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# Impact of June and July Rainfall on Seasonal Monsoon Performance in India

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**Abstract**

This study examines the relationship between monthly rainfall patterns in June, July and the pre-monsoonal rainfall (June+July) overall seasonal performance of the Indian southwest monsoon (June to September). Using data spanning 1901–2015, the analysis highlights the influence of early monsoon rainfall on seasonal totals. Findings indicate that deficit or excess rainfall in June and July strongly correlates with below- or above-average seasonal rainfall. The study further reveals that rainfall deficiencies in these months are frequently associated with El Niño events, whereas La Niña years tend to exhibit above-normal seasonal rainfall. The persistence of circulation anomalies formed in June is proposed as a key factor influencing seasonal monsoon variability.

**Key Point:**

1. The increasing inter annual variability, a strong influence of ElNino and LaNina on monsoon soon rainfall registered drought and flood years.
2. Indian annual rainfall trend indicates an over all decline with an increasing inter annual variability. ElNino and LaNina events strongly influence the monsoon which resulted in droughts and floods during these years.
2. The rise in extreme events (both drought and floods) emphasizes the need for better water resource management and drought mitigation strategies.
3. Excess June rain boosts monsoon chances; normal June links to normal monsoon; deficit June signals likely monsoon shortfall.
4. Excess June rainfall significantly increases the likelihood of excess monsoon rainfall. Normal June rainfall strongly correlates with normal monsoon rainfall. Deficit June rainfall is a strong indicator of monsoon deficit, with minimal chances of excess rainfall.
5. Excess July rainfall significantly increases the likelihood of excess monsoon rainfall. Normal July rainfall strongly correlates with normal monsoon rainfall. Deficit July rainfall is a strong indicator of monsoon deficit, with minimal chances of excess rainfall.
6. 5. Early monsoon rainfall is a strong predictor of the overall monsoon season. If June + July rainfall is low, there is a high chance of a monsoon deficit, June + July rainfall is high, the monsoon is likely to be excess, but a normal early monsoon rainfall does not guarantee a normal overall monsoon. The June + July rainfall is moderately variable, with occasional extreme years.

## INTRODUCTION:

The Indian Southwest Monsoon (ISM) is a crucial climatic phenomenon that significantly influences the nation's agriculture, water resources, and economy (Gadgil et al., 2002; Webster et al., 1998). Variability in monsoon performance has far-reaching consequences, including extreme events such as severe droughts and floods, which necessitate advanced and accurate forecasting methods to mitigate socio-economic impacts (Parthasarathy et al., 1992; Sikka, 1980; Shukla and Paolino, 1983). The interannual variability of the ISM is largely modulated by global climate drivers, particularly the El Niño-Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), and other coupled ocean-atmosphere interactions (Krishna Kumar et al., 1999; Kripalani and Kulkarni, 1997; Ashok et al., 2004).

Previous studies have established a strong correlation between ENSO and Indian monsoon variability, wherein El Niño events are often associated with weaker monsoons, leading to droughts, while La Niña years tend to enhance monsoon performance, resulting in above-normal rainfall (Rasmusson and Carpenter, 1982; Ju and Slingo, 1995; Rajeevan and Pai, 2007). Additionally, the role of the IOD in modulating ISM variability has gained increasing attention, with positive IOD events reinforcing monsoon activity, whereas negative IOD phases weaken monsoons (Saji et al., 1999; Behera et al., 2006; Ashok et al., 2003). Apart from large-scale climatic factors, intra-seasonal oscillations, land-atmosphere interactions, and regional circulation patterns significantly impact monsoon variability (Madden and Julian, 1971; Krishnamurti and Ardanuy, 1980; Vecchi and Harrison, 2004).

Understanding the role of early monsoon rainfall, particularly during June and July, is essential for improving seasonal monsoon predictions (DelSole and Shukla, 2012; Wang et al., 2009). Studies indicate that the performance of these initial monsoon months often sets the tone for the overall seasonal rainfall, with strong rainfall anomalies persisting into later months (Pai et al., 2011). Moreover, atmospheric circulation anomalies formed in June and July are believed to play a significant role in determining the subsequent evolution of the monsoon season (Goswami et al., 2018). Sivaram and AALN Sarma (2008, 2011) have highlighted the link between the ocean-atmospheric interactions, such as El Niño and LaNina and the performance of the Indian summer monsoon.

This study aims to investigate the relationship between early monsoon rainfall (June and July) and the overall seasonal performance of the ISM from June to September. By analyzing rainfall data spanning over a century (1901–2015), this research assesses whether early monsoon rainfall serves as an effective predictor of seasonal totals. Insights from this study can enhance monsoon forecasting models and provide valuable guidance for agriculture, water management, and disaster preparedness.

## Data and Methodology:

The study utilizes monthly and seasonal rainfall data for India from 1901 to 2015. Data were sourced from the Indian Institute of Tropical Meteorology (IITM), Pune. Rainfall variability was analysed using statistical methods, including probability calculations, correlation coefficients to establish dependencies between monthly, pre monsoonal and seasonal rainfall trends. Parthasarathy et.al (1992) classified the All India seasonal rainfall into Excess, Deficit and Normal. The rainfall over and above the sum of mean and standard deviation is considered as excess, between difference of mean and 1 standard deviation and sum of mean and 1 standard deviation will be Normal and rainfall which is below the difference of mean and 1 standard deviation is deficit. Mathematically, we can represent them as:

| Type | Condition |
|---|---|
| Excess Rainfall | $R \geq Mean + S.D$ |
| Deficit Rainfall | $R \leq Mean - S.D$ |
| Normal Rainfall | $Mean - S.D < R < Mean + S.D.$ |

The chances of occurrence of excess or deficit seasonal rainfall when the rainfall in June, July and sum of June and July rainfalls is excess or deficit have been calculated and analysed. Whether there is a significant dependency of seasonal rainfall on the rainfall of June, July and sum of June and July rainfalls have been tested through the correlation coefficients between them. The dependency of seasonal rainfall on monthly rainfalls during ElNino and LaNina years also have been calculated for the ElNino and LaNina years listed by Halpert and Ropelewski (1992).

**Results and Discussion:**

**Annual rainfall analysis:** India's annual rainfall plays a critical role in agriculture, water resources, and overall climate stability. This report analyzes the India's annual rainfall trends from 1901 to 2015, key patterns, variability, and correlations with global climate phenomena such as El Niño and La Niña. To understand the rainfall variability the annual mean, variance, standard deviation, and coefficient of variation (CV) have been calculated. The coefficient of variation is the percentage ratio of standard deviation to mean. The mean, standard deviation and coefficient of deviation of annual rainfall of India are 1182mm, 110 mm and 9.3% (Table.1). It was observed that during period of study, India has experienced 21 drought events and 20 flood years and the rest of the years received the normal rainfall (Table.1). Some of the drought events may be correlated to the land sea interactions such as ENSO which reduces the rainfall and flood events may be correlated to the LNSO which increase the rainfall of India. From the time series of the annual rainfall for the study period 1901-2015 (Fig.1), it was observed the deficiency in the rainfall in the years, which are notable drought years include 1905, 1918, 1965, 1987, 2002, and 2009 and the failure of the monsoon in the year 1902, 1905, 1911, 1965, 1972, 1982, 1997, 2002, 2009 coincide with the negative impact of ElNino on Indian rainfall.

On the other hand the excess rainfall which resulted a severe flood during the years 1917, 1961, 1975, 1994, and 2013.and the strong monsoon during the years 1903, 1917, 1956, 1975, 1988, 2010 accompanied by LaNina that enhanced the Indian rainfall. From this analysis we conclude that there is strong correlation between the Indian summer rainfall and ocean atmospheric interactions such as El Nino and LaNina.

**Monsoon rainfall analysis:**

The mean monsoon rainfall (June-September) over the period is approximately 890.3 mm with a standard deviation (σ) of 89.1mm that indicates the scope of variation from the mean. During the period of study, India witnessed 25 deficit monsoons, and 16 excess rainfall years that caused severe droughts and floods respectively (Table-1). A significant inter annual variability (10.0%) of monsoon rainfall is observed from the time series with years of above and below average rainfall. 1917 (~1094.5 mm), 1959 (~1051.7 mm), 1988 (~1066.1 mm) are high rainfall years and 1972 (~679.5 mm), 2002 (~689.2 mm), 2009 (~702.4 mm) are low rainfall years during the period of study. During the period of years 1930s, 1950s and 1990s there are prolonged above average rainfall (Fig.2). In the years 1965, 1972, 2002 and 2015 a drought like condition has been observed which are due to the very less monsoon rainfall. The decade 2000-2015 experienced frequent droughts in the years 2002, 2009, 2014 and 2015 which is due to the changing

climates which effect the monsoon patterns. Due to ongoing monsoon variability the years 2007 and 2013 received a high amount of rainfall in the present decade (2000-2015).

**Relation between June & Monsoon rainfall:**

The June monthly rainfall has a mean $\mu = 168.36mm$ ,standard deviation $(\sigma) = 35.4$mm with a variability of 21%. The time series of June monthly rainfall of India for the study period shows high interannual variability 17 years experienced below the difference of mean and standard deviation, and 25 years witnessed above the sum of mean and standard deviation (Table-1). Most of the rainfall values are in between $mean - std\ and\ mean + std\ dev$ (Fig.3). The high fluctuations in the rainfall may be due to climate change, deforestation or urbanisation that affect the monsoon pattern.

To understand the impact of rainfall in the month of June on the Monsoon rainfall the conditional probabilities have been calculated. It was observed that there is a possibility of 58.06% excess rainfall, 35.48% normal rainfall and 6.45% deficient rainfall during the monsoon period if the June rainfall is excess (Table.2). When the June rainfall is normal then there is 91.43% possibility to receive normal rainfall during the monsoon period and very less possibility of excess rainfall (0.95%) and with a chance of deficiency 7.62%.

If the June rainfall is deficit, then there is no possibility of excess rainfall during the monsoon period, but 70.59% chance to have a deficient rainfall that leads to a drought and 29.41% of chance to receive a normal rainfall, in support of the moderate correlation coefficient(r=0.41) between June and Monsoon period rainfall.

The correlation coefficient (r=0.41) between the June and Monsoon period rainfall also indicates that there is a moderate positive correlation correlation between the June rainfall and Monsoon period rainfall. If June receives higher rainfall, there is a moderate chance that the entire monsoon season will also have higher rainfall, but it is not a strong predictor of other factors such as monsoon weather pattern, ocean atmospheric interactions ElNino &LaNina etc. The 58.06% chance of excess rainfall during the monsoon period when June rainfall is excess with a positive moderate correlation coefficient (r=0.41) is an indication that early monsoon activity (June rains) plays an important role in setting the trend for the rest of the season.

**Relation between July & Monsoon rainfall:**

From the time series of July rainfall of India, it was observed that a 14.1% of interannual variability in the July rainfall from the mean during the study period 1901-2015 (Fig.4). During the study period 16 years have experience droughts and 16 years have witness flood situations and the rest have received the normal rainfall (Table.1). A positive correlation coefficient of (0.66) is an indication of dependency of monsoon rainfall on the rainfall of July. The excess and deficit rainfalls during the month of July may be due to the changes in the climatic conditions, ocean atmospheric interactions such as LaNina and ElNino. The dependency of monsoon rainfall on the rainfall of July has been calculated and presented (Table.3). There is a chance of 56.25% to receive an excess, moderate chance (31.25%) to experience normal rainfall and 12.5% possibility of deficit in the monsoon rainfall when there is an excess rainfall in the month of July.

The Monsoon receives normal rainfall with the probability (88.10%), a deficit rainfall with a probability of 7.14% and less chance (4.76%) of receiving an excess rainfall, given that the July rainfall is Normal.

When the rainfall in the month of July is in deficit, there is a high probability (71.43%) to receive a deficit rainfall, moderate chance (28.57%) for normal rainfall during the monsoon period. There is no possibility of excess rainfall during the monsoon period when the July rainfall is in deficit.

**Effect of June & July rainfall on Monsoon rainfall**:

The time series of the pre monsoon (June and July) rainfall of India (Fig.5) indicates an 11.5% of interannual variability with 17 deficient and 18 excessive rainfall events during the study period. Most of the years the pre monsoon rainfall is in the limits of one sigma deviation from the mean. The fluctuations in the pre monsoonal rainfall may be due to the changes in the climate, ocean atmospheric interaction such as ElNino and LaNina, deforestation. Very high or very low June + July rainfall, leading to excess or deficit monsoon seasons are observed in some years. High variability can lead to uncertainty in agricultural planning, as farmers depend on stable early monsoon rains for crop sowing. Years with extreme low June + July rainfall often result in drought-like conditions, impacting water availability and crop yields. Sudden surges in early rainfall can cause flooding, affecting infrastructure and livelihoods. The link between early monsoon variability and total monsoon rainfall suggests early warnings can help predict seasonal outcomes.

The correlation coefficient between summer monsoon rainfall (June–September) and early monsoon rainfall (June + July) is 0.78 (Table.1)**,** which indicates a strong positive correlation, suggesting that higher rainfall in June and July is generally associated with higher total monsoon rainfall. 68.4% of the years had excess total monsoon rainfall and 7.9% of the years had deficit monsoon rainfall when the early monsoon (June+July) rainfall is high, that suggests a strong early monsoon is an indication of above average monsoon rainfall. The monsoon rainfall was deficit in 65.8% of the years of study with only 10.5% had excess monsoon rainfall in conjunction with low pre monsoon rainfall. This indicates that a weak early monsoon strongly correlates with the weak monsoon (Table-4).

There is a chance of 53.8% of the years receiving normal monsoon rainfall with a chance of 25% of excess or deficit rainfall if the pre monsoon rainfall is normal. This suggests that a normal early monsoon rainfall doen't strongly predict the extreme monsoon rainfalls.

**Conclusions:**

Indian annual rainfall trend indicates an over all decline with an increasing inter annual variability. ElNino and LaNina events strongly influence the monsoon which resulted in droughts and floods during these years. These years coincide with significant monsoon failures, confirming El Niño's negative impact on Indian rainfall.

The Indian monsoon exhibits high inter-annual variability but remains within a predictable statistical range most of the time. The presence of extreme events (both high and low rainfall years) emphasizes the need for better water resource management and drought mitigation strategies. The increasing number of drought years in recent decades could be a sign of climate change impacts on the monsoon system.

Excess June rainfall significantly increases the likelihood of excess monsoon rainfall. Normal June rainfall strongly correlates with normal monsoon rainfall. Deficit June rainfall is a strong indicator of monsoon deficit, with minimal chances of excess rainfall.

Excess July rainfall significantly increases the likelihood of excess monsoon rainfall. Normal July rainfall strongly correlates with normal monsoon rainfall. Deficit July rainfall is a strong indicator of monsoon deficit, with minimal chances of excess rainfall.

Early monsoon rainfall is a strong predictor of the overall monsoon season. If June + July rainfall is low, there is a high chance of a monsoon deficit, June + July rainfall is high, the monsoon is likely to be excess, but a normal early monsoon rainfall does not guarantee a normal overall monsoon. The June + July rainfall is moderately variable, with occasional extreme years.

Its variability strongly influences total monsoon rainfall, making it an important predictor for monsoon season planning. Monitoring trends in early monsoon variability can help improve weather forecasts and water management strategies. Understanding these patterns can aid in more reliable seasonal predictions, helping policymakers, farmers, and other stakeholders make informed decisions regarding water resource management and agricultural planning.

The study confirms the significant impact of June and July rainfall on seasonal monsoon performance. A deficit in these months substantially increases the likelihood of a below-average monsoon, particularly during El Niño years. Incorporating early monsoon rainfall data into forecasting models could enhance the accuracy of seasonal rainfall predictions.

Keywords: Southwest monsoon, rainfall variability, El Niño, La Niña, seasonal prediction, Indian monsoon.

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