Exploratory Analysis of RainFall Data in India for Agriculture

TEAM LEADER : PRIYA VISHNU A S

TEAM MEMBER 1: MAHESH KUMAR R

TEAM MEMBER 2:SURYA PRAKASH P

TEAM MEMBER 3:VIJAYKUMAR D

LITERATURE SURVEY

1. Exploratory Data Analysis of Indian Rainfall Data : Author - Anusha Gajinkar

India is an agricultural country and secondary agro based market will be steady with a good monsoon. The economic growth of each year depends on the amount of duration of monsoon rain, bad monsoon can lead to destruction of some crops, which may result in scarcity of some agricultural products which in turn can cause food inflation, insecurity and public unrest. In our analysis we are trying to understand the behavior of rainfall in India over the years, by months and different subdivisions.

Understanding the Monsoon in India:

We will see what exactly is monsoon, different types of monsoon winds in India, which subdivisions of India receives rainfall from which monsoon winds and why only particular subdivisions receive highest rainfall during this monsoon season.

The Southwest Monsoon usually starts in the first week of June and ends by first week of September and monsoon usually starts retreating from the Indian Subcontinent by the start of September and leaves the subcontinent completely by the end of November. And as we have seen in the previous graphs that Southwest monsoon provides almost 80% of the rainfall in India. This Southwest Monsoon has two branches, namely Arabian Sea branch and Bay of Bengal Branch.

Now, due to the presence of high rising Western Ghats which runs along the South West coast of India in the states of Kerala, Karnataka, Goa and Maharashtra, they block the Arabian Sea branch of southwest monsoon and hence these regions receive very high rainfall during monsoon season. This is shown in the graph below. (For all the graphs we have considered the last 3 decades i.e. last 30 years data (1987–2017))

Annual Rainfall trend over the years for whole India:

10 years moving average was plotted, we can see that there is a decreasing trend in rainfall in the recent years. The trend analysis of Annual rainfall considering India as whole show decreasing trend however when trend is analysed for all subdivision individually we can see some division showing increasing trend and some showing decreasing trend. It showed that is is import to study subdivision for better forecasting

2. Analysis of long-term rainfall trends in India : author -sharad k.jain and yatveer singh

The study of precipitation trends is critically important for a country like India whose food security and economy are dependent on the timely availability of water. In this work, monthly, seasonal and annual trends of rainfall have been studied using monthly data series of 135 years (1871–2005) for 30 sub-divisions (sub-regions) in India. Half of the sub-divisions showed an increasing trend in annual rainfall, but for only three (Haryana, Punjab and Coastal Karnataka), this trend was statistically significant. Similarly, only one sub-division (Chattisgarh) indicated a significant decreasing trend out of the 15 sub-divisions showing decreasing trend in annual rainfall. In India, the monsoon months of June to September account for more than 80% of the annual rainfall. During June and July, the number of sub-divisions showing increasing rainfall is almost equal to those showing decreasing rainfall. In August, the number of sub-divisions showing an increasing trend exceeds those showing a decreasing trend, whereas in September, the situation is the opposite. The majority of sub-divisions showed very little change in rainfall in non-monsoon months. The five main regions of India showed no significant trend in annual, seasonal and monthly rainfall in most of the months. For the whole of India, no significant trend was detected for annual, seasonal, or monthly rainfall. Annual and monsoon rainfall decreased, while pre-monsoon, post-monsoon and winter rainfall increased at the national scale. Rainfall in June, July and September decreased, whereas in August it increased, at the national scale.

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), future climate change is likely to affect agriculture, increase the risk of hunger and water scarcity, and lead to more rapid melting of glaciers. Freshwater availability in many river basins in India is likely to decrease due to climate change (Gosain *et al.*, 2006). This decrease, along with population growth and rising living standards, could adversely affect many people in India by the 2050s. Accelerated glacier melt is likely to cause an increase in the number and severity of glacier melt-related floods, slope destabilization and a decrease in river flows as glaciers recede (IPCC, 2007). Lal (2001) discussed the implications of climate change on Indian water resources. Gosain *et al.* (2006) have quantified the impact of climate change on the water resources of Indian river systems. Kalra *et al.* (2008) found that the yield of wheat, mustard, barley and chickpea show signs of stagnation or decrease following a rise in temperature in four northern states of India.

METHODOLOGY:

The magnitude of the trend in the time series was determined using Sen's estimator (Sen, 1968). This method has been widely used for determining the magnitude of trend in hydro-meteorological time series, and details are available in Lettenmaier *et al*. (1994); Yue & Hashino (2003) and Partal & Kahya (2006). The statistical significance of the trend in monthly, seasonal and annual series was analysed using the non-parametric Mann-Kendall (MK) test (Mann, 1945; Kendall, 1975). The MK test has been employed by a number of researchers (e.g. Yu *et al*., 1993; Douglas *et al*., 2000; Yue *et al*., 2003; Burn *et al*., 2004; Singh *et al*., 2008a,b) to ascertain the presence of statistically significant trend in hydrological climatic variables, such as temperature, precipitation and streamflow, with reference to climate change. The MK test checks the null hypothesis of no trend *versus* the alternative hypothesis of the existence of increasing or decreasing trend. Following Bayazit & Onoz (2007), no pre-whitening of the data series was carried out, as the sample size was large ($n \geq 50$) and the slope of trend was high (>0.01). Details of this method are available in the papers cited above.

On an all-India basis, February, April, August, October and November experienced increasing rainfall, whereas June, July and September showed decreasing rainfall. The months of January, March, May and December showed little or no change in rainfall. The monsoon rainfall showed a decreasing trend and all other seasons' rainfall showed an increasing trend. The maximum magnitude of trend was found in the monsoon season (negative), and the minimum in the winter season (positive). Annual rainfall showed a decreasing trend on an all-India basis, although it was not statistically significant.

3. Working paper -Estimating the Impact on Agriculture : author - Ashok Gulati ,Shweta Saini ,Surbhi Jain.

Impact of robust monsoon rains of 2013 on the Agricultural Gross Domestic Product (GDP) growth in India. The model hypothesizes that the performance of agriculture in India depends upon (1) investments in agriculture (private and public); (2) agricultural price incentives; and (3) rainfall. A log-linear model fitted over 1996-97 to 2012-13 period can explain 95 percent of the variations in agri-GDP with all variables being statistically significant. The model also forecasts that the agri-GDP growth rate for the agricultural year (July-June) 2013-14 is likely to be between 5.2% and 5.7%. An alternative model to double check the results is also used. In this model, the AGCF is replaced by a simple trend variable; the idea being that the trend captures development of various investments and technologies that take place in agriculture over this period. Other variables remain the same. This model also suggests that the agri-GDP growth will be between 5.1% and 5.6%. The paper estimates that agri-GDP growth in 2013-14 is likely to be about three times higher than last year. And it is likely to come largely from oilseeds, pulses, cotton, and coarse cereals belt of central and western parts of the country, which is less irrigated and thereby more dependent on rains. It is very likely that any damage to kharif crops due to excess rainfall (with extended monsoons and cyclones) would be offset by a bumper rabi crop, given that there is excellent soil moisture and ample surplus water in reservoirs. This high growth in agri-GDP is likely to trigger a multiplier effect on manufacturing and services sectors, and thereby propel overall GDP growth rate. The study reviews the pattern of rainfall, as also the increase and structural transformation in irrigation cover since 1950. Studying this is important as it is the interaction of these factors, along with many others, that impacts the performance of agriculture over time. We have tried to capture that by using a log-linear regression model with different variables influencing variations in agricultural GDP. But, since the monsoon rainfall (June to September) of any year influences the agricultural performance during the agricultural year (July to June); we had to construct a new series of agri-GDP as per the agricultural year (July to June). For this we needed quarterly data of agri-GDP, which is given only from 1996-97. Hence the analysis is restricted from 1996-97 to 2013-14, a period of 18 years. The model specification hypothesizes that the performance of agriculture depends upon (1) investments in agriculture (both private and public, which incorporates the investments in irrigation and farm machinery, etc), as embedded in Gross Capital Formation in agriculture (AGCF); (2) agricultural price incentives, as reflected by the ratio of WPI agricultural price index to WPI of Non-agricultural prices index; and (3) rainfall, which is totally exogenous.

Backdrop:

Indian agriculture is still heavily dependent on monsoons. Almost 53 percent of its gross cropped area (GCA) is rainfed, and even the area that is irrigated through canals, tanks, watersheds, and groundwater gets impacted when rainfall is low, and reservoir levels and ground water levels dip. Broadly, only about 35-40 percent of its area is under assured irrigation. There is no doubt that over the years irrigation cover has increased from 17 percent in 1951 to 34 percent in 1991 to 47 percent 1 in 2011; and that the share of groundwater has surpassed the share of canal irrigation (Chart 1). This may have helped to build an increased resilience to droughts as in 2002-03, a year of severe drought, agricultural growth rate turned negative at (-) 6.6 percent but in the year 2009-10, the worst drought year since 1972; agriculture recorded a low but positive growth rate of 0.8 percent.

Besides this cumulative precipitation, the spread of rains too has been fairly good. Except Bihar, Jharkhand, and sates of north-east, rest of India received either normal or above normal rainfall in the period between June 1 and September 30, 2013. As can be seen from the graphs below, of these states, Bihar and Assam & Meghalaya have benefitted from the unexpected extension of rains into October. These late showers have helped these states to move from being "deficient" to one experiencing "normal" rains.

4.Time Series Analysis and Forecasting of Rainfall for Agricultural Crops in India: An Application of Artificial Neural Network: authors- Debasis Mithiya, Kumarjit Mandal, Simanti Bandyopadhyay.

Indian agriculture depends heavily on rainfall. It not only influences agricultural production but also affects the prices of all agricultural commodities. Rainfall is an exogenous variable which is beyond farmers' control. The outcome of rainfall fluctuation is quite natural. It has been observed that fluctuation in rainfall brings about fluctuation in output leading to price changes. Considering the importance of rainfall in determining agricultural production and prices, the study has attempted to forecast monthly rainfall in India with the help of time series analysis using monthly rainfall data. Both linear and non-linear models have been used. The value of diagnostic checking parameters (MAE, MSE, RMSE) is lower in a non-linear model compared to a linear one.The non-linear model-Artificial Neural Network (ANN) has been chosen instead of linear models, namely, simple seasonal exponential smoothing and Seasonal Auto-Regressive Integrated Moving Average to forecast rainfall. This will help to identify the proper cropping pattern. Keywords: artificial neural network, mean absolute error, mean square error, root mean square error, simple seasonal exponential smoothing, seasonal auto-regressive integrated moving average, time series analysis GEL Classification.

Gulati Ashok et.al. (2013), attempted to project the likely impact of robust monsoon rains of 2013 on the Agricultural Gross Domestic Product (GDP) growth in India. The model hypothesizes that the performance of agriculture in India depends upon (1) investments in agriculture (private and public); (2)

agricultural price incentives; and (3) rainfall. A log-linear model fitted over 1996-97 to 2012-13 period can explain 95 percent of the variations in agri-GDP with all variables being statistically significant. The model also forecasts that the agri-GDP growth rate for the agricultural year (July-June) 2013-14 is likely to be between 5.2% and 5.7%. They also estimates that agri-GDP growth in 2013-14 is likely to be about three times higher than previous year. This growth in agri-GDP is likely to come mainly from oilseeds, pulses, cotton, and coarse cereals belt of central and western parts of the country, which is less irrigated and thereby more dependent on rain. It is very likely that any damage to kharif crops due to excess rainfall (with extended monsoons and cyclones) would be offset by a bumper rabi crop harvest, given that there is excellent soil moisture and ample surplus water in reservoirs.

distribution across regions in a particular season is what matters. Therefore, a fluctuation in the distribution of rainfall over the cropping season adversely impacts rain-fed crops. If severe drought or flood occurs during the reproductive, stages the possibility of crop failure is inevitable. So, there is a strong positive impact of rainfall on crop production. The effect of poor monsoon or monsoon failure is generally understood by looking at the changes in output between the years of monsoon failure and the normal years (Chand and Raju, 2009). Hence, rainfall pattern is one of the most important limiting factors for rain-fed crop production.

So, it can be said that in order to select the proper cropping pattern in India, it is very important to determine the exact relationship between rainfall and crop production. At the same time, it is equally important to know the expected monthly rainfall to select the most suitable crops for cultivation.

The present study intends to analyse and forecast the monthly rainfall based on the basis of time series data on rainfall. Monthly rainfall forecasts will in advance inform the farmers of the volume of rainfall. This information will help them to decide what to cultivate and by how much during a particular season. The specific objective of the study is as follows.

i) To analyze the nature of monthly rainfall in India and forecast the future monthly rainfall.

ii). Review of Literature

Artificial neural networks are a class of flexible nonlinear models that can discover patterns adaptively from the data. Theoretically, it has been shown that given an appropriate number of nonlinear processing units, neural networks can learn from experience and estimate any complex functional relationship with high accuracy (Zhang and Qi, 2005). The most widely used ANNs in forecasting problems are multi-layer perceptron (MLPs), which use a single hidden layer feed forward network (Zhang et.al., 1998). The model is characterized by a network of three layers, viz. input, hidden and output layers, connected by acyclic links. There may be more than one hidden layers. The nodes in various layers are also known as processing elements. The three-layer feed forward architecture of ANN models

Karuiru Elias Kimani et al. (2016), have analyzed and forecasted precipitation in Keneya. They have used linear time series model of Seasonal Autoregressive Integrated Moving Average (SARIMA) and non-linear model of Time Lagged Feed forward Neural Network (TLFN). In their study, the values of diagnostic checking parameters including Mean Absolute Deviation (MAD), Mean Squared Deviation (MSD) and Mean Absolute Percentage Error (MAPE) have been found lower in TLFN than SARIMA. They conclude that the Time Lagged Feed forward Neural Network model has performed better than Seasonal Autoregressive Integrated Moving Average for forecasting precipitation.

In the analysis of time series, several methods of forecasting are used. Most common methods are the Moving Average method, Linear Regression with Time, Non-seasonal and Seasonal Exponential Smoothing, Autoregressive Integrated Moving average etc.

The monthly rainfall data of India exhibit seasonality (which is explained later). According to the nature of the data, this study concentrates on the Simple seasonal Exponential Smoothing and Seasonal Autoregressive Integrated Moving Average models among the linear models.

5.Non-linear Time Series Model for predicting rainfall : Article

Sometimes the time series often contains nonlinear components; under such situations the linear models are not adequate for modeling and forecasting. To overcome this difficulty, a non-linear model has been successfully used. When the linear restriction of the model form is relaxed, the possible number of nonlinear structures (ARCH, GARCH, EGARCH, TAR, NAR, NMA model, etc.) that can be used to describe and forecast a time series are enormous. A good nonlinear model should be "general enough to capture some of the nonlinear phenomena in the data" (De Gooijer and Kumar, 1992). Artificial neural networks (ANNs).

6. A Data-Driven Approach for Accurate Rainfall Prediction: authors- Shilpa Manandhar soumyabrata Dev;Yee Hui Lee.

In recent years, there has been growing interest in using precipitable water vapor (PWV) derived from global positioning system (GPS) signal delays to predict rainfall. However, the occurrence of rainfall is dependent on a myriad of atmospheric parameters. This paper proposes a systematic approach to analyze various parameters that affect precipitation in the atmosphere. Different ground-based weather features such as Temperature, Relative Humidity, Dew Point, Solar Radiation, PWV along with Seasonal and Diurnal variables are identified, and a detailed feature correlation study is presented. While all features play a significant role in rainfall classification, only a few of them, such as PWV, Solar Radiation, Seasonal, and Diurnal features, stand out for rainfall prediction. Based on these findings, an optimum set of features are used in a data-driven machine learning algorithm for rainfall prediction. The experimental evaluation using a 4-year (2012-2015) database shows a true detection rate of 80.4%, a false alarm rate of 20.3%, and an overall accuracy of 79.6%. Compared to the existing literature, our method significantly reduces the false alarm rates.

Rainfall prediction in this paper is a spatial interpolation problem that makes use of the daily rainfall information to predict volume of rainfall at unknown locations within area covered by existing observations. This paper proposed the use of self-organising map (SOM), backpropagation neural networks (BPNN) and fuzzy rule systems to perform rainfall spatial interpolation based on local method. The SOM is first used to separate the whole data space into some local surface automatically without any knowledge from the analyst. In each sub-surface, the complexity of the whole data space is reduced to something more homogeneous. After classification, BPNNs are then use to learn the generalization characteristics from the data within each cluster. Fuzzy rules for each cluster are then extracted. The fuzzy rule base is then used for rainfall prediction. This method is used to compare with an established method, which uses radial basis function networks and orographic effect. Results show that this method could provide similar results from the established method. However, this method has the advantage of allowing analyst to understand and interact with the model using fuzzy rules.

The study analyses and compares the relative advantages and limitations of each time-series analysis technique, used for issuing rainfall forecasts for lead-times varying from 1 to 6 h. The results also indicate how the considered time-series analysis techniques, and especially those based on the use of ANN, provide a significant improvement in the flood forecasting accuracy in comparison to the use of simple rainfall prediction approaches of heuristic type, which are often applied in hydrological practice.

• Rainfall prediction was carried out using AI methods such as ANN, PSOANFIS and SVM.

• R, MAE, Skill Score and contingency scores were employed to validate the models.

• Monte Carlo method was applied to analyze the robustness of AI models.

• AI based study would be helpful in quick and accurate prediction of daily rainfall.

7. Big Data in Precision Agriculture Through ICT: Rainfall Prediction Using Neural Network Approach : author- M. R. Bendre, R. C. Thool.

Weather forecasting with detailed and time-based information gathering is essential for future farming. This paper gives an abstract idea about big data in precision agriculture and how it discovers insights from big precision agriculture data through information and communication technology (ICT) resources for future farming. We proposed an e-Agriculture model for the use of ICT services in agricultural environment for collecting big data. Big data analytics provides a new insight to give advance decision support, improve yield productivity, and avoid unnecessary costs related to harvesting, use of pesticide, and fertilizers. The paper lists out the different sources of big data and types in precision agriculture, ICT-based e-Agriculture model, its future applications, and challenges. Finally, we have discussed rainfall prediction application using supervised and unsupervised method for data processing and forecasting.

The advent of Big Data analytics is changing some of the current knowledge paradigms in Science as well in Industry. Although, the term and some of the core methodologies have been around for many years, the continuous price reduction of hardware and some services (e.g. cloud computing) are making more affordable the application of these methodologies to almost any Research Area being developed in Academic Institutions or Company Research Centers. This growing popularity is also raising some concerns regarding some of its core concepts and the way Data is treated through the analysis process. It is the aim of this paper to address these concerns because big Data Methodologies will be extensively use in the new ICT Agriculture project granted by NEDO, in order to improve the efficiency and accuracy of the proposed system, therefore it is necessary to establish a common background for all the project members in which Sojo University plays a fundamental role in the improvement of the general performance of the proposed system.

big data methodologies will be extensively used in the new ICT Agriculture project, in order to know how to handle them, and how they could impact normal operations among the project members, or the information flow between the system parts. The new paradigm of Big Data and its multiple benefits have being used in the novel nutrition-based vegetable production and distribution system in order to generate a healthy food recommendation to the end user and to provide different analytics to improve the system efficiency. Also, different version of the user interface (PC and Smartphone) was designed keeping in mind features like: easy navigation, usability, etc.

8. Rainfall Pattern Analysis over India in Relation to the State : author- Shajimon K John

Rainfall over a region across the earth is the prima face reason of its uniqueness. Different regions over the earth having different rainfall pattern in turn is directly related to the regions uniqueness, it is referred as ecosystem. India is one of the ancient regions having different rainfall pattern which has developed into places with its own unique ecosystem prevailing over its different states. Kerala the southernmost tip of this sub-continent has almost clear green top throughout the year in comparison to various other states in the country. This work mainly concentrates on the variation of rainfall over the state of Kerala in comparison with other states which are its neighbours. Rainfall data over the last century is being analysed for finding out whether the rainfall pattern over the state of Kerala has any relation with the rainfall pattern across the country. Solar activity and the number of sun spots and how these activities effect the rainfall pattern also a major area to be investigated.

The climate within India can be mainly classified into four major categories: tropical dry, tropical wet, sub-tropical humid and mountain climate. The elevated regions in the Himalayas experience snow during the winter season. At the same time Thar Desert experience tropical dry climate. The Himalayas and the Thar Desert influences the climate over the Indian sub-continent a lot. The Himalayas act as a barrier against katabatic winds which blow from Central Asia [8, 9, 10]. Overall the country's climate inclined more towards tropical since the Tropic of Cancer passes through the middle of the country. The tropical wet climatic regions within the country can be sub divided into; tropical monsoon climate and savannah climate. The major areas which fall in tropical monsoon region are Lakshadweep, Andaman and Nicobar Islands, southern Assam, the Western Ghats and Malabar Coast. These areas experience moderate to high temperature along with high rainfall during monsoon season; from June to November. The high amount of rain received in these regions keeps these regions green throughout the year [11, 12]. The savannah climate is the most commonly prevailing climate in the country. Almost all inland areas experience the savannah (tropical wet and dry) climate, with extremely high temperature during summer and moderate to heavy rainfall during monsoon which normally occurs during June to September [13, 14].The tropical dry climate is again sub divided into three mainly; sub-tropical arid (steppe) climate, tropical semi-arid (steppe) climate, and sub-tropical arid (desert) climate. Regions around Karnataka, Central Maharashtra, Andra Pradesh and some parts of Tamil Nadu experiences Tropical semi-arid climate experience with hot and dry summers during March to May and almost very unreliable and erratic rainfall. Western Rajasthan regions of Thar Desert fall into the sub-tropical arid (desert) climatic region. The region where the desert extends like parts of Punjab, and Haryana comes under sub-tropical semi-arid climate regions. These regions experience high temperature during summer and rain normally occurs during summer monsoon only. Sub-tropical humid climate experienced in most of the North and Northeast regions. In these regions summers are hot to very hot while during winter season the temperature may dip to 0°C [15, 16]. These regions also experience rainfall during summer with sporadic rain or snowfall during winter. The summer occurs during May to July while the winter occurs during December and January. The mountain climate mainly happens in the Himalayas region with an average temperature fall of almost 0.5°C with every 100 meters rise in height.

The effect of these different climatic styles on the country is that it has mainly four different seasons; winter, summer, rainy season and autumn.

9. Climate Change and Agriculture Review Article with rainfall in India: author-T. Jayaraman

One of the critical issues in Indian agriculture is the high proportion of rainfed agriculture in the part of the country climatically classified as semi-arid tropics (SAT).41 Rainfed agriculture42 in the semi-arid tropics is particularly vulnerable to climate change. In 1999–2000, rainfed agriculture as a whole accounted for roughly 60 per cent of net sown area, amounting to nearly 87.5 million hectares out of a total of 142 million hectares. In the semi-arid tropic States of Andhra Pradesh, Gujarat, Maharashtra, Karnataka, Rajasthan, Tamil Nadu and Madhya Pradesh, rainfed agriculture accounted for 72.8 per cent of net sown area, whereas in the non-semi-arid tropics it accounted for 42.2 per cent of net sown area.

Rainfed agriculture in the semi-arid tropics carries a much higher degree of risk, and is characterised by high variability in production, low yields and low returns, often not even covering the cost of cultivation for several crops in many regions. The semi-arid tropics are important to total agricultural production, gross cropped area and farmers’ livelihoods in India, particularly with respect to the cultivation of minor millets, oilseeds and pulses.44 Climate change theorists may want to note that relative water-abundance is not a sufficient condition for the removal of income-poverty. The incidence of income-poverty does not appear necessarily very different between the semi-arid and humid zones of India, nor does the Human Development Index show any clear trend or pattern that correlates with agro-climatic zones or levels of irrigation

There is little evidence of any direct impact of ongoing climate change on current agricultural production, especially with respect to major food and horticultural crops, and related activities such as livestock rearing and fisheries. Two observations, however, are noteworthy.

The first concerns the impact of climate change on apple production in Himachal Pradesh.48 Apple production is sensitive to the extent of cold weather in a specified range during the winter months. This is calculated in terms of “chilling units” (the cumulative number of hours over which winter temperatures are in the correct range of coldness). The number of hours above the specified maximum during the winter months has a negative effect on apple yields. The data show that, below a height of approximately 2,400 metres above sea level, the number of chilling units has been decreasing, whereas above this height the number of days of suitable temperature has been increasing. This change is reflected in the pattern of apple production: the extent of apple cultivation is increasing at higher altitudes and declining at lower altitudes. Thus the extent of apple cultivation has increased sharply in Lahul-Spiti and the upper reaches of Kinnaur district, whereas it has reduced in the State as a whole, particularly in Kullu and Shimla. Apple yields per hectare have also declined overall in the State, from 10.8 to 5.8 tonnes/hectare. According to some studies (cited in Rana et al. 2009), these observations appear to match farmers’ perceptions.

10. Spatial analysis of Indian summer monsoon rainfall: author -Markand Oza and C.M. Kishtawal

Changing rainfall has significant effect on water resources, agricultural output and hence economy. To understand the variability in rainfall, a spatio-temporal analysis of Indian summer monsoon rainfall was taken up. The objective for the present analysis was to identify trends in amount of Indian summer monsoon at various spatial scales. Daily gridded rainfall data (10 X 10 spatial resolution) for the period 1951-2010 corresponding to monsoon season and monthly rainfall data at meteorological sub-division level for 1901 - 2010 were analysed. From the gridded data, a series of rainfall at agroclimatic regions was constructed. The analysis was based on linear trend analysis. Both parametric and non-parametric methods were used. From statistical analysis of data it was concluded that there is a decreasing trend in all-India Indian summer monsoon rainfall.

Northeast India is one big cluster having highly decreasing trend. Also, there is a strong agreement between gridded and meteorological subdivision based rainfall. Data of MSBD 1 and 2 were not analysed as the dataset was not complete. MSBD 1 had data missing for 1941 – 1945 whereas MSBD 2 had missing data for 1901-15, 1950, 1954-56 and 1971. So the analysis is done for remaining 34 MSBDs. The data are analysed for 4 months (June, July, August and September) and total of these four months.

As with gridded data, a series of moving average of 30-years was prepared and a least square linear trend model was fitted to such a smoothed series. of 34 x 4 = 136 monthly series, the slopes for 29 series were statistically significant with 13 having positive slopes and 16 having negative slopes MSBD 33 (North interior Karnataka) had positive slope for 2 months (Jun and Aug). MSBDs 4 (Manipur, Mizoram, Nagaland and Tripura in NE) and 15 (Himachal Pradesh) had 3 months having negative slope whereas 12 (Uttaranchal) had 2 months having negative slopes and remaining two months showing lack of trend.