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# Rainfall variability analysis of Uttar Pradesh for crop planning and management

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**सार -** इस शोध पत्र में मेन-केण्डल परीक्षण सांख्यिकीय मानक का उपयोग करते हुए वर्षा आंकड़ों में समय श्रृंखलाओं के विश्लेषण और सांख्यिकीय महत्व की प्रवृति का पता लगाया गया है। जलवायु अनुसंधान में व्यापक रूप से उपयोग किए जाने वाले गैर पैरामीट्रीक मेन-केण्डल (M-K) स्थाई रैंक परीक्षण को इस अध्ययन में किसी एक स्टेशन पर वर्षा के समय श्रृंखला में होने वाले उतार-चढ़ाव तथा प्रवृति और क्षेत्रीय औसत का पता लगाने के लिए लगाया गया है। उत्तर-प्रदेश के वर्षा आंकड़ों (वर्ष 1981-2012 तक) के विश्लेषण से पता चला है कि वार्षिक वर्षा की कुल मात्रा में विशेष रूप से गिरावट की प्रवृति रही है। यह भी देखा गया है कि वर्ष 1990 के पूर्व वार्षिक वर्षा की आवृति सामान्य से कम रही है जबकि 1990 के बाद इसमें वृद्धि हुई है। वर्ष 1996 के बाद से वार्षिक वर्षा की मात्रा 1040.5 मि.मी. से घटकर 988 मि.मी. हो गई है अर्थात् 5 प्रतिशत की कमी हुई है। इसमें मासिक वर्षा की मात्रा में बहुत ही रोचक प्रवृति देखी गई है अर्थात् वर्ष 1996 के बाद शरद ऋतु के महीनों (अक्तूबर से फरवरी) में वर्षा में गिरावट देखी गई है जबकि मई के अलावा ग्रीष्मऋतु के समान महीनों में वर्ष 1996 के पहले की तुलना में वृद्धि पाई गई है। वर्ष 1996 के बाद मानसून ऋतु के आंरभिक और अंतिम महीनों में मासिक वर्षा की मात्रा में अधिक गिरावट देखी गई है अर्थात जून और सितम्बर में जबकि मध्य के महीनों अर्थात जुलाई और अगस्त में वर्ष 1996 के पहले की तुलना में वृद्धि देखी गई है। इस अध्ययन में दशकीय परिवर्तनों से पता चला है कि इन सभी तीनों दशकों जैसेः- 1981-1990, 1991-2000 और 2001-2010 में वार्षिक वर्षा में बारी-बारी से गिरावट और वृद्धि की प्रवृति रही है।

**ABSTRACT.** Time series analysis and statistical significance of trends in rainfall data was carried out using standard Mann-Kendall test statistics. The non-parametric Mann-Kendall (M-K) statistical rank test, which is widely used in climate research, was employed in this study to find out fluctuations and presence of trend in time series data of rainfall at a single station, as well as regional averages. Analysis of rainfall data (1981-2012) of Uttar Pradesh reveals significant decreasing trend in total quantum of annual rainfall. It was also noticed that the frequency of occurrence of annual rainfall below normal was less before 1990s while increased after 1990s. The amount of annual rainfall decreased significantly after 1996 from 1040.5 mm to 988 mm, *i.e*., a decrease of 5 percent. A very interesting trend has been noticed for the quantum of monthly rainfall, *i.e*., it was found significantly decreased after 1996 for the months of winter season (October-February) while at par for the months of summer season except May only which was found increased as compared to before 1996. The quantum of monthly rainfall was found significantly decreased after 1996 for initial and last months of monsoon season, *i.e*., June and September while increased for the middle months, *i.e*., July and August as compared to before 1996. The study of decadal variability in annual rainfall showed that an alternate decreasing and increasing trend in all the three decades *viz*., 1981-1990, 1991-2000 and 2001-2010.

**Key words** – Rainfall, Trend analysis, South-west monsoon, Decadal rainfall, Seasonal rainfall, Crop management and rain fed ecosystem**.**

## 1. Introduction

Rainfall is the single most important factor in crop production planning in rain-fed ecologies. Around 60% of the Indian agriculture is rain dependent, diverse, complex, under-invested, risky, distress prone and vulnerable. Intra-seasonal variability of rain has been further compounded due to increase in frequency and intensity of the extreme

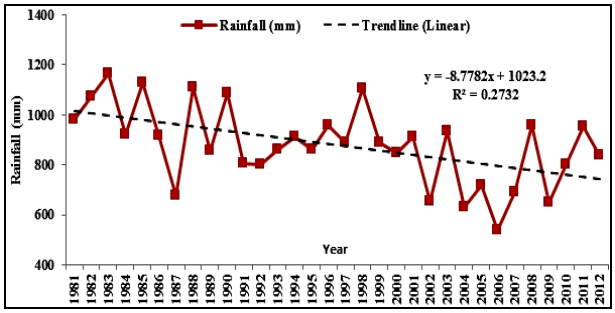



**Fig. 1.** Variability in annual rainfall of U. P. during past 32 years

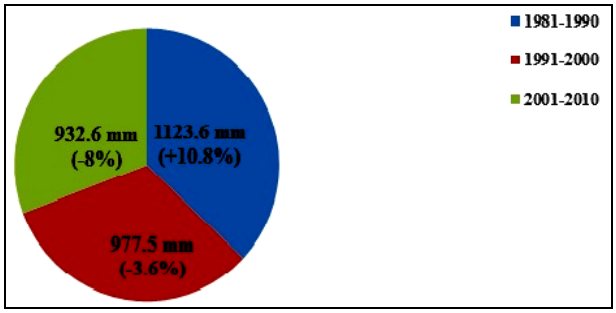



**Fig. 2.** Variability in quantum of decadal rainfall (mm) of U. P. with deviation (%) from normal

rainfall and weather events due to global warming. Rainfall, being considered as the prime input for agriculture has its own erratic behavior in terms of amount and distribution. For better crop planning, a detailed study on rainfall behavior is vital. Rainfall variability, both in time and space influences the agricultural productivity and sustainability of a region, as opined by Virmani, 1994. The agricultural crop productivity largely depends on the rainfall distribution and its intensity during the rainy season. Rainfall analysis for crop planning was carried out in different regions of the country as reported by Chaudhary and Tomar (1999); Ghadekar and Thakare (1991). The information on annual, decadal and seasonal rainfall of a region is useful to design water harvesting structure for agricultural operations, field preparation, seeding, irrigation, fertilizer application and overall in field crop planning (Sharma *et al*., 1979). In this context, an attempt was made to analyse the temporal variability of rainfall in Uttar Pradesh for suitable crop planning under rice-wheat cropping system. Despite increased grain yield through green revolution, the agricultural scenario of the state is still greatly dependent on annual rainfall and rainfall distribution pattern. So, studying rainfall and its variability is becoming important for agricultural production and management. As the cropping pattern of any region is greatly governed by rainfall and its distribution especially in rain-fed regions hence this study was carried out to find the trends in rainfall as annual, decadal and seasonal analysis in the Uttar Pradesh. Climate change is very likely to have a major impact on hydrological cycle and consequently on available water resources, flood and drought frequencies, natural ecosystems, society and the economy (Ramos, 2001). The aim of this study was to analyse the possible trends of annual, decadal and seasonal rainfall using observed historical time series weather data of recent years of Uttar Pradesh.

Water, the most precious resource is sometimes scarce, sometimes plentiful and always unevenly distributed in space and time. The detection of current pattern of rainfall in changing scenario of climate, in terms of annual, seasonal and decadal basis certainly has profound importance on the local, regional and national scales, due to the associated critical socioeconomic consequences. Therefore, an attempt has been made to give a clear picture about annual, seasonal, monthly, decadal rainfall pattern and rainfall characteristics of Uttar Pradesh.

## 2. Data and methodology

Total monthly rainfall of 32 years (1981-2012) of Uttar Pradesh was collected from India Meteorological Department (IMD), Pune and Meteorological Centre (MC), Lucknow. The collected data was further divided in two segments; (*i*) pre 1997 period (1981-1996) & (*ii*) post 1997 period (1997-2012) and variability analysis of rainfall was done accordingly. These data were analyzed on annual, seasonal and decadal basis for the entire series under the study period. The season was decided as per IMD classification, *i.e*., monsoon season from June-September ($23^{rd}$ to $39^{th}$ meteorological week), post-monsoon season from October-November ($40^{th}$ to $49^{th}$ meteorological week), winter season from December-February ($49^{th}$ to $9^{th}$ meteorological week) and summer season from March-May ($10^{th}$ to $22^{nd}$ meteorological week). Time series analysis and statistical significance of trends in rainfall data was carried out using standard Mann-Kendall test statistics (Libiseller and Grimall, 2002). The non-parametric Mann-Kendall (M-K) statistical rank test (WMO, 1966) which is widely used in climate research, was employed in this study to find out fluctuations and presence of trend in time series data of rainfall at a single station, as well as regional averages. The statistical significance was tested at 95% level.

The M-K rank statistics (t) is computed from

$$t = \frac{4\sum n_i}{N(N-1)} - 1 \qquad (1)$$

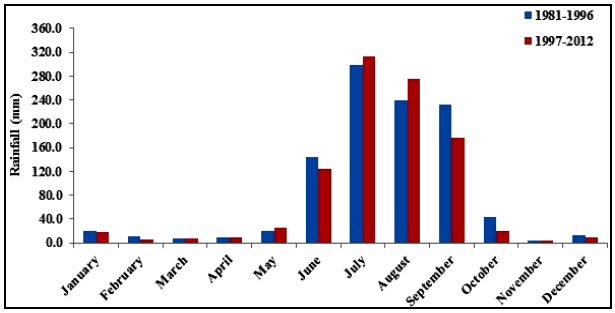



**Fig. 3.** Variability in monthly rainfall of U. P. during pre and post 1997 period

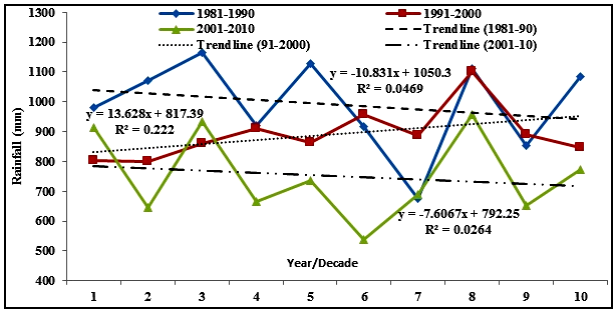



**Fig. 4.** Variability in decadal rainfall of U. P. during 1981-2010

where, $n_i$ is the number of data values larger than the $i^{th}$ value, subsequent to its position in the series and N is the total number of data in the series. The statistic ($T_t$) is calculated by

$$T_t = \pm t_g \sqrt{\frac{(4N+10)}{[9N(N-1)]}} \qquad (2)$$

where $t_g$ is the appropriate value of the probability point in the Gaussian distribution corresponding to the two-tailed test. The significance of the trend is decided on the basis of comparison of M-K rank statistic '*t*' and statistic '$T_t$'.

## 3. Results and discussion

Data of annual rainfall since 1981-2012 (last 32 years) have been analyzed and results reflected a significant decreasing trend in total quantum of annual rainfall for Uttar Pradesh (Fig. 1). In Uttar Pradesh, there are some areas like Bundelkhand and western region receiving less amount of rainfall as compared to central and eastern Uttar Pradesh. Tripathi (2012) reported the same trend for different sectors of Uttar Pradesh. The mean total annual rainfall of Uttar Pradesh was found 988 mm. A significant decline of 5% in annual rainfall was also observed after 1996 in Uttar Pradesh. The frequency of occurrence of annual rainfall below normal was found increased after 1990s. Considering the average water requirement of rice crop is 1000 to 1200 mm for medium and long duration rice varieties, the quantum of rainfall below normal in most of the years clearly indicated that there is an imperative need to suitably modify the crop management and cropping pattern. In this context, simulation of rice yield in rain-fed areas where the rice crop is fully dependent upon south west monsoon rainfall would be helpful in management and planning of crop under aberrant weather condition. A relatively higher productivity of rice can be obtained with adoption of

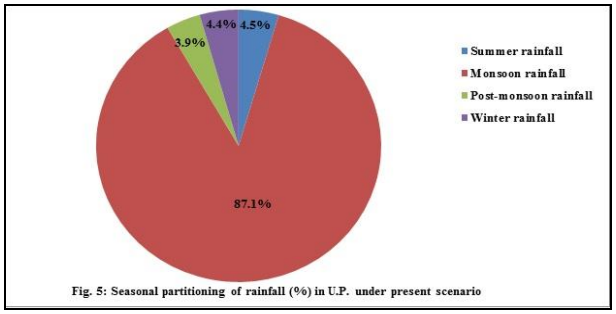
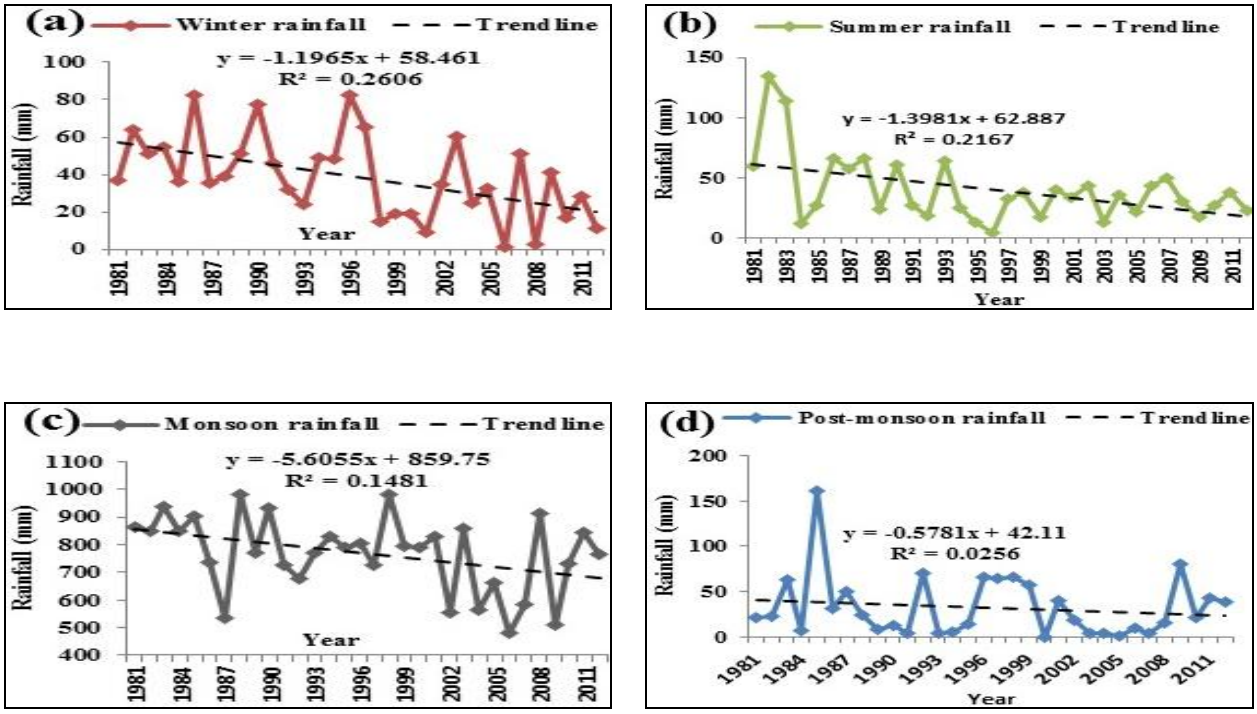



**Fig. 5.** Seasonal partitioning of rainfall (%) in U. P. under present scenario

proper water conservation and recycling practices. Similar findings were also reported by Sastri *et al*. (1999). The monsoon rainfall does not follow any definite trend in all India scale, although some significant trends exist in some pockets of India when long term data were analysed [Kolli *et al*. (1992)].

The analysis of rainfall for pre and post 1997 period of Uttar Pradesh has also been performed. It was quite evident from the study that the amount of annual rainfall in Uttar Pradesh decreased significantly after 1996 from 1040.5 to 988 mm, *i.e*., a decrease of 5 percent. Results revealed that the quantum of total rainfall was found increased by 10.8% from normal rainfall during the decade 1981-1990 while it decreased for the rest two decades, *i.e*., 1991-2000 & 2001-2010 by 3.6% and 8%, respectively (Fig. 2). A very interesting trend has been noticed for the quantum of monthly rainfall. It was significantly decreased after 1996 for the months of post monsoon and winter seasons (October-February) while at par for the months of summer season except May when it increased as compared to the quantum of monthly rainfall before 1996. The quantum of monthly rainfall was found significantly decreased after 1996 for initial and last months of monsoon season, *i.e*., June and September while it increased for the middle months, *i.e*., July and




**Figs. 6(a-d).** Seasonal rainfall variability in U. P. (a) Winter season (b) Summer season (c) Monsoon season and (d) Post-monsoon rainfall (mm)

August as compared to before 1996 (Fig. 3). The study of long term (1981-2012) decadal variability of annual rainfall has been performed and an alternate decreasing and increasing trend was observed for Uttar Pradesh in all the three decades *viz.*, 1981-1990, 1991-2000 and 2001-2010, respectively (Fig. 4). Since monthly rainfall was noticed significantly decreased after 1996 in the month of June hence when onset of monsoon delayed by two weeks there would be no change in crop/ cropping system including variety of rice. Raised staggered rice nursery should be grown at 15 days interval in small areas at least two times. Intercropping/ mixed cropping of maize/ sorghum/ pearl millet with long duration varieties of pigeon pea may be used as agronomic measures. Pigeon pea should be sown on raised beds and may be intercropped with maize/ green gram/ black gram. When rainfall was decreased in the month of September, foliar spray of 2.5 kg urea and 2.5 kg potash per hectare would be beneficial to conserve moisture in the soil. Alternate management of irrigation should be insured to provide life saving irrigation. Under such condition, an advance crop planning for rabi season may be sowing of Toria Type-9, PT-303, PT-30 and Ageti Rai should be sown in 1$^{st}$ week of September while Bhawani variety can be sown in 2$^{nd}$ week of September. This analysis might be helpful in preparation of crop planning and management for the area in advance which would be greatly influenced the crop management and cropping pattern of the state in positive way.

As far as the pattern of seasonal rainfall is concerned, it is quite evident from the data that the south west monsoon contributes 87.1 per cent (767.3 mm), post monsoon 3.9% (32.6 mm), winter season rainfall 4.4 per cent (38.7 mm) and only 4.5 per cent (39.8 mm) contribution by summer season rainfall (Fig. 5). Part of the rain water percolates below the root zone of the plants and part of the rain water flows away over the soil surface as run-off. This deep percolation water and run-off water cannot be used by the plants. In other words, part of the rainfall is not effective. The remaining part is stored in the root zone and can be used by the plants. This remaining part is the so-called effective rainfall. The factors which influence which part is effective and which part is not effective include the climate, the soil texture, the soil structure and the depth of the root zone. If the rainfall is high, a relatively large part of the water is lost through deep percolation and run-off. If the soil is still wet when the next rain occurs, the soil will simply not be able to store more water and the rain water will thus percolate below the root zone and eventually reach the groundwater. Heavy rainfall may cause the groundwater table to rise temporarily. Especially in sloping areas, heavy rainfall will result in a large percentage of the rainwater being lost

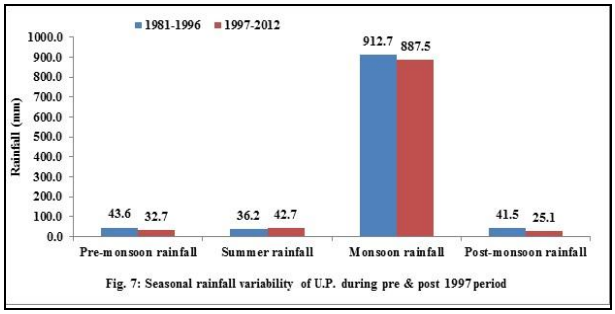



**Fig. 7.** Seasonal rainfall variability of U. P. during pre and post 1997 period

by surface run-off. Thus, during monsoon season, a major part of the rainfall amount is generally lost in different ways which can be stored through water harvesting structures such as farm ponds and lakes, etc. and used during the post monsoon season for growing rain-fed crops like lentil, mustard, gram, fodder, etc. in those areas where irrigation facility is not available. Analysis of rainfall on seasonal basis revealed that the pattern was in significantly decreasing trend in all the crop seasons while the rate of decrease of rainfall was in the tune of monsoon season > summer season > winter season >post monsoon rainfall (Fig. 6). However, a drastic decline in quantum of seasonal rainfall has been noticed from pre to post 1997 period in Uttar Pradesh except summer season. It is also revealed from the data that the rate of decrease of total amount of rainfall after 1996 was highest in post-monsoon season (39.5%) followed by pre-monsoon season (25%) and monsoon season (2.8%), respectively (Fig. 7). It was also observed from the data that the quantum of total rainfall increased during summer season only by 17.9% after 1996. This gives a good indication in Uttar Pradesh as a whole that summer rainfall would also be helpful for land preparation particularly for summer ploughing operation during the season. The rainfall received during summer season would be helpful to grow the green manures to increase the land productivity and to achieve sustainability. When monsoon delayed by 4 weeks, *i.e.*, onset of monsoon is in 3$^{rd}$ week of July then short duration varieties of paddy such as NDR-97, NDR-80, NDR-118, Saket-4 may be sown. Transplanting of paddy with 3-4 seedlings per hill to increase the plant population 60 hills per m$^2$ instead of 50 hills per m$^2$ may be done as agronomic measures. Pruning and thinning of overage paddy seedlings might be helpful for better establishment and optimum plant stand. Mulching with straw/ grass cover may also be done to conserve soil moisture for better yield under dry spell/ less rainfall condition.

## 4. Conclusions

On the basis of long term data analysis (1981-2012) of Uttar Pradesh it was observed that after 1996 the rate of decrease of total quantum of annual rainfall was more in Uttar Pradesh as compare to before 1996. The decadal rainfall variability was in an alternate trend. In recent decade (2001-2010), the rainfall trend was depicted to have decreasing trend in Uttar Pradesh. The seasonal rainfall was also observed in decreasing trend in the order of monsoon rainfall > summer rainfall > winter rainfall > post-monsoon rainfall in Uttar Pradesh.

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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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