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Rainy days and rainfall intensity trends in Basar (Arunachal Pradesh) during 1979-2015

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सार- हिमालयी क्षेत्र के लिए, विशेष रूप से विस्तृत वर्षा-जलवायु विज्ञान के परिदृश्य में जलवायु परिवर्तन का आकलन करना अत्यंत महत्वपूर्ण है। वर्तमान अध्ययन का मुख्य उद्देश्य वर्ष 1979-2015 के दौरान भारत के उत्तर-पूर्वी हिमालयी क्षेत्र में स्थित बसर (अरूणाचल प्रदेश) में वार्षिक एवं मौसमी कुल 'वर्षा के दिनों' और 'वर्षा तीव्रता' की प्रवृत्तियों की जांच करने के लिए किया गया तथा द्वितीय उद्देश्य कुल वर्षा के प्रति, हल्की, मध्यम, भारी और बहुत भारी वर्षा के योगदान में परिवर्तन का भी मूल्यांकन किया गया। प्रवृत्ति विश्लेषण के लिए रेखीय प्रतिगमन (लीनियर रिग्रेशन) सांख्यिकीय विधि की मदद ली गई। अध्ययन के दौरान कुल वार्षिक एवं मौसमी वर्षा में स्पष्ट व संगत प्रवृत्तियाँ नहीं देखी गयी, हालांकि चल औसत के संकेत धीमी गति से बढ़ती प्रवृत्ति की ओर है। वार्षिक एवं मौसमी कुल वर्षा के दिन घट रहे हैं, हालांकि दक्षिण पश्चिम मानसून और मानसूनोत्तर में ये प्रवृत्तियाँ आंकड़ों की दृष्टि से महत्वपूर्ण नहीं हैं। वार्षिक और मौसमी पैमानो में वर्षा तीव्रता में अतुलनीय वृद्धि पायी गयी, जो क्षेत्र में अत्यधिक वर्षा में वृद्धि का कारक है। इस अवधि के दौरान, भारी और अति भारी वर्षा के प्रतिशत योगदान में वृद्धि तथा हल्की और मध्यम वर्षा के प्रतिशत योगदान में कमी देखी गयी। अंततः यह कहा जा सकता है कि क्षेत्र की जलवायु में वास्तविक परिवर्तन हो रहा है, किंतु अध्ययन में प्राप्त अस्थिर प्रवृत्तियाँ इसके अप्रत्याशित व अनिश्चित भविष्य का संकेत है।

ABSTRACT. Particularly for the Himalayan region, detail rainfall climatology is vital for assessing climate change scenario. The primary objective of current study was to investigate the seasonal and annual trends of rainy days and rainfall intensity over Basar (Arunachal Pradesh) in North-eastern Himalayan region of India during 1979-2015. Secondly it aims to evaluate the change in contributions of light, moderate, heavy and very heavy rainfall towards total rainfall. Linear regression was used for trend analysis. During the study period, no clear, consistent and significant trends in total annual and seasonal rainfall was observed over the location, but running average indicated slow increasing trends, except during post-monsoon. The annual and seasonal rainy days show decreasing trends, though not much significant during southwest monsoon and post-monsoon. The study reveal appreciable increase in rainfall intensity both in annual and seasonal scale leading to increase in extreme rainfall events in the region. During the period, it was observed that the percentage contribution of heavy and very heavy rainfall intensity class towards rainfall totals has been increasing and that of light and moderate rainfall has been decreasing. From the study it is concluded that climate of the region is changing, but the erratic trends point towards a very unpredictable and uncertain future.

Key words – Linear regression, Extreme events, Climate change, Rainfall climatology, Himalaya.

1. Introduction

The study of rainfall climatology is vital for assessing the magnitude and impact of climate change over an area, especially in the hilly regions where rainfall is the most determining factor for sustainability of ecosystem and productivity of agriculture. Amount of water available to meet various demands of agricultural, industrial and household activities depends on amount of rainfall received and its distribution in temporal and spatial scale. Beside monthly, seasonal and annual rainfall data, two very important and simple parameters that facilitate in detail understanding of rainfall climatology of a location are number of rainy days and mean daily rainfall intensity. These two factors provide a clear picture of frequency of occurrence and a crude measure of intensity of rain which is very significant for both agricultural and hydrological studies (Nandargi and

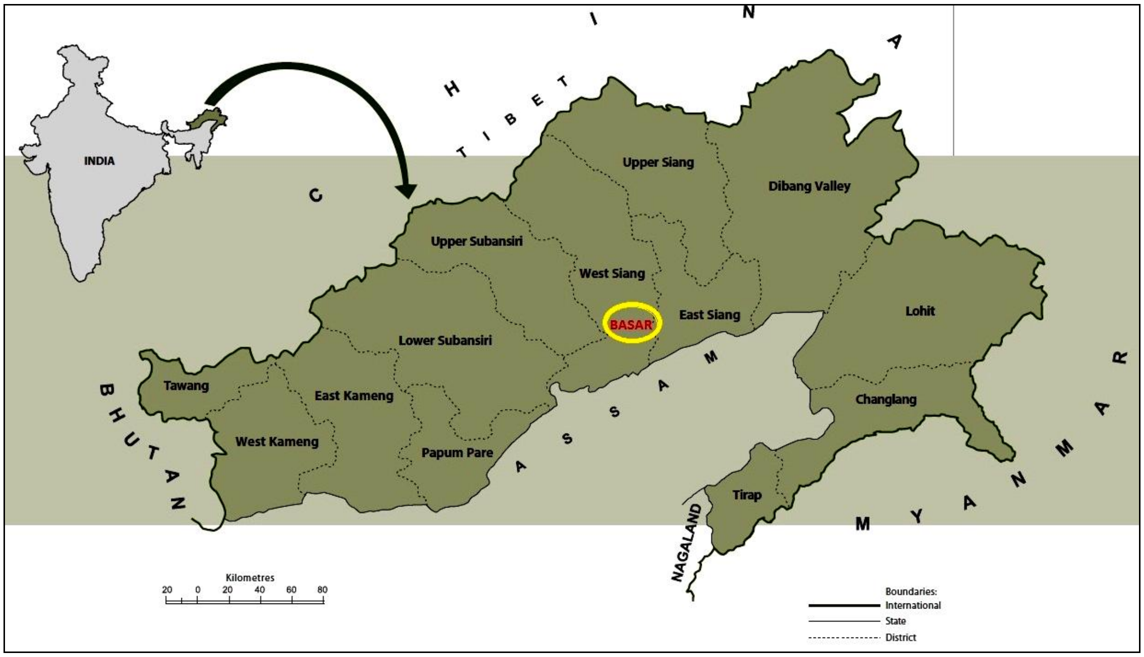

Fig. 1. Location of Basar depicted as red spot in West Siang District of Arunachal Pradesh

Mulye, 2012). Also, the information regarding frequency and intensity of rain events during varied weather conditions can also be derived from rainy days study. To describe the nature of precipitation changes, it is also important to know whether the change in rainfall frequency is due to a change in the number of days with heavy rainfall or with light rainfall. The variation in frequency of heavier rainfall days and the corresponding amount of rainfall exerts major control over the rainfall totals.

The current study was concentrated in subtropical hills of Basar (27°59.53' N and 94°41.27' E with average elevation of 616 meters above mean sea level) situated in West Siang district of Arunachal Pradesh in Northeastern Himalayan region of India (Fig. 1). The region as a whole comes under Eastern Himalayan Ecozone-II. Also Basar is located in Sub-tropical Hill Zone under Thermic Per-humid Mid-hills and Valleys. Around 82 per cent of the population of the region directly or indirectly depends on agriculture for their livelihood. As only 19 per cent of cropped area under is irrigation (SAPCC, 2011), the agriculture of the region mainly depends on rainfall. Climate change, especially the change in precipitation pattern is of particular significance for such Himalayan regions as it leads to changes in river runoff and ultimately affecting agricultural productivity, hydrological systems and well being of communities both in hills and downstream. Previous studies clearly indicated that the frequency and magnitude of high intensity rainfall events are increasing across India as a whole (Goswami *et al*., 2006; Cruz *et al*., 2007). Variation in onset and length of southwest monsoon seems to be changing (Ramesh and Goswami, 2007) and seasonal drought and water stress are very common in this region. In this Himalayan region, the trend of climate change and its impact have been less explored and less known which make the future scenarios more worrisome and uncertain (Das *et al*., 2009) due to its strategic location.

Keeping above factors in consideration, the present study seeks to examine the rainfall climatology of the location based on the seasonal and annual trends in rainy days and mean daily rainfall intensity with respect to variation in rainfall over the location during last 37 years (1979-2015). An attempt was also made to evaluate the contribution of different rainfall intensity class (low, moderate, heavy or very heavy) towards annual rainfall totals.

2. Data and methodology

The daily recorded rainfall data in Agro-meteorological Observatory of ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar for the period of 37 years (1979-2015) was used for the current study. The data were quality checked by removing apparent anomalies due to typographical errors, instrument malfunction, change in measurement technique etc. The time series of monthly, seasonal and annual

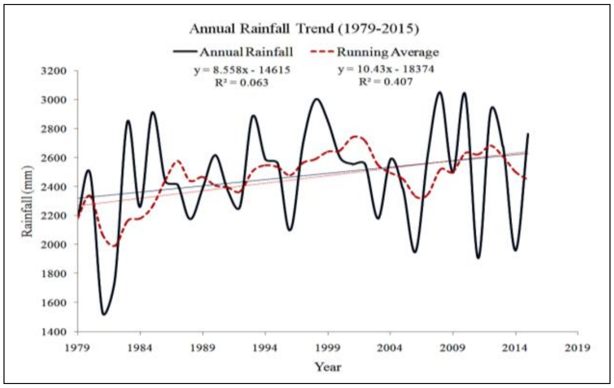

Fig. 2. Rainfall trend during the study period (1979-2015) with bold line representing the annual trends while dashed line represents the running average

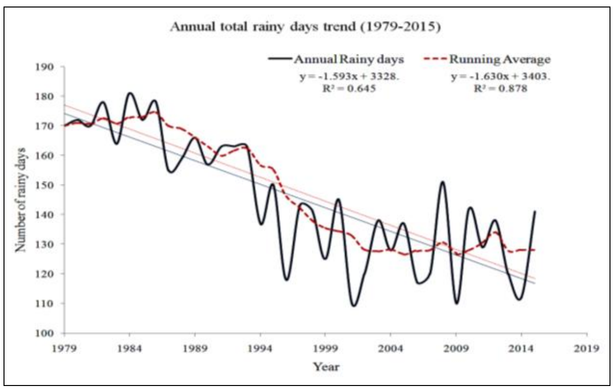

Fig. 3. Annual rainy days trend represented by bold line while dashed line depict the running average

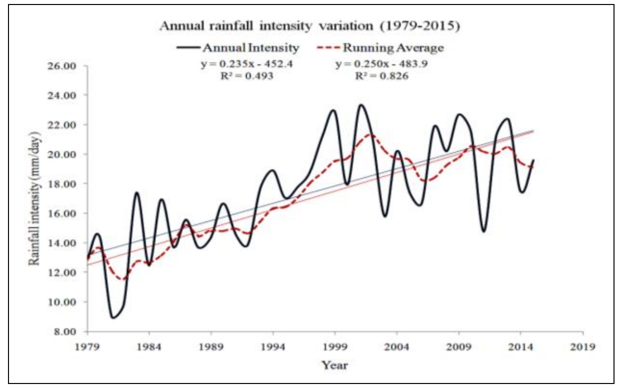

Fig. 4. Variation in the annual rainfall intensity (bold line) and the running average represented by dashed line

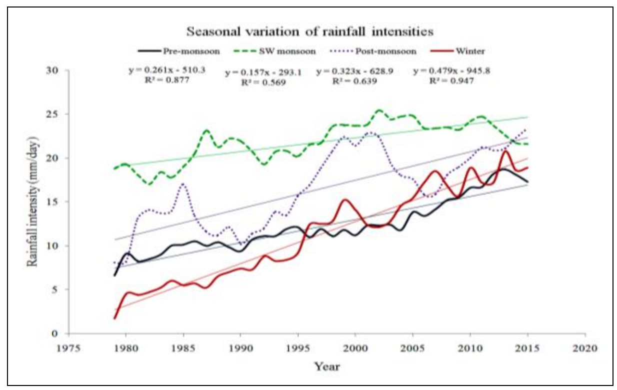

Fig. 5. Variation in seasonal rainfall intensities with significant increasing trend during winter & pre-monsoon seasons

rainfall were prepared. Based on India Meteorological Department (IMD) criteria, a day with rainfall ≥2.5 mm is considered as "rainy-day," the number of rainy days was counted and averaged over years and seasons. Basic statistical characteristics like mean and coefficient of variation (CV) of rainfall and rainy days were calculated on yearly and seasonal basis. Based on IMD criteria, the four seasons are winter (January and February), summer or pre-monsoon (March, April and May), southwest monsoon (June, July, August and September) and northeast monsoon or post-monsoon (October, November and December) (Kothawale and Rajeevan, 2017).

Linear regression analysis was used for the trend analysis. To determine the magnitude of trend in the time series, time is taken as the independent variable and rainfall/rainy days/rainfall intensity as dependent variable. The regression analysis can be carried out directly on the time series or on the anomalies (*i.e.*, deviation from mean). A linear equation, $y = mt + c$, defined by c (the intercept) and trend m (the slope of line), can be fitted by regression. The linear trend value represented by the slope of the simple least-square regression line provided the rate of rise/fall in the variable. The statistical significance of the regression was checked according to the p-value from the t-test at 95 per cent confidence level. To get better picture of trends or gradual change, the running averages were analysed, that remove influence of some extreme value on the whole trend. For comparing the annual as well as seasonal rainfall strength, the mean daily rainfall intensity in terms of amount of rainfall per day were obtained by dividing total rainfall by number of rainy days for the specified period (annual or seasonal). The factor compares the relative change in rainfall and number of rainy days during the period.

As per the standard used by India Meteorological Department, the rainfall events were divided into four intensity classes: light (2.5 to 7.5 mm), moderate/rather heavy (7.6 to 64.4 mm/day), heavy (64.5 to 124.4 mm/day) and very heavy (>124.5 mm/day) (Arthi Rani *et al*., 2014). The percentage contribution of each categories of rainfall towards total rainfall has been calculated and trends were analysed and compared.

TABLE 1

Seasonal rainfall and rainy days contributions towards totals and respective trends during 1979-2015

Season	Rainfall			Rainy days		
	Average	%	Trend (R-squared)	Average	%	Trend (R-squared)
Winter	165.3 ± 8.9	6.6	(+) 0.185	16.4 ± 1.2	11.3	(-) 0.45
Pre monsoon	531.6 ± 20.4	21.8	(+) 0.105	41.1 ± 1.1	28.2	(-) 0.59*
SW monsoon	1558.3 ± 55.2	62.9	(+) 0.00	72.9 ± 1.5	50.1	(-) 0.30
Post monsoon	211.7 ± 8.0	8.7	(-) 0.058	14.7 ± 1.0	10.4	(-) 0.32

Mean ± standard error, * moderately significant, (+) increasing, (-) decreasing

3. Result and discussion

3.1. *Rainfall and rainy days trends*

The region comes under one of the highest rainfall recipient regions of the country with average annual rainfall of around 2500 mm. The rainfall in this region is highly vulnerable to seasonal activities. Over the entire region, there is little evidence of significant long-term increasing or decreasing trends in annual rainfall totals, but the running average indicated slow increasing trend (Fig. 2). The 37 years average total annual rainy days was found to be 145 days with CV of 14.7% and analysis indicated decreasing trend of annual rainy days (Fig. 3).

The seasonal distributions of total rainfall and rainy days and respective trends during the period are described in Table 1. The winter rainfall accounts for 5.3% of total annual rainfall and shows statistically insignificantly increasing trend. The winter season on an average had 11.4% of total rainy days with CV of 43.2 per cent. Winter rainy days showed non-significant decreasing trend. The pre-monsoon rainfall indicated non-significant increasing trend and account for 7.7% of total annual rainfall. During the season the rainy days have been decreasing and are 28.2% of total rainfall with CV of 16.2%. Nearly 66.5% of annual rainfall occurred in the southwest monsoon season, mostly in the months of July and August. There was no definite trend of rainfall during the season. The season on an average have 73 rainy days (49.6%) having CV of 14.5% and maximum number of rainy days has been distributed in the months of July (21 days) and June (20 days). The trend analysis indicated decreasing trend of rainy days during the southwest monsoon season, though statistically not much significant. Both rainfall and rainy days during post-monsoon season have very weak decreasing trend. The season on an average have account for 10.6% of rainy days with CV of 43.01% indicating high variability. The most of the rainy days occurs in the month of October (8.3 days).

3.2. *Change in mean daily rainfall intensity and rainfall events*

The mean daily rainfall intensity is a factor that indicates whether the rainfall is getting stronger or weaker. More intensity means more rain per rainy day which increases the chances of heavy rainfall in terms of mm/h. As depicted in Fig. 4, the annual mean daily rainfall intensity has been increasing throughout the period. Also, the seasonal mean daily rainfall intensities shows increasing trend in all the seasons, particularly during winter and pre-monsoon (Fig. 5). The increase in rain per rainy day leads to the increase in percentage contribution of very heavy and heavy rainfall to the total rainfall (Fig. 6). The percentage contribution of very heavy rainfall was significantly increasing while that of light rainfall is decreasing. The respective weak increasing and decreasing trends of heavy and moderate rainfall were observed. Though some relationships are weak accounted by the R-squared value, but the trend is real in most of the cases. It is well known that R-squared value summarize the strength of linear relationship between the variables. There is every chance of some relationship between them which is just not linear.

The lack of noticeable trend in rainfall (both annual and seasonal) and decrease in annual as well as seasonal rainy days indicated more rain per rainy day. This may be due to increase in atmospheric moisture content that occurred as a direct effect of a warmer climate leading increase in rain per rainy day rather than in the number of rainy days in many areas of the globe (Fowler and Hennessy, 1995). The increase in the proportion of daily rainfall falling in high intensity class (rainfall ≥150 mm/day) in the region implies extreme rainfall events like floods that become more frequent and intense in the recent past. For instance in the year 2004 and 2008 heavy rainfall

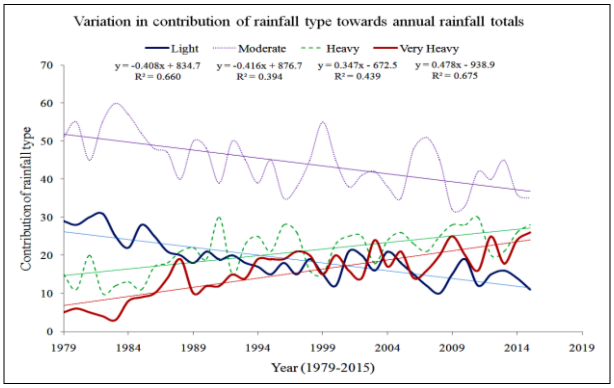

Fig. 6. Comparison of trends of contribution of different rainfall extents towards rainfall totals

in Arunachal Pradesh resulted in devastating flash flood in adjoining low-lying state Assam leading to hundreds of deaths and enormous loss to the animals and agriculture (Das *et al.*, 2009). The heavy downpour originated from the Tropical Depression over the West Central Bay of Bengal may also be responsible for several episodes of flash floods over the region. Studies over central India revealed statistically significant long-term trend of 6 per cent per decade in the frequency of extreme rainfall events (Rajeevan *et al*., 2008). Both climate model simulation and empirical evidences indicated that global warming lead to increases water vapour in atmosphere and hence resulting in more intense precipitation events (IPCC, 2007). This increase is believed to be associated with the increasing trend of sea surface temperature and surface latent heat flux over the tropical Indian Ocean. Instead of average rainfall amount, decreasing rainy days implies increase in drought frequency as substantial amount of rainfall is contributed by few heavy and very heavy rainfall events. Several instances of mid-season dry spells were observed in region and reported from different districts of the state. The dry spells have significant impact on the farming system and calendar of the location leaving innumerable farmland without any activity due to lack of operational irrigation facilities. However, observed changes in rainy days and rainfall events cannot be attributed to changes in the frequency or intensity of any one particular synoptic system but may be due to several interrelated changes across whole sub continent. One important factor may be due to rapid change in the land use pattern because of alteration in shifting cultivation practices with increasing frequency and shortening of the cropping cycle affecting forest coverage and type. Compared to climatic means, changes in extreme events are better indicator of climate change (Von Storch and Zwiers, 1999). Thus, the climates of the region is changing, but lack of some definite trends make the scenario more complicated and the future more uncertain.

It is worth mentioning here that in climate change studies, beside the statistical significance of the trend we must also consider the vulnerability and fragility of the study site as well as the coping capacity of the communities to the change. The resource poor farmers residing in high-exposure areas are more vulnerable to small change in the environment and have low adaptive capacity to cope with the climate change impacts and risks (World Bank, 2010). This brings the fact that interpretation in terms of statistical tests or methods is not enough. Having good notion of the real significance or impact of changes on environment and livelihood is more crucial, irrespective of the magnitude. Assessment in terms of statistical means and averages does not always give true picture of the impacts and it sometime rule out or shadow some prominent events. Small changes in climate may result in noticeable changes in the frequency and intensity of extreme rainfall events like flood and drought as suggested by several theoretical, modelling & empirical analyses (Katz and Acero, 1994; Wagner, 1996). The definition of extreme event also depends on the potential of the event to cause appreciable damages which in turn depends on the fragility and vulnerability of the location. Especially in this Himalayan region which is highly prone to the consequences of climate change due to its geo-ecological fragility, strategic location, trans-boundary river basins and inherent socio-economic instabilities, even small change in climate may have wide impact challenging sustainability of environment and agriculture.

4. Conclusions

The study has shown that:

(*i*) There is no statistically significant annual and seasonal rainfall trend over subtropical hills of Basar, though they are inclined towards increasing trend except during post monsoon season. This is in agreement with the previous study (Das and Goswami, 2003) that indicated lack of significant increasing or decreasing rainfall trend over entire northeast India. The increase in the summer rainfall trend in the current study is in accordance with the previous finding over the country (Dash *et al*., 2007). While the decreasing trend of post-monsoon rainfall over Basar is in conformity with the study of Ramesh and Goswami (2007).

(*ii*) The number of rainy days (both annual and seasonal) over Basar shows decreasing trends during entire period, the change is real though low in some cases marked by increasing trend of rainfall intensity in terms of rainfall per day. The finding is in agreement with the previous finding where increasing rainfall trend and decreasing rainy days was observed over Barak river basin and adjoining areas (Kumar and Jain, 2010). Also Ramesh and Goswami (2007) observed decrease in number of rainy days over India particularly during early and late monsoon seasons. Similar trend was also observed over Coimbatore and adjoining areas (Arthi Rani *et al*., 2014).

(*iii*) The contribution of heavy rainfall events are increasing in the region and that of low rainfall events are decreasing,

(*iv*) The study shows that the region is exceptionally vulnerable to extreme events like flood and drought.

The climate change in the region, especially the rainfall trends was found to be real but exhibit statistically insignificant relationship. This makes the scenario more complicated and makes it extremely difficult to predict the possibilities. Though it is one of the highest rainfall recipient regions of the country, the seasonality, distribution and the timing of rainfall has been very erratic marked by delayed onsets, declining number of rainy days and increased intensities altering farming calendars with negative effects on the yields.

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.

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