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Priyanka Swami
Research Scholar, Department of Agrometeorology, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

RK Singh
Professor & Head, Department of Agrometeorology, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

AS Nain
Director Research, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

Corresponding Author
Priyanka Swami
Research Scholar, Department of Agrometeorology, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

Rainfall trend analysis for Almora district of Uttarakhand

Priyanka Swami, RK Singh and AS Nain

Abstract
Dependency of Indian agriculture on rainfall make it very essential to study the variations in rainfall patterns of an area so as to know how the contribution of monthly rainfall in overall food grain production of country. Besides agricultural production study rainfall patterns also help us to know occurrence of hazardous weather event like drought, flood etc and their temporal and spatial scale. Present study includes rainfall pattern analysis of Almora district of Uttarakhand for the period of 120 years (1901-2020). Under this study various statistical techniques have been used to explain the variations in rainfall. Output of each statistical analysis indicated that rainfall in the district was observed highly variable (CV more than 40%) thought the period. Decadal rainfall analysis given that the decade 1901 to 1911 recorded highest rainfall in the district while 1911 to 1921 was with lowest rainfall.

Keywords: Rainfall trends, Almora, statistical analysis etc.

Introduction

The inter-related effect of climate change causes deep impact on global sustainable food production system. Climate change impact seen throughout all aspects of world we live in. Our food supply depends on climate and weather conditions. Although researchers may be able to develop some agricultural techniques to overcome the impact. Increased temperatures, drought and water stress, diseases, and weather extremes create challenges for the farmers and ranchers who put food on our tables. Climate change will continue to have a significant impact on ecosystems and organisms, though they are not impacted equally.

Cropping system is extremely vulnerable to climate change. Increased temperature reduces the yield of major crop by forced maturity. It also encourages the weed and pest population. All these effects ultimately turning into reduced yield. Decline in yield of major crops in developing countries will hit hard on the population. Climate change can nullify the good effect of using improved varieties, fertilizer and other inputs which were introduced to achieve the goal of higher productivity. Impact of climate change varies with crop, season and type of cropping pattern. In rabi crops the yield loss is mainly due to forced maturity due to increased temperature in the months of January and February while in kharif crops the severe impact is due to reduces moisture supply to the crop plants at time of their peak demand period. Increased number of pest population per season due to climate change results into severe yield losses. The erratic pattern of rainfall in previous years introduced new pests in the areas where they were not reported earlier. To estimate the impact of climate change we use techniques which are defined at global scale which are sometimes not able to define the regional impact. To implement the mitigation strategies we must know the depth of the impact. We should regionalise the impact of climate change for each Agro-climatic zone separately so that we can come up with better policy planning to mitigate the impact of climate change at regional level.

Indian summer monsoon (ISM) also known as south-west (SW) monsoon is an inter-hemispheric circulation system, coupled with land, atmosphere and ocean.being the major source of rainfall in country is considered to be the main factor in defining the length of growing period in the country. It supplies about 80% of the rainfall to fulfil the water requirement of the entire of the crops. The inter-annual standard deviation of the ISMR is about 10% of its climatological seasonal mean, which has a large impact on the agriculture, power generation and industrial production, hence, the overall economy of the country (Gadgil and Kumar 2006) [2]. Some areas receive plenty of rainfall and sometimes may lead to flood also while some parts like North-Western Rajathan receive little amount which is not even able to bring the soil to optimum moisture level. The high rainfall zone includes Western Ghats and the North-Eastern Hills.

The variability of Indian Summer Monsoon changes when we move from South to North.
Being variable in spatial as well as temporal scale the exact forecast of the amount and intensity of the rainfall is complicated is affected by so many land and ocean factors. Strong connections have been found among ISMR and teleconnections (El Nino, La Nina, SOI, and NAO). Inter annual variability in sea surface temperature and the circulations leads to the change in the position of low pressure and high pressure areas. These localized changes in the sea circulations leads to greater impact on global as well as regional weather phenomena. Under changing climate scenario the periodicity of these circulations has been introduced to higher degree of variation. So it is essential that the relationships among regional weather phenomena must be re-established each year to know the exact outcome.
As per IPCC AR6 2021 a warmer climate will intensify very wet and very dry weather and climate events and seasons, with implications for flooding or drought (high confidence), but the location and frequency of these events depend on projected changes in regional atmospheric circulation, including monsoons and mid-latitude storm tracks. It is very likely that rainfall variability related to the El Niño–Southern Oscillation is projected to be amplified by the second half of the 21st century in the SSP2-4.5, SSP3-7.0 and SSP5-8.5 scenarios. In the long-term, it is very likely that the precipitation variance 5 related to El Niño–Southern Oscillation will increase. The Indian Ocean, western equatorial Pacific Ocean and western boundary currents have warmed faster than the global average (very high confidence), with the largest changes in the frequency of marine heat waves (MHWs) projected in the western tropical Pacific and the Arctic Ocean (medium confidence). The intensity and duration of Agricultural drought in going to increase. Frequency of heat waves coupled with drought will increase. Total land area subjected to drought will increase. One fifth of India’s land area (21.06 per cent) is facing drought-like conditions, according to recent data released by Drought Early Warning System (DEWS). It is 62% higher than the area under drought during last year’s 7.86%. 21.06% area is affected by different degree of drought (abnormally dry to exceptionally dry). While 1.63 per cent area and 1.73 per cent land is under ‘extreme dry’ and ‘exceptional dry’ conditions, 2.17 per cent is under ‘severe’ dry conditions. As much as 8.15 per cent is under ‘moderate’ dry conditions. Around 7.38 per cent land is ‘abnormally’ dry, according to the latest data released August 16, 2021.
Indian economy largely depends on the features of ISMR. Despite great scientific efforts due to substantial topographical variability in the Indian subcontinent the forecast of ISMR is a tedious process where outcomes vary temporally and spatially. Cropping pattern of the region is basically depended on the quantum of ISMR being forecasted for the particular region. In order to enhance the agricultural productivity and make the production system sustainable the accuracy of regional level forecast matters the most. Well defined connections between ISMR and factor influencing it may lead to sound contingency planning when abbreviations like late onset, early withdrawal and breaks have been introduced at regional level.
ISMR shows considerably large inter-annual variability, fluctuating significantly above and below normal over massive Indian subcontinent resulting in widespread drought and flood events in the past several years. The effect of drought is aggravated with higher coefficient of variability in those areas which have lower precipitation during the rainfall seasonal (Parthasarathy, 1984) [6] and multiple occurrences in many consecutive years at different occasions (Chowdhury *et. al*. 1989) [1].
The date of onset of ISMR over south Kerala is crucial from meteorological point of view in Indian calendar. Pai and Rajeevan, 2009 found that ISMR normally arrives over Kerala, located at the tip of southern plateau around 1 June with a SD of around 7 days during 1971-2007. Stern and Coe (1982) used a general definition for the start of rain as 20 mm rainfall in two consecutive days and 10 days wet spell in next 30 days and determine the potential start and false start at different probability levels.
Kavi (1986) [4] studied the weekly rainfall variation of research stations, Hebbal and Bangalore. He found that first peak appeared during 20th week, the second peak during 34th week and the third during 39th standard meteorological week of the year. He also found sudden increase in rainfall from 15th to 20th week and it remain steady for the next two to three weeks and then it declines. Ramanamurthy *et al.* (1987) [7] analysed monthly, seasonal and annual rainfall of upper Narmada catchments up to Narmada Sagar and using the daily data of 38 stations from 1901-1980. The statistical parameters trend analysis showed some significant changes in rainfall of the upper Narmada catchments during the past 80 years. The annual rainfall showed an increasing trend from the beginning of precedent century up to 1985; therefore, it stabilized around the 1921 to 1950 over the catchments, mainly due to an increase in the July rainfall of this period. During the later decades (1951-1980) there was no significant departure in rainfall over the upper Narmada catchments from the long term mean.
While analysing trend and periodicity of ISMR and annual rainfall of 12 districts of Haryana and Delhi for 9 decades (1901-1990) using data from 36 rain-gauge stations, Lal *et al.* (1990) [5] observed that variability of annual and monsoonal rainfall was similar but least variability was noticed where precipitation was maximum. They also noticed positive trend in ISMR of Delhi. Sutherland (1991) observed that monthly or annual values showed no significant decrease with time but the annual number of rainy days decreased and noted a significant decrease during months of March, July and October in Kenya. Rupakumar *et al.* (1992) noticed a decreasing trend within the ISMR in the NE peninsular region, NE India and NW peninsular region. However an increasing trend was experienced in the western coastal region, central peninsular region and NW India. Biswas and Gupta (1993) presented and discussed the differences in monthly and seasonal variation of ISMR over the Gangatic and sub-Himalayan districts of West Bengal. They discussed the latitudinal variation of monsoon rainfall. They compared decadal mean of seasonal rainfall over plains with those at higher elevations and northern latitudes. Samui (1994) observed variations in Teesta valley along mountainous slope of Sikkim state of India using twelve stations data with varying period of 4 to 25 years and observed that, precipitation decreased with increase in altitude of Teesta Basin even during peak monsoon season. Chhabra *et al*. (1997) noticed reduced precipitation at hill stations and enhanced precipitation at urban/industrialized cities from 1931-60 and 1961-90, respectively. Kothyari and Singh (1998) found no noticeable trends within the long-term time series of ISMR but decadal variations were registered above

and below the long period average for 3 consecutive decades alternatively.

Study Area

The state falls under Agroclimatic zone-I I.e. Western Himalayan region. The climate of Uttarakhand is temperate, marked with the aid of using seasonal versions in temperature however additionally tormented by tropical monsoons. January is the coldest month, with each day excessive temperatures averaging beneath freezing in the north and close to 70°F (21 °C) in the southeast. In the north, July is the most up to date month, with temperatures generally growing from the mid-40s °F (approximately 7 °C) to approximately 70°F each day. In the southeast, May is the warmest month, with each day temperatures commonly attaining the low 100s F (approximately 38 °C) from a low round 80°F (27 °C). Most of the state's more or less 60 inches (1,500 mm) of annual precipitation is delivered through the southwest monsoon, which blows from July to September. Floods and landslides are problems for the duration of the wet season in the decreased stretches of the valleys. In the northern components of the state, 10 to 15 feet (3 to 5 metres) of snowfall is common in December and March.

Methods used

Data were analyzed using statistical techniques. The statistical methods/techniques used included the mean, standard deviation, coefficient of variation, trend analysis (moving average) and comparative analysis (deviation from mean value).

Variability is defined as the deviation from mean" or "ratio of the standard deviation to the mean rainfall and in other words variability of coefficient of variation. The variability terms (standard deviation and coefficient of variation) were computed for the state as well as at district level for the period 1901 to 2020. Based on the coefficient of variation (CV) Biswas and Dutta (1998) classified rainfall variability into four categories:

Table 1: Categories of rainfall variability

Sr. No.	Rainfall Variability	CV range
I.	Low variability	15-19%
II.	Moderate variability	20-29.9%
III.	High variability	30-49.9%
IV.	Very high variability	>50%

Results and Discussion

Rainfall patterns were analyzed using statistical techniques. Declining trends were shown during 70s and 80s while the periods of sixties shown ever increasing trends in rainfall. (Figure 1& 2)

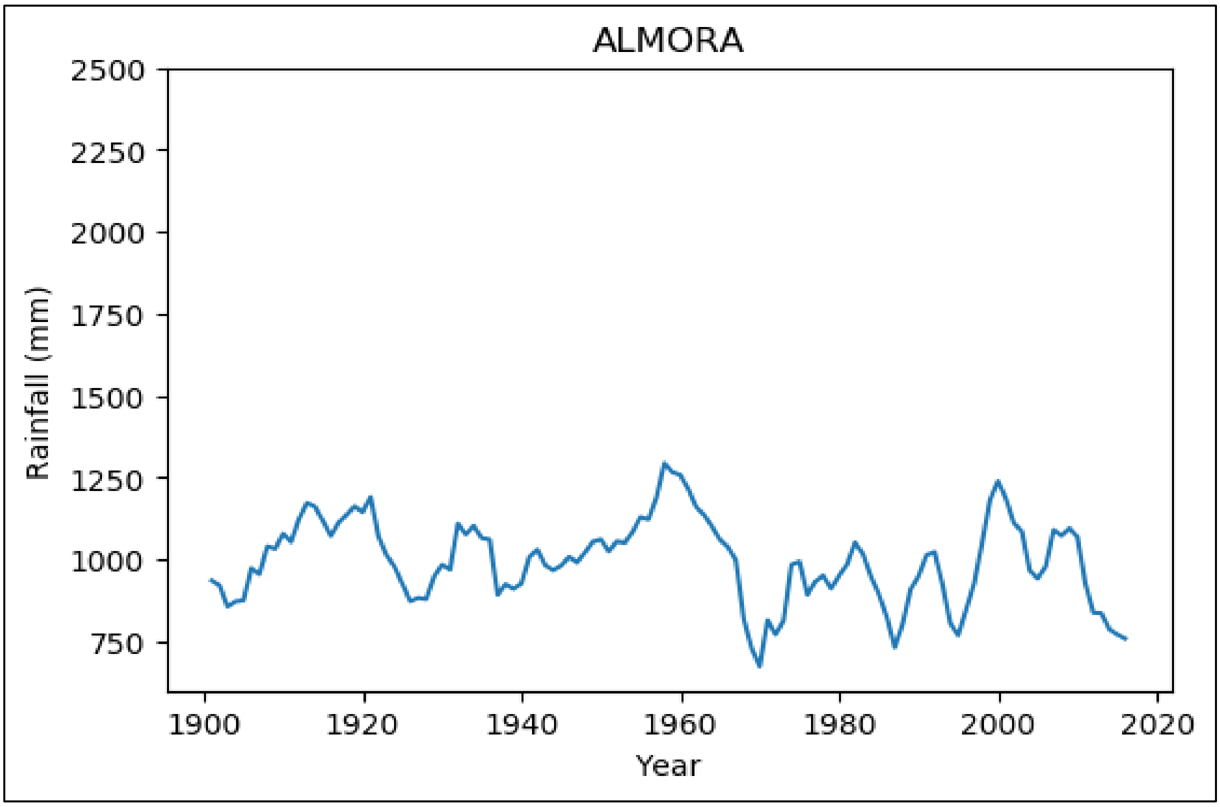

Fig 1: Rainfall normal for 120 years

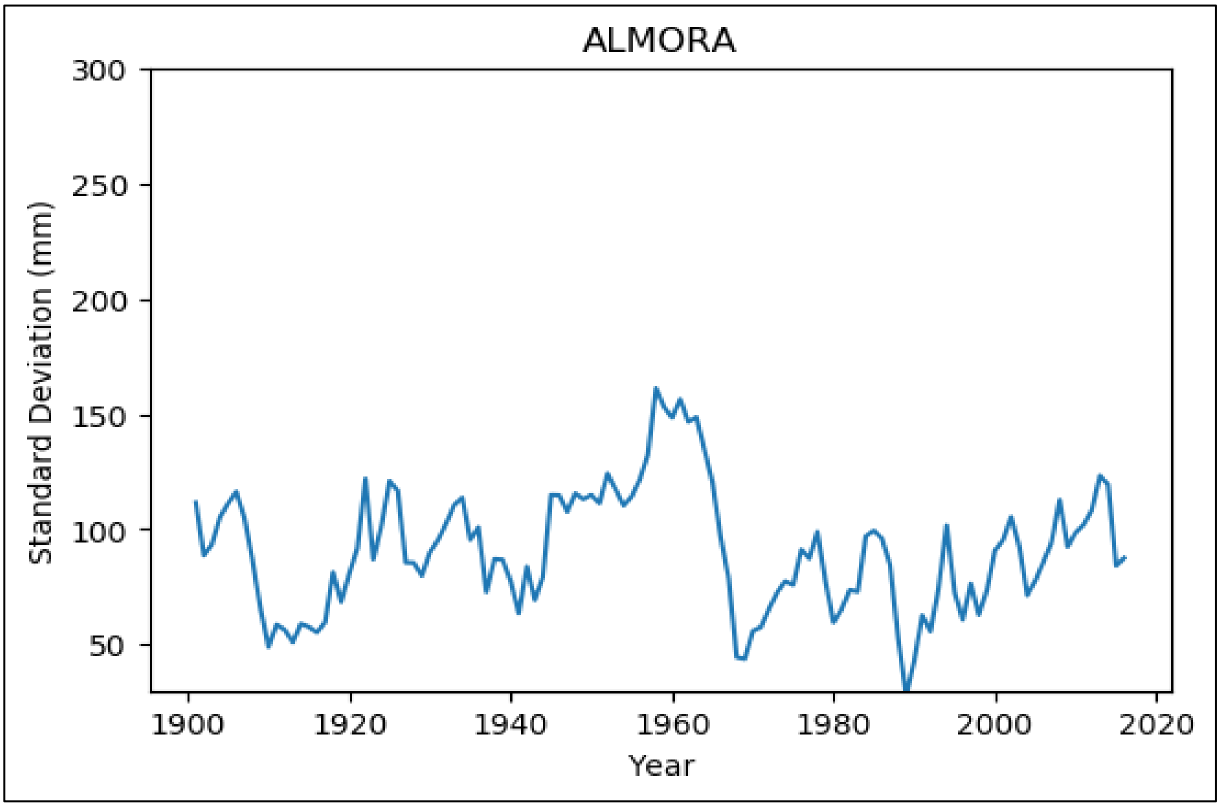

Fig 2: Standard deviation for the period from 1901 to 2020

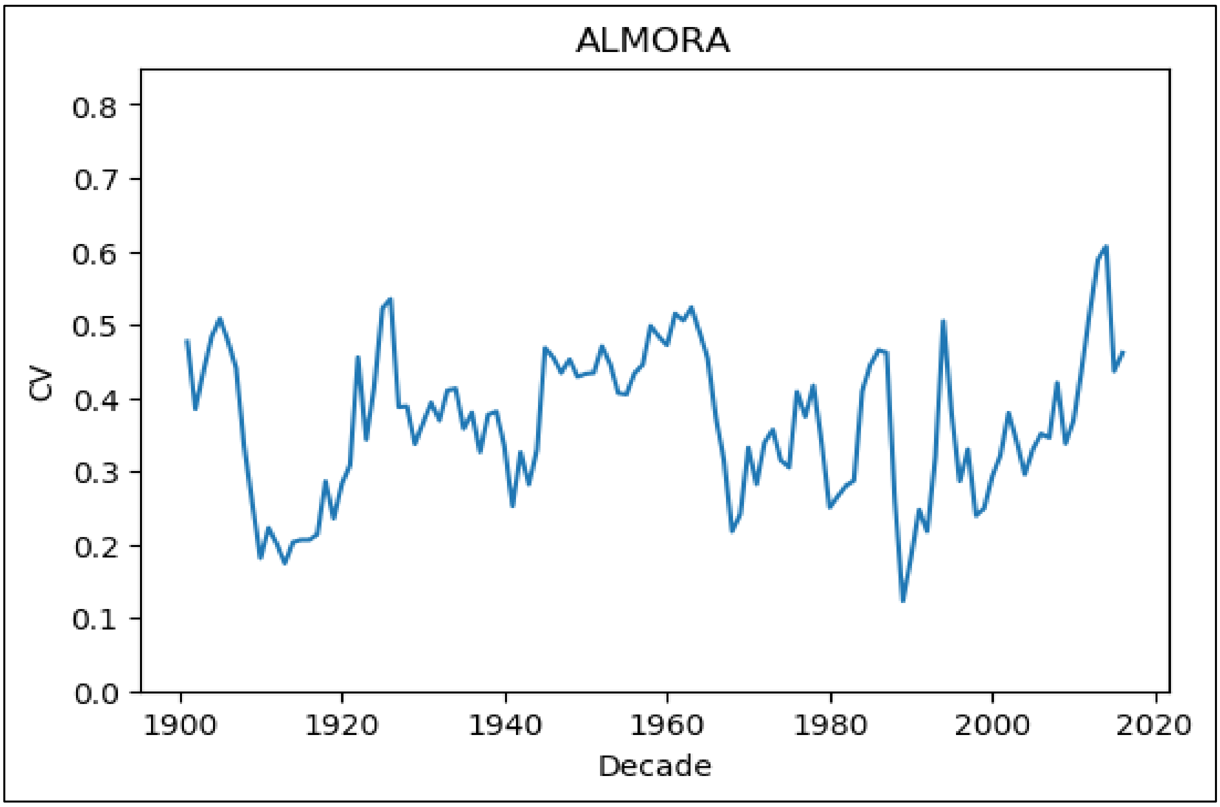

Fig 3: Rainfall variability using Coefficient of variation

Rainfall was found highly variable in the district (Figure 3). Twenties have shown a sharp increase in rainfall amount and this period also marked the highest variability in rainfall amount.

Rainfall analysis at decadal level shown that there was no trend in rainfall amount received. The period between 1960 to 1970 shown an abrupt decline in the rainfall while the period between 1991 to 2001 was the reverse of the same (Figure 4 & 5).

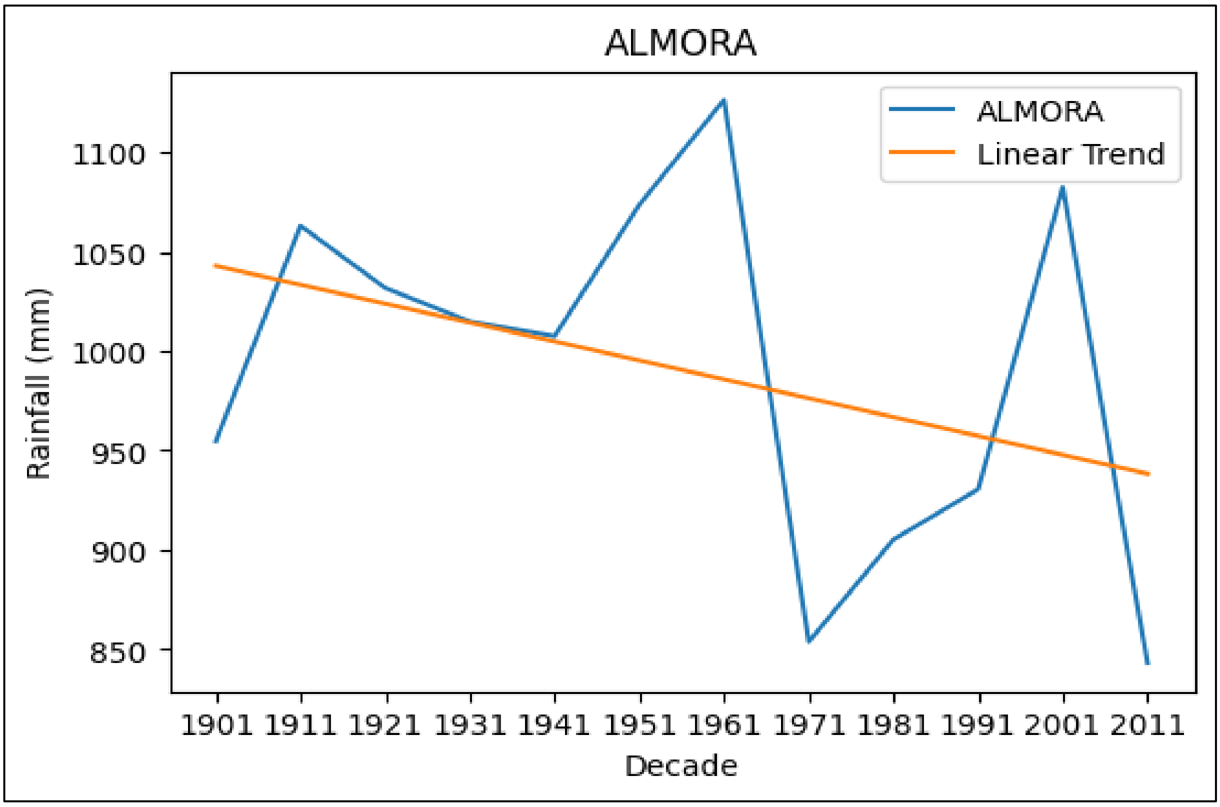

Fig 4: Trends in decadal rainfall

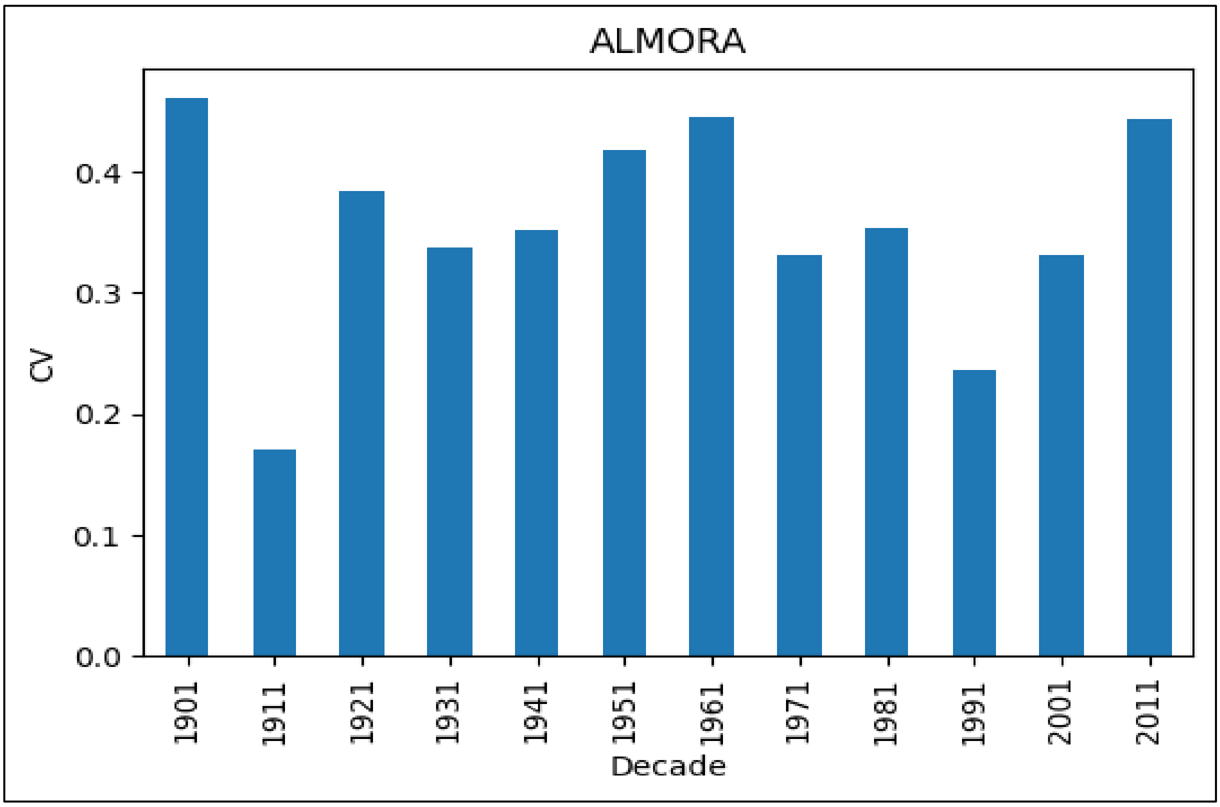

Fig 5: Variability in decadal rainfall

Conclusion

For the past several decades the abrupt rainfall trends are the proof that not only the intensity and distribution of rainfall have changed but also the annual amount of rainfall received at a particular location. This may be attributed to climate change or other factors leading to the disturbances in annual hydrological cycle.

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