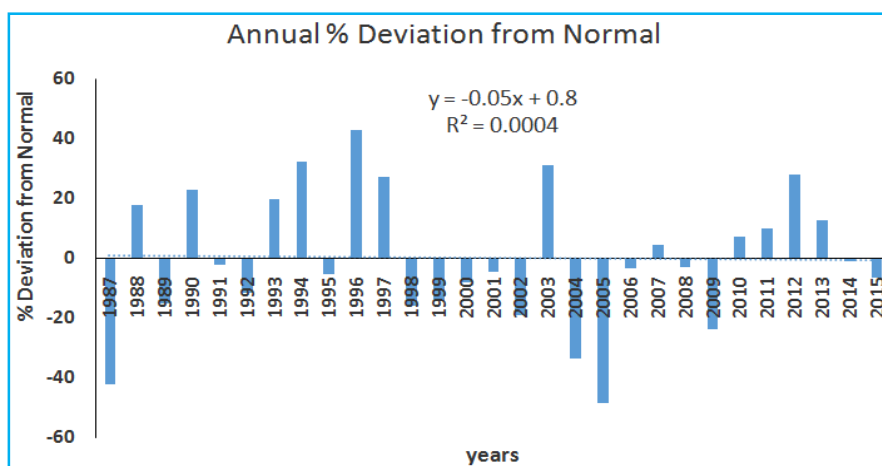


Fig. 6. Annual Rainfall trend during 1987-2015

Rainfall trend and total rainfall received during different seasons: The normal annual rainfall received in the study area is 1176 mm. The normal rainfall received in different seasons, viz., winter, pre-monsoon, monsoon and post monsoon season are 103, 137, 887 and 48 mm respectively. The highest rainfall received during winter, pre-monsoon, monsoon and post monsoon season are 244, 502, 1266 and 123 mm respectively during 2005, 2015, 1996 and 1998 while lowest rainfall received during is 14,

34, 457 and 0 mm respectively during 2002, 1999, 2005 and 2005. The highest ever rainfall, 1825 mm was received during the year 1990 while the lowest ever rainfall, 830 mm during the year 2002. The trend analysis for each season was also done and results showed increase of 0.64 mm and 0.40 mm during winter and post-monsoon period and decrease of 0.05 and 0.45 mm respectively during monsoon and pre-monsoon period. The decadal trend analysis for each season was also analysed

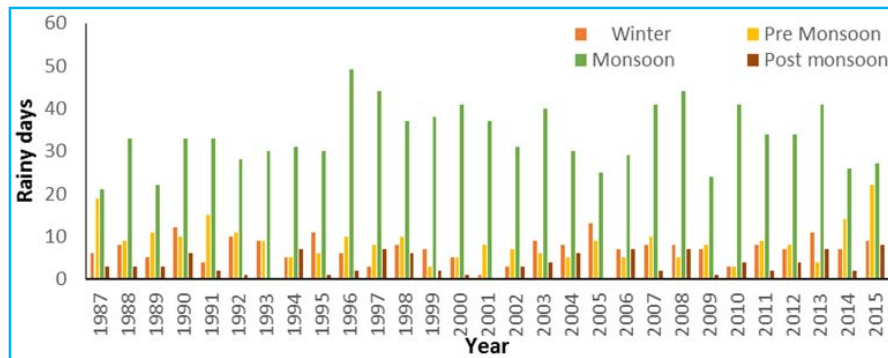


Fig. 7. Total rainy days under different seasons

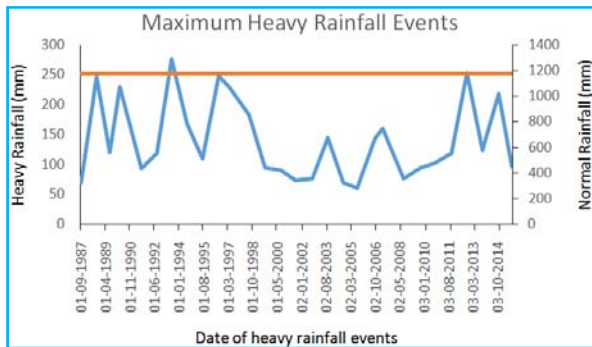
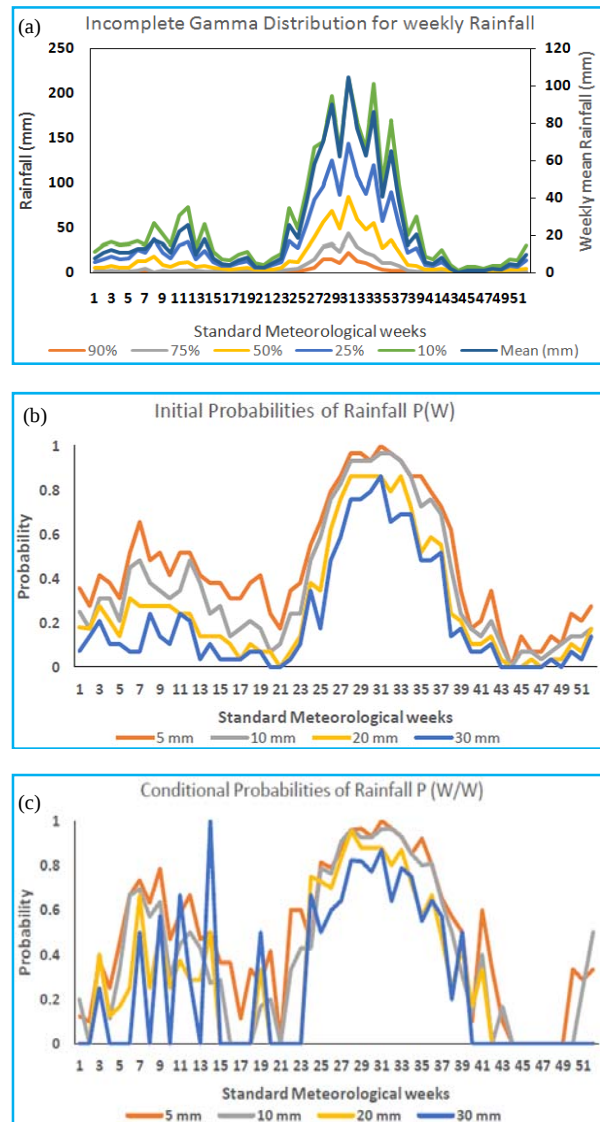


Fig. 8. Maximum heavy rainfall events in 29 years of study period

separately and results showed that there is increase in winter precipitation by 3.71 mm (1987-1996), 5.5 mm (1997-2006) and 8.5 mm (2007-2015) respectively (Fig. 2). The decadal trend analysis results of pre-monsoon season revealed that there is decrease in precipitation by 13 mm (1987-1996), 11.6 mm (1997-2007) and 14.4 mm (2007-2015) respectively (Fig. 3). In all the decades for all the seasons, the results were non-significant except the rainfall trend between 2007-2015 for winter and pre-monsoon season which showed R^2 values of 0.20 and 0.25 and were significant at 95% confidence level. However no specific trend was observed for monsoon season. The results revealed an increasing trend by 4.9 mm during 1987-1996 and then decreasing trend (3.0 mm) during 1997-2006 and then again increasing trend by 0.99 mm during 2007-2015 respectively (Fig. 4). Similarly the trend analysis results for post monsoon season (Fig. 5) showed a decreasing trend (5.7 and 7.3 mm) during 1987-1996 and 1997-2006 respectively. However an increasing trend (8.4 mm) was shown during 2007-2015 respectively. Similar results were observed by Jaswal *et al.*, 2010 in which they observed an increase in winter precipitation as compared to other seasons in Jammu region. Similarly the overall trend analysis (Fig. 6) for rainfall results showed decrease of 0.05 mm per year from 1987 to 2015 respectively.



Figs. 9(a-c). (a) Incomplete gamma distribution for weekly rainfall, (b) Initial probabilities of rainfall $P(W)$ and (c) conditional probabilities of rainfall $P(W/W)$

TABLE 1
Analysis for Agricultural drought during 29 years of study period

	Year	1987	1988	1989	1994	1995	2005	2008	2009	2014	2015
Kharif	Drought week	24-31	32-37	22-25	22-25	37-40	22-25 32-40	34-39	22-28 34-39	22-25	33-37
Rabi	Year	-	-	-	-	-	-	-	-	-	-
	Drought Week	No Drought									

Total rainy days under different seasons : The total rainy days during monsoon season were highest followed by pre-monsoon, winter and then post monsoon (Fig. 7). Further winter rainy days were increasing in the last one decade as compared to other seasons. However, no specific trend was observed during pre-monsoon, monsoon and post monsoon seasons. Similar trend was observed by Bharti *et al.*, 2015 in which they observed an increase in total rainy days and heavy rainfall events over the north-west Himalayan region using satellite data.

Maximum heavy rainfall events in 29 years of study period: The study on maximum heavy rainfall events was also done and results revealed that maximum heavy rainfall events were highest during the years 1987, 1993, 1997 and 2012. Similarly, the results of total rainy days showed that highest rainy days were observed during 1990, 1994, 2007, 2008 and 2015 respectively (Fig. 8).

Computation of assured rainfall at different probability levels (10-90%): The amount of rainfall at different probability levels (10-90%) called assured rainfall have been computed for each standard week by fitting Incomplete Gamma Distribution model. The results showed that 10% probability was receiving highest amount of rainfall and 90% probability received the least amount of rainfall [Fig. 9(a)]. Initial and conditional probability calculates percentage probability to get certain amount of rainfall in a given week was also worked out for the threshold limits of 5 mm, 10 mm, 20 mm and 30 mm as most of the agricultural operations are rainfall dependent. Initial probability of the study region showed that from 23rd to 40th standard week the probability of getting wet week for 5 and 10 mm is maximum followed by 20 and 30 mm rainfall which falls between 25th to 37th standard weeks at 50% probability [Fig. 9(b)]. The conditional probability for wet week followed by wet week was also carried out and found that 21st to 31st standard week broadly falls under this category for 5 and 10 mm rainfall, which is followed by 20 and 30 mm with one week reduction in both start and end period than that of P(W) [Fig. 9(c)]. The initial probabilities for 5 mm, 10 mm, 20 mm and 30 mm rainfall was done to start the

sowing with onset of monsoon which may be sufficient for the initial crop establishment.

The conditional probability P(W/W) was also done as it is important for important management practices like irrigation, fertilizer application and pesticide spray. It is very tough to till the land for sowing of kharif crops in absence of pre-monsoon shower. At least 10 mm of weekly rainfall is required to start land preparation, sowing work and other cultural practices in agriculture. For successful crop production the normal requirement of rainfall is considered as 20 mm/week in general and 50mm/week in particular for rice crops. In many years, only a few weeks have been found to have the wet periods causing persistent drought condition in this region. In order to mitigate the effects of such monsoon anomalous situations the existing cropping pattern would need a suitable modification/change, preferably the contingent crop planning would be needed.

Agricultural drought : Prevalence of agricultural drought, adopting the IMD's old criterion, has been worked out and presented in Table 1. The agricultural drought analysis was also done for this region and results showed that out of total 29 years of study 10 years were identified as drought years during kharif season, while no drought years were identified during Rabi season. The results also showed clearly that drought weeks were becoming more prominent during recent years (2000-2015) as compared to period during 1987-2000. The agricultural drought was most frequently observed in early (22-25 standard meteorological weeks) as well as late (32-40 standard meteorological weeks) stages of kharif crops which coincided with the seedling and reproductive stages of rice crop, respectively. In recent decade (2001-10) 3 years were encountered by agricultural drought during different standard meteorological weeks which limited the rice production in this region. Similar results were observed by Pragyan *et al.*, 2014 in Palamau region in Jharkhand. The frequent agricultural droughts in recent years restricted the rice crop coverage in this area thereby causing a heavy shortfall in rice production. However, the increased crop coverage under maize and

TABLE 2

Analysis for meteorological drought during 29 years of study period

Drought condition	No. of years	Drought (%)
No Drought	23	0
Moderate Drought	6	79
Severe Drought	0	21
Total	29	100

Drought criteria	
% Deviation from Normal	Drought Type
-25 and above	No Drought
-26 to -50	Moderate Drought
< -50	Severe Drought

other crops, like pulses and vegetables, out of the farmers own wisdom compensated the loss to some extent. The medium-duration ('PC 19') and long-duration ('Jaya') variety of rice can be replaced by short-duration ('IET 1410'). The existing rice-wheat cropping system can be diversified to short-duration rice ('IET 1410') - garlic (*Allium sativum* L.) - cowpea [*Vigna unguiculata* (L.) Walp.]. Similar results were also reported by Kachroo *et al.*, 2014 in rice based cropping systems.

Meteorological drought : According to old criteria of India Meteorological Department, there are three types of droughts based on rainfall deficit from normal, i.e., mild (deviation % from normal is -25 and above), moderate (deviation % from normal is -26 to -50) and severe drought (deviation % from normal is < -50). Probability of occurrence of each drought type over the years was determined for the study region and results showed that out of total 29 years of study, 6 years were identified as moderate drought years (1987, 1999, 2002, 2004, 2005 and 2009) and 23 years were identified as no drought years (Table 2). The results also showed clearly that drought weeks were becoming more prominent during recent years (2002-2015). Increase in number of drought years and drought intensity over the decades has been depicted through Fig. 10. Frequency of occurrence of mild drought was more during 2000-2010. There were 4 moderate droughts during the decade 2000-2010 whereas the decade 1991-2000 had only 1 moderate drought. The recent decade 2001-2010 experienced maximum number of drought years (4) of which all were moderate droughts.

5. The trend analysis for each season results showed an increase of 0.64 mm and 0.40 mm during winter and post-monsoon period and decrease of 0.05 and 0.45 mm respectively during monsoon and pre-monsoon

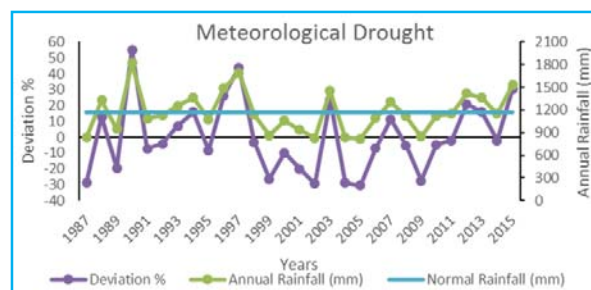


Fig. 10. Analysis for meteorological drought during 29 years of study period

period. The overall trend analysis for rainfall results showed least decrease from 1987-2015. Similarly, during summer, monsoon and post monsoon season, highest frequency of rainfall varied between 34.2-118.2 mm (18 times), 757.5-907.5 mm (10 times) and 0-25 mm (11 times) respectively.. The study on maximum heavy rainfall events revealed that maximum heavy rainfall events were highest during the years 1987, 1993, 1997 and 2012. The Meteorological drought analysis for the study region showed that out of total 29 years of study, 6 years were identified as moderate drought years (1987, 1999, 2002, 2004, 2005 and 2009) and 23 years were identified as no drought years. Similarly agricultural drought analysis was also done and results revealed that out of total 29 years of study, 10 years were identified as drought years during kharif season, while no drought years were identified during Rabi season. The results also showed clearly that drought weeks were becoming more prominent during recent years (2005-2015) as compared to period during 1987-2005. Above results are in agreement with Kundu *et al.*, 2019 and Mallya *et al.*, 2016.

Having characterized the region in terms of rainfall and drought it seems essential to give a rethinking on the existing cropping pattern which has been often subjected to have been adversely affected by rainfall anomalies and droughts. There is an urgent need of reconsidering the cropping pattern, selection of crops, their varieties and management practices for the Chatha region to minimize the risk involved in food production. The entire agriculture being based on rainfall pattern, it is recommended to cultivate only those varieties which do not have crop duration of more than 13 or 14 weeks. The medium-duration ('PC 19') and long-duration ('Jaya') variety of rice can be replaced by short-duration ('IET 1410'). The existing rice-wheat cropping system can be diversified to short-duration rice ('IET 1410') - garlic (*Allium sativum* L.) - cowpea [*Vigna unguiculata* (L.) Walp.]. Inter-cropping of maize with garlic and cowpea in different recommended combinations should also get priority to minimize the risk. Further studies must be

carried out by using test field trials for alternate cropping in the study region/agroclimatic zone using SPI and dry spells for accessing the adaptivity of proposed alternate cropping pattern. Several remote sensing based indices (NDVI, VCI and NDWI), soil moisture based indices and hydrological indices must be incorporated to get more clear picture about drought in a particular agroclimatic zone/region.

The authors are thankful to Shri A. V. M. Subha Rao, Senior scientist, CRIDA, Hyderabad for his kind guidance and providing data for this paper. The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

References

- Arnell, N. W., 2007, "Climate change and drought", *Options Méditerranéennes series A*, **80**, 13-20.
- Bharti, V., 2015, "Investigation of heavy rainfall events over north-west Himalayan region using satellite data", Ph. D thesis.
- Climate Change, 2007, "Synthesis Report, An Assessment of the Intergovernmental Panel on Climate Change", IPCC XXVII (Valencia, Spain, 12-17 November, 2007), Forth Assessment Report.
- Climatological series of Jammu and Kashmir, India Meteorological Department Pune 2014, series 20, 77-83
- Dore, M. H. I., 2005, "Climate change and changes in global precipitation patterns : What do we know?", *Environ. Int.*, **31**, 1167-1181.
- Jaswal, A. and Prakasa, R., 2010, "Recent trends in meteorological parameters over Jammu and Kashmir", *Mausam*, **61**, 3, 369-382.
- Kachroo, D., Thakur, N. P., Kour, M., Kumar, P., Sharma, R. and Khajuria, V., 2014, "Diversification of rice (*Oryza sativa*)-based cropping system for enhancing productivity and employment", *Indian Journal of Agronomy*, **59**, 1, 21-25
- Kar, G., 2002, "Rainfall probability analysis for sustainable production strategies in coastal Orissa", *Journal of Agrometeorology*, **4**, 2, 181-185.
- Kundu, K. S. and Singh, S., 2019, "Computation of flood and drought years over the NW Himalayan region using IMD rainfall data", *International Journal of Geological and Environmental Engineering*, **13**, 7, 491-494.
- Manual for drought management, Govt. of India, 2016, 4-17.
- Mallya, G., Mishra, V., Niyogi, D., Tripathi, S. and Govindaraju, R. S., 2016, "Trends and variability of droughts over the Indian monsoon region", *Weather and Climate Extremes, Journal of Agrometeorology*, **12**, 43-68.
- Naidu, C. V., Durgalakshmi, K., Muni Krishna, K., Ramalingeswara Rao, S., Satyanarayana, G. C., Lakshminarayana, P. and Malleswara Rao, L., 2009, "Is summer monsoon rainfall decreasing over India in the global warming era?", *Journal of Geophysical Research*, 114(D24), D24108.
- Pragyan, K., Rajan, K. O., Wadood, A. and Kumar, R., 2014, "Rainfall and drought characteristics for crop planning in Palamau region of Jharkhand", *Mausam*, **65**, 1, 67-72.
- Sigdel, M. and Ikeda, M., 2010, "Spatial and Temporal Analysis of Drought in Nepal using Standardized Precipitation Index and its Relationship with Climate Indices", *Journal of Hydrology and Meteorology*, **7**, 1, 59-74.
- Singh, K. A., Sikka, A. K. and Rai, S. K., 2008, "Rainfall distribution pattern and crop planning at Pusa in Bihar", *Journal of Agrometeorology*, **10**, 2, 198-203.
- Sivakumar, S., Faiz, M. A., Mustafizur Rahman, A. H. M. and Islam, K. R. (Eds.), 2011, "Climate Change and Food Security in South Asia", Dordrecht : Springer Netherlands, ISBN:10.1007/978-90-481-9516-9.
- Vairavan, K. Singh, Durai, R. and Kannam Kand Goneche, C., 2002, "Sustainable agricultural planning with Agrometeorological observation", *Madras Agricultural journal*, **89**, 1-3, 151-154.
- Wilhite, D. and Knutson, C., 2008, "Drought management planning: Conditions for success", *Options Méditerranéennes Series A*, **80**, 141-148.
- World Meteorological Department; <http://www.wmo.int/pages/prog/wcp/ccl/faqs.html>.

**MUKHTAR AHMED
SONAM LOTUS
RAJALAKSHMI D.*
SHIVINDER SINGH**
SUBHA RAO, A. V. M.*****

M. C. Srinagar (IMD), MoES, Srinagar – 190 015, India
**AMS Kozhikode (IMD), MoES, Kozhikode – 673647, India*
***M. C. Chandigarh (IMD), MoES, Chandigarh – 160 037, India*
****Central Research Institute for Dryland Agriculture Hyderabad (ICAR) – 500059, India*

(Received 27 March 2018, Accepted 4 September 2020)
 *e mail : mukhtarssc@gmail.com