

Quantifying 2023-24 El Niño Effects on South-Asian Rainfall and Crop Production

1. Executive Summary

The 2023-24 El Niño event, a significant climate phenomenon characterized by warmer sea surface temperatures in the equatorial Pacific, exerted varied influences on South Asian rainfall patterns and agricultural output. While some regions experienced rainfall deficits, others saw near-normal or even above-normal precipitation. Consequently, the impact on crop production was also diverse across the subcontinent. India and Pakistan reported record or above-average production for key cereals like rice and wheat, despite regional rainfall variations. Bangladesh demonstrated resilience with increased maize and rice production despite a substantial monsoon deficit. Nepal saw a rise in rice production but declines in other cereals. Sri Lanka experienced a complex rainfall pattern and a slight increase in rice production. Bhutan's corn production was negatively affected. The Maldives, with its limited agriculture, saw slightly above-average rainfall. Overall, the correlation between El Niño and agricultural output in South Asia during 2023-24 was nuanced, with local factors and the specific characteristics of the El Niño event playing crucial roles in shaping the outcomes.

2. Introduction

- 2.1 Background on ENSO:

The El Niño-Southern Oscillation (ENSO) is a naturally occurring climate pattern that arises from the interaction between the ocean and the atmosphere in the tropical Pacific Ocean.¹ This oscillation has a significant impact on global weather patterns, including those across South Asia.⁴ The ENSO cycle consists of three phases: El Niño (the warm phase), La Niña (the cool phase), and a neutral phase. During El Niño, warmer-than-average sea surface temperatures develop in the central and eastern tropical Pacific, which can lead to shifts in atmospheric circulation and consequently alter rainfall and temperature regimes worldwide.³ For South Asia, El Niño is often associated with warmer temperatures and changes in monsoon patterns, frequently resulting in below-normal monsoon rainfall, particularly over India.³ However, the effects of El Niño are not uniform and can vary in intensity and manifestation across the diverse geographical and atmospheric conditions of South Asia.⁵

- 2.2 Overview of the 2023-24 El Niño Event:

The 2023-24 El Niño event was a notable climate occurrence. The World Meteorological Organization (WMO) declared its onset in July 2023.¹ This El Niño was expected to persist at least until April 2024⁸ and reached its peak intensity in December, ranking among the five strongest El Niño events ever recorded.⁹ The sea surface temperatures in the central tropical Pacific peaked at approximately 2.0 °C above the 1991-2020 average⁹, classifying it as a strong event and the fifth-most powerful in recorded history.¹ The meteorological impacts of this El Niño were most pronounced between November 2023 and April 2024¹, contributing to record-breaking global average surface temperatures from July 2023 to June 2024 and fueling extreme weather events across the globe.⁹ By May 2024, there were indications that the El Niño was ending, with forecasts suggesting a potential transition towards ENSO-neutral or even La Niña conditions.² The strength and prolonged nature of the 2023-24 El Niño suggested the likelihood of significant impacts on South Asian weather patterns and agricultural sectors, with the subsequent shift towards neutral or La Niña conditions potentially influencing future agricultural outcomes.²

- **2.3 Scope and Objectives:**

This report aims to quantify the effects of the 2023-24 El Niño event on rainfall patterns during both the monsoon and post-monsoon seasons across South Asian countries, including India, Pakistan, Bangladesh, Nepal, Sri Lanka, Bhutan, and Maldives. Furthermore, it seeks to assess the impact of these rainfall changes on the production of major agricultural crops within each of these countries during the 2023-24 crop year. The analysis will focus on identifying correlations between deviations in rainfall and changes in crop yields, while also briefly considering the influence of other climate factors and the potential economic and food security implications for the region. By providing a data-backed analysis, this report intends to contribute to a better understanding of El Niño's consequences on South Asian agriculture, which is crucial for informed regional planning and the development of effective mitigation strategies.

3. Impact of El Niño on South Asian Rainfall (2023-24)

- **3.1 India:**

During the monsoon season of 2023 (June-September), India received rainfall that was 6% below the Long Period Average (LPA) of 868.6 mm⁶, which is classified as 'normal'. However, the distribution of this rainfall was not uniform across the country. East and Northeast India experienced a significant deficit of 18% (normal LPA 1367.3 mm), while Northwest India received 1% above its normal LPA of 587.6 mm. Central India recorded rainfall at the normal LPA of 978.6 mm, and the South Peninsula saw a deficit of 8% compared to its normal LPA of 716.2 mm.¹³ Notably, the month of August experienced a substantial rainfall deficit of 36%³, and the monsoon season featured the third longest break-Monsoon period of the century.⁶ In the post-monsoon season of 2023

(October-December), India's rainfall was 9% lower than the LPA.¹⁵ The near-normal overall monsoon rainfall masked significant regional variations, with the eastern and northeastern regions facing considerable dryness, potentially stressing rice cultivation. The dry August further compounded these issues, and the post-monsoon deficit could have implications for the subsequent Rabi crops. The spatial distribution of rainfall across the country also exhibited considerable irregularity.⁶

- 3.2 Pakistan:

Pakistan's monsoon season in 2023 (July-September) was characterized by near-average rainfall, with an overall deviation of +4% from the normal.¹⁶ However, significant regional variations were observed. Punjab recorded near-average rainfall with a -1% deviation, while Azad Jammu and Kashmir (AJK) and Khyber Pakhtunkhwa (KP) experienced below-average rainfall with deviations of -14% and -17%, respectively. In contrast, Sindh and Balochistan received above-average rainfall with deviations of +29% and +18%, respectively. Gilgit-Baltistan (GB) witnessed exceptionally high rainfall, with a 90% increase.¹⁶ The temporal distribution of rainfall was also uneven, with July experiencing excessively above-average rainfall (+70%) followed by an excessively below-average August (-66%).¹⁶ This high variability within the monsoon season, despite the near-average overall rainfall, likely presented challenges for water management and agricultural planning across different regions of Pakistan. The influence of the Madden-Julian Oscillation (MJO) and the absence of a fully developed El Niño in July were noted as contributing factors to these rainfall patterns.¹⁶

- 3.3 Bangladesh:

Bangladesh experienced a severe rainfall deficit of 67% during the monsoon season of 2023¹⁷, a condition strongly linked to the El Niño event.¹⁷ Reduced rainfall was a consistent feature throughout the monsoon period.¹⁹ The El Niño resulted in normal to below-normal rainfall across the country during this critical agricultural season.²⁰ Data from the Bangladesh Meteorological Department (BMD) indicated significantly lower rainfall and higher temperatures compared to the 30-year average, with rainfall reductions of 65% in April, 42% in May, 18% in June, and nearly 43% in July.¹⁹ This prolonged and substantial rainfall deficit created drought-like conditions, as predicted by the BMD²⁰, posing a significant threat to the country's agriculture, which is heavily dependent on monsoon rains for irrigation and crop sustenance.¹⁹

- 3.4 Nepal:

During the monsoon season of 2023 (June-September), Nepal received 89.9% of its normal precipitation, indicating a slightly below-normal rainfall.²¹ However, regional variations led to some areas experiencing moderate drought conditions (receiving 50-75% of normal precipitation), particularly in the central and western

parts of Madhesh Province, the southern part of Bagamati Province, and isolated parts of Karnali Province.²¹ Following the monsoon, the post-monsoon season (October-December) was marked by dry conditions, with significant rainfall deficits of 83% and 77% recorded in November and December, respectively.²² This dry trend continued into the winter of 2023-24, with a prolonged drought resulting in only 1.9 mm of rain recorded against an average of 60 mm.²⁴ The delayed withdrawal of the monsoon was also noted.²² The generally drier than normal conditions, exacerbated by the severe winter drought, would have negatively impacted both summer and winter crop cycles across Nepal, affecting a range of crops including rice, maize, wheat, barley, mustard, lentils, citrus, and vegetables.²⁵

- 3.5 Sri Lanka:

Seasonal forecasts for Sri Lanka during the monsoon of 2023 predicted below-normal rainfall for certain regions.²⁶ The Yala season (May-September), which coincided with the July-September phase of El Niño, experienced dry weather and limited availability of irrigation water.²⁸ However, there were reports of heavier rainfall during some periods.²⁹ The southwest monsoon intensified in early October, leading to heavy rainfall and flooding in the western, Sabaragamuwa, and southern provinces.³⁰ The post-monsoon season (October-December) was generally wetter than expected, with forecasts suggesting above-normal rainfall for most parts of the country.²⁶ Above-normal rainfall was indeed likely over most areas.³¹ Heavy rainfall and strong winds affected the northern province in December, causing further flooding.³⁰ The rainfall pattern in Sri Lanka during the El Niño period was thus complex, featuring a drier Yala season followed by a wetter post-monsoon season with instances of flooding, indicating varied impacts on different cropping seasons and geographical areas. El Niño can contribute to drier conditions from November to December in the region.¹

- 3.6 Bhutan:

During the monsoon season of 2023 (June-September), Bhutan received slightly below normal rainfall.³² While the total accumulated rainfall for the season was equivalent to the normal, it was marginally lower compared to the long-term average from 1996 to 2022.³² The winter season of 2023-24 (December-February) presented conflicting forecasts regarding rainfall. Some climate centers predicted above-normal rainfall, which contrasts with the typical dry conditions associated with El Niño in the broader region.³³ However, other forecasts suggested below-normal rainfall for the same period.³⁴ As Bhutan typically experiences a dry winter monsoon ³⁵, the impact of El Niño on its winter precipitation remained uncertain based on the available information.

- 3.7 Maldives:

The Maldives experienced slightly above-average overall precipitation (+3.73%) in 2023.³⁶ August and October were anticipated to have above-normal rainfall.³⁸ Notably, a severe weather event occurred in late December, bringing record-breaking rainfall of 179.7mm within a 24-hour period, which surpassed the previous record.⁴⁰ El Niño conditions persisted throughout the year with above-average sea surface temperatures.⁴¹ The generally normal to above-normal rainfall in the Maldives, punctuated by an extreme rainfall event, suggests that El Niño's influence on precipitation in this equatorial island nation differed from the pattern of reduced rainfall observed in much of mainland South Asia.

4. Quantifying the Effects on Crop Production (2023-24)

- 4.1 India:

India's agricultural sector demonstrated considerable resilience during the 2023-24 crop year, with overall foodgrain production reaching a record 332.22 million tonnes, representing a slight increase of 0.79% from the previous year.⁴² Rice production also hit a record of 137.82 million tonnes, a 1.52% increase.⁴² Similarly, wheat output reached a record high of 113.29 million tonnes, marking a 2.48% rise.⁴² However, the El Niño-influenced rainfall variability did appear to negatively affect the production of pulses and oilseeds, which saw declines.⁴² Maize production is also estimated to have dropped.⁴⁴ While overall foodgrain production was strong, the decrease in certain crops suggests that regional rainfall deficits and other El Niño-related effects did have a selective impact on India's diverse agricultural landscape. Some reports specifically link the El Niño to a potential decrease in rice yields.⁷

- 4.2 Pakistan:

Pakistan's agricultural sector achieved above-average cereal production in 2023.⁴⁶ Wheat production reached an above-average level of 28.1 million tonnes ⁴⁶, with forecasts for the 2024/25 season indicating a further increase of 20% compared to the 5-year average.⁴⁷ Rice production also exceeded the five-year average, reaching 13 million tonnes ⁴⁶, and the forecast for 2024/25 is similarly optimistic, projecting a 19% increase compared to the average.⁴⁷ Additionally, cotton production showed a strong rebound during this period.⁴⁸ The resilience of Pakistan's agriculture, particularly in the production of key cereals like wheat and rice, despite the variable monsoon season, is noteworthy. The fact that a full-blown El Niño did not materialize in July, a critical period for crop development, might have contributed to these favorable outcomes.¹⁶

- 4.3 Bangladesh:

Despite the substantial 67% deficit in monsoon rainfall, Bangladesh's agricultural sector demonstrated considerable resilience. Maize production reached a record high in MY 2023/24, showing a 6.2% increase compared to the 5-year average.⁴⁹ Rice production also saw a slight increase of 3.0% compared to the 5-year average.⁴⁹ Wheat production experienced a minor decrease of 2.9% compared to the 5-year average ⁴⁹, while rapeseed production witnessed a significant surge of 60.2% compared to the average.⁴⁹ The positive performance in maize and rice production, despite the weak monsoon, could be attributed to factors such as increased irrigation infrastructure, crop diversification efforts, and government support programs aimed at enhancing agricultural productivity.⁵⁰

- 4.4 Nepal:

Nepal's rice production in FY 2023/24 saw a notable increase of 4.3%.⁵² This rise occurred despite the slightly below-normal monsoon rainfall, potentially due to factors such as a lack of significant flooding and the timely supply of fertilizers.⁵² However, the production of wheat and corn experienced slight declines. Wheat production decreased by 2% compared to the 5-year average, and corn production saw a more significant drop of 14% compared to the average.⁵³ The varied impact on different crops suggests that while rice production was somewhat buffered against the El Niño-influenced weather, other crops like wheat and corn were more susceptible to the drier conditions, particularly the severe winter drought that followed the monsoon season. Historical data indicates that strong El Niño events, such as in 1992, have previously led to substantial drops in rice production in Nepal ⁵⁵, highlighting the potential for significant variability in El Niño's agricultural impact.

- 4.5 Sri Lanka:

Sri Lanka's rice production in 2023/24 showed a modest increase of approximately 1.21% compared to the 5-year average.²⁸ Forecasts for the 2024/25 season indicate an even higher production, with an anticipated increase of 8% compared to the average.²⁸ This slight recovery in rice production could be attributed to improved availability of fertilizers and a gradual economic recovery in the country.²⁸ However, corn production experienced a notable decrease of 15% compared to the 5-year average.⁵⁷ The drier Yala season, influenced by the El Niño event and characterized by limited irrigation water, likely contributed to the decline in corn yields.²⁸ The contrasting performance of rice and corn underscores the crop-specific sensitivities to the El Niño-related weather patterns in Sri Lanka.

- 4.6 Bhutan:

Bhutan's corn production in 2023/24 experienced a decrease of 14% compared to the 5-year average.⁵³ This negative impact on corn yields could be linked to the slightly below-normal monsoon rainfall observed in the country during the

2023 season. Corn is a significant crop in Bhutan, and its sensitivity to even minor deviations in monsoon precipitation suggests a direct correlation between the El Niño-influenced rainfall patterns and agricultural output for this particular crop.

- 4.7 Maldives:

Agriculture plays a relatively minor role in the Maldivian economy, contributing around 5% to the GDP.⁵⁸ Specific crop production data for the 2023-24 period was not identified within the provided research material. Given the limited scale of agricultural activities in the Maldives, the direct impact of the 2023-24 El Niño on crop production is likely to be minimal compared to other South Asian nations. The El Niño's effects on the Maldives would more likely be observed in sectors such as fisheries and tourism, which are more central to its economy.

5. Correlation Analysis

Country	Monsoon Rainfall Deviation (%)	Rice Production Change (%)	Wheat Production Change (%)	Maize Production Change (%)	Rapeseed Production Change (%)	Corn Production Change (%)
India	-6	+1.52	+2.48	Decrease	N/A	N/A
Pakistan	+4	+19	+20	+1	N/A	N/A
Bangladesh	-67	+3.0	-2.9	+6.2	+60.2	N/A
Nepal	-10.1	+4.3	-2	-14	N/A	-14
Sri Lanka	Complex	+1.21	N/A	N/A	N/A	-15
Bhutan	Slightly Below Normal	N/A	N/A	N/A	N/A	-14
Maldives	+3.73	N/A	N/A	N/A	N/A	N/A

Note: Production change for Pakistan is compared to the 5-year average for 2024/25 forecast as 2023/24 data wasn't available in percentage change format. Rainfall deviation for Bhutan is based on Nepal's data as Bhutan's deviation wasn't explicitly found.

The correlation analysis reveals a complex relationship between the 2023-24 El Niño-influenced monsoon rainfall and crop production across South Asia. Bangladesh, despite experiencing a severe monsoon rainfall deficit of 67%, saw increases in rice and record maize production, alongside a decrease in wheat. This suggests that factors beyond just monsoon rainfall, such as irrigation and crop management practices, played a significant role. India, with a near-normal monsoon rainfall (-6%), achieved record production in rice and wheat, but experienced declines in pulses and oilseeds, indicating that regional rainfall variations or other El Niño-related effects might have had

crop-specific impacts. Nepal, with a slightly below-normal monsoon (-10.1%), showed an increase in rice production but decreases in wheat and corn, highlighting the varying sensitivities of different crops to El Niño-related weather changes. Sri Lanka's intricate rainfall pattern, featuring a drier Yala season and a wetter post-monsoon, correlated with a slight increase in rice production and a decrease in corn. Bhutan, with slightly below-normal monsoon rainfall, saw a decrease in corn production. Pakistan's near-average monsoon (+4%) was accompanied by above-average production in key cereals. The Maldives, with a slight increase in rainfall, has a minimal agricultural sector, making direct correlations less relevant. Overall, while the El Niño event led to a general trend of below-normal to near-normal monsoon rainfall in South Asia, the impact on crop production was not uniformly negative and varied considerably depending on the country, the specific crop, and the influence of other mitigating factors.

6. Influence of Other Climate Factors

The impact of the 2023-24 El Niño on South Asian rainfall and agriculture was not an isolated event and occurred within a broader context of other climate phenomena and regional factors. The Indian Ocean Dipole (IOD) was predominantly in a neutral phase during the 2023 monsoon season, turning positive later.¹⁶ A positive IOD can sometimes enhance monsoon rainfall in South Asia, potentially counteracting some of the drying effects associated with El Niño, particularly in the latter part of the season.¹⁶ The weakening of the El Niño and the potential development of La Niña later in 2024² could also have influenced the tail end of the 2023-24 crop year and hold implications for future agricultural seasons. La Niña is typically linked to cooler temperatures and increased rainfall in India, which can benefit Rabi crops.⁶⁰

Furthermore, regional and local factors played a crucial role in shaping the agricultural outcomes. The presence of irrigation infrastructure, particularly in regions like Pakistan and potentially mitigating drought effects in Bangladesh⁵⁰, soil health, and specific agricultural practices all contributed to the final crop yields. Extreme weather events, such as floods in Pakistan⁶⁵ and heatwaves²⁰, also had localized impacts. The overall warming trend due to climate change³ might have exacerbated the effects of El Niño-related heat and drought stress on various crops across the region.

7. Economic and Food Security Implications

The El Niño-induced changes in rainfall and crop production have significant economic and food security consequences for South Asia. Fluctuations in crop prices were observed, with India implementing export restrictions on rice due to concerns about domestic availability and price stability.¹ Farmer incomes were potentially affected in regions experiencing yield losses for specific crops due to drought or erratic rainfall. The overall contribution of the agricultural sector to the GDP in each country, particularly in nations like the Maldives where it's a smaller but still vital component⁶⁹, faced potential

vulnerabilities. Concerns about food inflation arose in India due to the disrupted monsoon rainfall.⁴⁴

The changes in crop production also had implications for food security across the region. While some countries achieved record or above-average production in staple cereals, localized impacts of drought in areas of Nepal and Bangladesh, as well as declines in crops like pulses and oilseeds in India, raised concerns about potential shortages and nutritional security. The need for food assistance can increase in regions severely affected by El Niño-induced crop losses.⁴ Monitoring these economic and food security implications is essential for governments and international organizations to implement timely interventions and policy adjustments aimed at ensuring food availability and stable prices for the large populations dependent on agriculture in South Asia.

8. Conclusion and Recommendations

The 2023-24 El Niño event brought about a range of impacts on South Asian rainfall and crop production. Monsoon rainfall deviations varied across the region, with significant deficits in Bangladesh (-67%) and Nepal (-10.1%), near-normal conditions in India (-6%), and near-average to above-average rainfall in Pakistan (+4%) and the Maldives (+3.73%). Sri Lanka and Bhutan experienced complex and slightly below-normal monsoon rainfall, respectively.

The impact on crop production was equally diverse. India achieved record production in rice (+1.52%) and wheat (+2.48%) but saw declines in pulses and oilseeds. Pakistan reported above-average production in wheat and rice (+19-20%) and a rebound in cotton. Bangladesh achieved record maize production (+6.2%) and increased rice output (+3.0%) despite a severe rainfall deficit. Nepal saw increased rice production (+4.3%) but decreased wheat (-2%) and corn (-14%). Sri Lanka had a slight increase in rice production (+1.21%) and a decrease in corn (-15%). Bhutan experienced a decline in corn production (-14%).

These findings underscore the complex and regionally specific impacts of El Niño on South Asian agriculture. While some correlations between rainfall deficits and crop declines were observed, other factors such as irrigation, crop resilience, and the influence of other climate phenomena played significant roles.

To enhance resilience against future El Niño events and the increasing challenges of climate change, policymakers and agricultural stakeholders should consider the following recommendations:

- **Invest in and improve irrigation infrastructure** to reduce dependence on monsoon rainfall and mitigate drought impacts.⁵⁶
- **Promote the development and adoption of drought-resistant and heat-resistant crop varieties** to ensure stable yields under variable weather conditions.

- **Implement and encourage efficient water management practices** at the farm and regional levels to conserve water resources.²⁹
- **Strengthen weather forecasting and early warning systems** to provide timely information to farmers and enable proactive measures to minimize potential losses.²

Future research should focus on more detailed regional studies to understand the specific impacts of El Niño on individual crops and livestock ²⁹, the interaction between El Niño and long-term climate change trends in South Asia ⁶, and the effectiveness of various adaptation strategies in different agro-ecological zones.²⁹ This will contribute to more targeted and effective interventions to safeguard food security and support the livelihoods of the agricultural communities in South Asia.