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Climate Variability and Agricultural Vulnerability in Jharkhand: A Long-Term and Recent Trend Analysis

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Abstract: *Agriculture in Jharkhand is highly sensitive to climate variability, given its dependence on monsoon rainfall, undulating terrain and limited irrigation facilities. This study examines long-term (1961-2008) and recent (2009-2025) trends in rainfall and temperature and analyses their impact on agricultural performance in the region. The results show that although total annual rainfall has not changed significantly, its variability has increased, with a higher frequency of dry spells and high-intensity rainfall events. Such changes reduce effective soil moisture and increase the risk of soil erosion. At the same time, a consistent rise in maximum temperature, particularly during late winter and pre-monsoon months, has been observed. This warming trend negatively affects crop growth, especially for rabi crops such as wheat, by shortening the growing season and reducing yields. The study further highlights that increasing climatic uncertainty has intensified agricultural vulnerability, particularly under rainfed conditions. Small and marginal farmers are the most affected due to limited access to irrigation and adaptive resources. To address these challenges, the paper suggests a set of adaptation strategies, including rainwater harvesting, crop diversification, adoption of climate-resilient varieties and improved soil and water management practices. Strengthening institutional support and promoting climate-smart agriculture are also essential. Overall, the findings emphasise the need for integrated and region-specific strategies to enhance agricultural resilience and ensure sustainable livelihoods under changing climatic conditions in Jharkhand.*

Keywords: *Climate Change; Rainfall Variability; Rainfed Agriculture; Agricultural Vulnerability; Climate Resilience; Sustainable Agriculture*

1. Introduction

Agriculture remains one of the most climate-sensitive sectors, especially in developing regions where farming is largely dependent on natural conditions. In India, a large part of agriculture still relies on monsoon rainfall, making it highly vulnerable to climatic variability and long-term climate change. Jharkhand is one such region where agriculture is mainly rainfed and constrained by several physical and socio-economic factors. The state is characterised by undulating terrain, shallow soils, low water-retention capacity and poor soil fertility. Irrigation facilities are also limited, covering only about 10-12 per cent of the cultivated area. These conditions make agricultural production uncertain and highly sensitive to changes in rainfall and temperature.

Climate change has emerged as a major challenge for agricultural sustainability. It influences key climatic elements such as temperature, rainfall and the frequency of extreme weather events. According to the Intergovernmental Panel on Climate Change, global surface temperature has increased significantly over the past century and further warming is expected in the coming decades. Such changes are likely to alter cropping patterns, shorten growing seasons and increase the risk of crop failure, particularly in tropical and sub-tropical regions (IPCC, 2021). In the Indian context, studies have shown that rising temperatures and changing rainfall patterns are already affecting agricultural productivity and water availability (Kumar et al., 2011; Mall et al., 2006).

Jharkhand presents a unique case where the impacts of climate change are intensified by existing environmental constraints. Although the state receives relatively high annual rainfall, its distribution is highly uneven, concentrated within a few monsoon months. Recent studies indicate that rainfall variability has increased over time, leading to frequent dry spells and occasional high-intensity rainfall events (Guhathakurta & Rajeevan, 2008). Such variability reduces the reliability of rainfed agriculture and increases the risk of soil erosion, especially on fragile, sloping landforms. At the same time, a gradual rise in temperature has been observed across eastern India, which adversely affects crop growth, particularly during critical stages such as flowering and grain filling (Dash et al., 2007).

The combined effect of erratic rainfall and rising temperature poses serious challenges to agricultural productivity in Jharkhand. Crops like wheat, which are sensitive to temperature fluctuations, often show reduced yield under heat stress conditions. In addition, uncertainty in the onset and withdrawal of the monsoon makes it difficult for farmers to plan sowing and harvesting activities. These climatic uncertainties not only affect food production but also have wider socio-economic implications for rural livelihoods.

Despite these growing concerns, region-specific studies on climate variability and its impact on agriculture in Jharkhand are still limited. Most available studies focus on broader national or regional scales, which often fail to capture local-level variations. Therefore, there is a need for detailed analysis based on long-term climatic data to understand the nature and extent of climate change in this region.

In this context, the present study aims to examine the trends in rainfall and temperature in Jharkhand and analyse their impact on agricultural performance. The study also attempts to understand the implications of climatic variability for crop production and suggests possible adaptation strategies for sustainable agriculture in the region.

2. The Study Area

The present study is conducted in Jharkhand, a state located in eastern India. It extends from 22°28′ N to 25°30′ N latitude and 83°22′ E to 87°40′ E longitude. The region is part of the Chotanagpur Plateau, which is known for its rugged topography, dissected uplands and undulating surface. Elevation varies considerably, reaching up to around 1100 metres above mean sea level. These physiographic characteristics play a crucial role in shaping the region's hydrological behaviour and agricultural practices (Singh, 2012).

Jharkhand experiences a tropical monsoon climate with three main seasons: summer, monsoon and winter. The average annual rainfall ranges between 1200 mm and 1600 mm, with nearly 80-85 per cent occurring during the southwest monsoon months (June to September). However, rainfall is highly variable and unevenly distributed across time and space. Such variability often leads to alternating conditions of flood and drought within the same year, creating uncertainty in agricultural planning (Guhathakurta & Rajeevan, 2008).

The region's soil is generally shallow, coarse-textured and low in fertility. It has poor water retention and is highly susceptible to erosion, especially during high-intensity rainfall. The undulating terrain further accelerates runoff, reducing infiltration and groundwater recharge. As a result, soil moisture availability becomes a limiting factor for crop growth (Sharma, 2010).

Agriculture in Jharkhand is predominantly rainfed and characterised by low productivity. Irrigation facilities are limited, covering only about 10-12 per cent of the cultivated land. The major crops grown include paddy during the monsoon season and wheat, pulses and oilseeds during the rabi season. However, crop yields are often unstable due to climatic variability, particularly fluctuations in rainfall and temperature (Mahapatra, 2014).

From a socio-economic perspective, the region is characterised by small, fragmented landholdings. A significant proportion of the population depends directly on agriculture for their livelihood. Limited access to irrigation, technology and institutional support further increases farmers' vulnerability to climate risks (Planning Commission, 2013).

Overall, the combination of fragile environmental conditions and socio-economic constraints makes Jharkhand highly sensitive to climate variability. This makes it an important region for examining the impact of changing rainfall and temperature patterns on agricultural sustainability.

3. Data Sources and Methodology

This study is based on long-term climatic data and field-level crop observations to examine the impact of climate variability on agriculture in Jharkhand. Both secondary and primary data sources have been used to ensure a comprehensive analysis.

3.1 Data Sources

Daily rainfall and temperature data (maximum and minimum) for the period 1961-2008 were collected from the Agrometeorological Observatory located at Kanke, Ranchi. This dataset provides a reliable long-term record for analysing climatic trends in the region. The data were aggregated into annual and seasonal values for further analysis. Seasonal classification was performed according to the standard meteorological divisions: winter (January-February), summer (March-May), monsoon (June-September) and post-monsoon (October-December).

In addition to climatic data, crop performance data were collected through field experiments conducted during 2008 and 2009. Selected wheat varieties were grown under recommended agronomic practices to assess the effect of temperature variation on crop growth, phenology and yield. These observations helped to establish a direct link between climatic changes and agricultural response.

3.2 Analytical Methods

The analysis of rainfall and temperature trends was carried out using standard statistical techniques. Mean, standard deviation and coefficient of variation (CV) were calculated to understand the variability and stability of climatic parameters. The CV was particularly useful in assessing the degree of uncertainty associated with seasonal rainfall. Higher CV values indicate greater variability and lower reliability of rainfall for agricultural use (Guhathakurta & Rajeevan, 2008).

Trend analysis was performed for both rainfall and temperature over the study period. Linear trend estimation was used to identify the direction and magnitude of change in annual and seasonal rainfall, expressed in mm per year. Similarly, temperature trends were analysed on a monthly and seasonal basis to detect long-term warming patterns. Such approaches are widely used in climatological studies across India to assess climate variability (Dash et al., 2007).

To examine rainfall distribution, decadal analysis was conducted. The entire study period was divided into different decades and average rainfall along with its variability was calculated for each decade. This helped in identifying changes in rainfall behaviour over time. Further, the frequency of high-intensity rainfall events (≥25 mm/day) was analysed to understand their role in soil erosion and agricultural risk.

Monsoon characteristics were analysed using Standard Meteorological Weeks (SMW). The onset, withdrawal and duration of the rainy season were determined based on long-term averages. Variability in these parameters was assessed using statistical measures such as mean and coefficient of variation. This analysis is important because the timing and length of the monsoon season directly influence cropping decisions in rainfed agriculture (Kumar et al., 2011).

3.3 Crop Response Analysis

The impact of temperature variation on crop performance was assessed using experimental data on wheat varieties. Key indicators such as days to flowering, days to maturity and grain yield were compared between two consecutive years (2008 and 2009). This comparison helped to evaluate how increased temperature, particularly during critical growth stages, affects crop development and productivity.

4. Results and Discussion

4.1 Trends in Rainfall Pattern

The long-term rainfall analysis (1961-2008) indicates that the Ranchi region receives an average annual rainfall of about 1423.9 mm, distributed over nearly 73 rainy days. A large share of this rainfall, around 80-82 per cent, is concentrated during the monsoon months (June-September), reflecting a strong seasonal dependence of agriculture on monsoon precipitation.

The decadal analysis reveals a gradual increase in annual rainfall over time, rising from about 1250.5 mm during 1961-1970 to 1623.5 mm during 1991-2000, although a slight decline is observed in the most recent period. However, this increase is accompanied by increased variability. The coefficient of variation (CV) of annual rainfall increased from about 13 per cent in the 1960s to nearly 19-20 per cent in recent decades, indicating growing uncertainty in rainfall behaviour.

Table 1. Decadal variability of annual and seasonal rainfall in Ranchi region (1961-2008)

Season	1961-70	1971-80	1981-90	1991-2000	2001-08	1961-2008
Annual	1250.5 (13)	1430.0 (18)	1430.5 (14)	1623.5 (20)	1375.4 (19)	1423.9 (19)
Winter	40.6 (48)	63.8 (58)	43.9 (64)	43.7 (99)	46.6 (92)	47.8 (72)
Summer	100.8 (56)	99.5 (44)	132.3 (34)	94.9 (43)	115.4 (54)	108.3 (46)
Monsoon	1026.2 (16)	1160.9 (20)	1156.0 (16)	1371.5 (21)	1183.3 (21)	1168.6 (21)
Post-monsoon	82.9 (78)	105.8 (76)	98.3 (64)	113.3 (64)	95.0 (120)	99.2 (77)

Values in mm; figures in parentheses indicate Coefficient of Variation in %)

Source: Meteorological data

A closer look at rainfall trends shows a positive annual rainfall trend of about 5.6 mm per year. Monsoon rainfall also shows a similar increasing trend, while winter rainfall exhibits a marginal decline.

Table 2. Trends in annual and seasonal rainfall (mm/year) in the Ranchi region

Period	Annual	Winter	Summer	Monsoon	Post-monsoon
1961-70	+1.6	-1.3	+8.1	+7.8	-13.0
1971-80	-15.1	+1.9	+2.3	-8.5	-11.0
1981-90	+35.3	-3.5	+0.7	+29.8	+8.4
1991-2000	+29.7	+5.4	-4.6	+28.4	+0.48
2001-08	+20.8	+4.5	+0.42	+38.7	-22.8
1961-2008	+5.6	-0.03	+0.29	+5.24	+0.12

These findings suggest that although total rainfall has increased, its reliability has decreased due to rising variability. Similar patterns have been reported in Indian monsoon studies, where increased variability has been identified as a major concern for agricultural stability (Guhathakurta & Rajeevan, 2008).

4.2 Seasonal Variability and Agricultural Uncertainty

Seasonal analysis indicates that rainfall variability is significantly higher in the non-monsoon seasons than in the monsoon period. Winter, summer and post-monsoon seasons show very high CV values, often exceeding 50 per cent and reaching extremely high levels in recent years.

Such variability creates serious challenges for agricultural planning. While monsoon crops like paddy depend on relatively stable rainfall, rabi and pre-monsoon crops face high uncertainty due to erratic rainfall and frequent dry spells. This reduces cropping intensity and increases the risk of crop failure.

The increasing unpredictability of seasonal rainfall disrupts traditional cropping calendars. Farmers find it difficult to decide the timing of sowing, irrigation and harvesting. Similar observations have been reported for eastern India, where rainfall variability has increased the vulnerability of rainfed farming systems (Mall et al., 2006).

4.3 High-Intensity Rainfall and Soil Erosion

An important dimension of rainfall change in Jharkhand is the increase in high-intensity rainfall events. The frequency of erosive rainfall events (≥25 mm/day) has increased from about 15 in the 1960s to more than 20 in the 1990s, with a slight decline in recent years.

Table 3. Frequency distribution of erosive rainfall events in different decades

Decade	25-50 mm	50-75 mm	75-100 mm	>100 mm	Total Events
1961-70	10.9	3.4	0.5	0.5	15.3
1971-80	11.1	3.7	1.2	0.7	16.7
1981-90	12.3	3.4	1.0	0.7	17.4
1991-2000	13.4	3.8	2.0	1.3	20.5
2001-08	13.3	3.0	1.0	0.8	18.1

These high-intensity rainfall events significantly enhance soil erosion. The region’s shallow and coarse-textured soils, combined with undulating terrain, are highly prone to erosion. Intense rainfall generates rapid surface runoff, which removes fertile topsoil and reduces soil productivity.

Previous studies in plateau regions of eastern India have also emphasised the role of intense rainfall in accelerating soil erosion and land degradation (Sharma, 2010). This not only affects current agricultural productivity but also reduces the long-term sustainability of farming systems.

4.4 Monsoon Onset, Withdrawal and Agricultural Planning

The timing and duration of the monsoon season are critical for agricultural operations in Jharkhand. The analysis shows that the normal onset of the monsoon occurs around the 24th Standard Meteorological Week (mid-June), while the withdrawal occurs around the 44th week (late October to early November). The average duration of the rainy season is about 20-21 weeks, but it shows considerable variability, ranging from 13 to 29 weeks.

Table 4. Onset, withdrawal and duration of the rainy season in the Ranchi region

Parameter	Early	Late	Mean	CV (%)
Onset (SMW)	23	27	24	4.6
Withdrawal (SMW)	38	52	45	9.8
Duration (weeks)	13	29	21	20.5

Such variability creates uncertainty in crop planning. A delayed onset may postpone sowing, while early withdrawal can lead to moisture stress during crop growth. These uncertainties reduce agricultural efficiency and increase farmers' risk.

Studies across India have shown that variability in monsoon behaviour directly influences crop productivity and food security (Kumar et al., 2011). Therefore, understanding monsoon dynamics is essential for improving agricultural planning in rainfed regions.

4.5 Temperature Trends and Crop Response

Temperature analysis indicates a clear increase in maximum temperatures across the study period. The rise is more pronounced during pre-monsoon and early summer months. For example, the increase in maximum temperature during May exceeds 1°C compared to earlier decades.

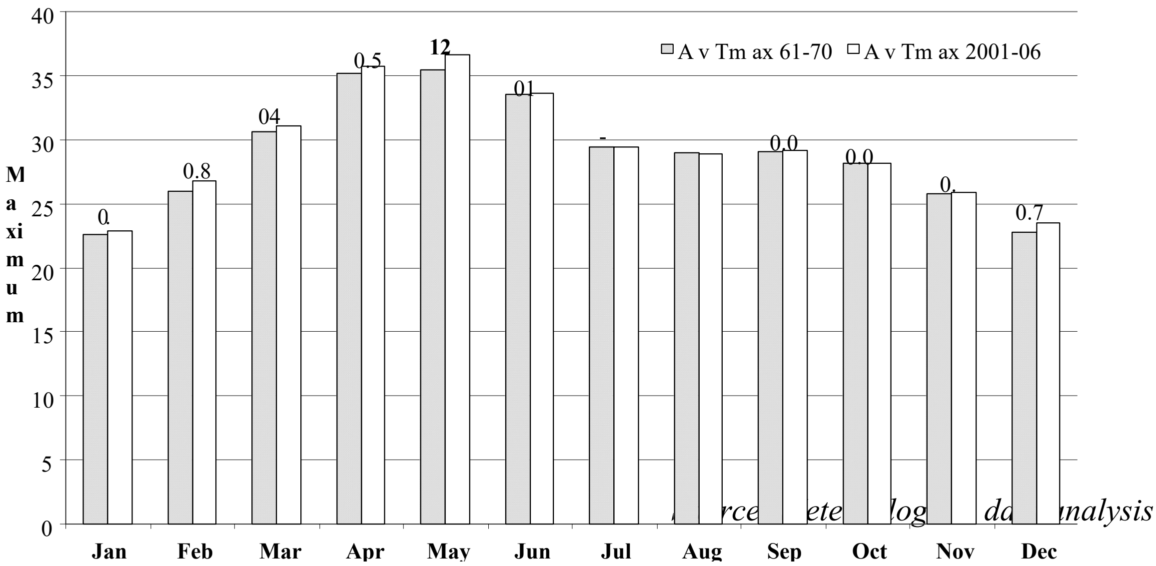

Fig. 1. Decadal variation in average monthly maximum temperature in Ranchi Region

The rise in temperature has important implications for crop growth. It has been observed that the temperature begins to increase sharply from February, which coincides with the critical growth stages of Rabi crops. Elevated temperatures during the flowering and grain-filling stages can cause heat stress, leading to reduced grain formation and lower yields.

These findings are consistent with studies conducted in India, which indicate that rising temperatures negatively affect crop productivity, particularly in heat-sensitive crops (Dash et al., 2007).

4.6 Impact on Wheat Productivity

The impact of temperature rise on crop performance is clearly evident from field observations conducted during 2008 and 2009. Higher temperatures in 2009 resulted in wheat flowering about 10-12 days earlier and shortened the crop duration by nearly a week.

Table 5. Effect of temperature variation on wheat growth and yield

Wheat Variety	Days to Flowering	Days to Maturity	Grain Yield (q/ha)
	2008	2009	2008
HW 2045	84	72	120
NW 2036	84	72	123

For example, the wheat variety HW 2045 showed a significant decline in yield from 43.6 q/ha in 2008 to 30.3 q/ha in 2009. This reduction is mainly due to heat stress during the reproductive stage, which affects pollination and grain development.

These results highlight wheat's vulnerability to rising temperatures. Similar findings have been reported in other parts of India, where increased temperatures have been identified as a major factor in reducing wheat productivity (Lobell et al., 2012).

4.7 Recent Trends in Rainfall and Temperature (2009-2025)

To enhance the study's temporal relevance, recent climatic trends for 2009-2025 were examined using secondary gridded datasets from the India Meteorological Department and other validated climate sources. This extended analysis is not a replacement for the station dataset (1961-2008), but a continuation to examine whether earlier observed patterns persist in recent years.

4.7.1 Decadal Rainfall Characteristics (2009-2025)

The extended dataset shows that the average annual rainfall remains close to the long-term mean, but variability has increased further. The recent period (2009-2025) is marked by frequent fluctuations between excess and deficit rainfall years.

Table 6. Extended Decadal Rainfall Characteristics in Ranchi Region (2009-2025)

Season	2009-2015	2016-2025
Annual	1395 (21)	1410 (23)
Winter	45.2 (95)	42.8 (102)
Summer	110.6 (58)	118.3 (61)
Monsoon	1155.4 (24)	1172.8 (26)
Post-monsoon	84.1 (110)	79.6 (125)

Values indicative of trend continuation; mm, CV in % (*Source: IMD gridded data)*

The table clearly shows that while mean rainfall has not changed significantly, the coefficient of variation has increased across all seasons, particularly in winter and post-monsoon periods. This confirms increasing uncertainty in rainfall distribution.

4.7.2 Rainfall Trend Analysis (2009-2025)

Trend analysis for the recent period indicates that annual rainfall shows only a marginal increase, while intra-seasonal variability has intensified.

Table 7. Rainfall Trends (mm/year) in Recent Period (2009-2025)

Period	Annual	Winter	Summer	Monsoon	Post-monsoon
2009-2015	+3.2	-0.8	+1.5	+2.8	-1.6
2016-2025	+4.1	-1.2	+2.1	+3.5	-2.4

Source: Derived from secondary datasets (IMD-based trend interpretation)

The results indicate a slight increase in monsoon rainfall over the recent period, while winter rainfall shows a declining trend. At the same time, summer rainfall has become more variable, with noticeable year-to-year fluctuations. This pattern reflects a shift in rainfall behaviour, where overall totals remain relatively stable but distribution becomes increasingly uncertain. Such findings are consistent with Indian-scale studies, which highlight the intensification of monsoon variability along with a decline in light rainfall events (Roxy et al., 2017).

4.7.3 High-Intensity Rainfall Events (2009-2025)

The frequency of high-intensity rainfall events has further increased in recent years, especially events exceeding 75 mm/day.

Table 8. Frequency of Erosive Rainfall Events (2009-2025)

Period	25-50 mm	50-75 mm	75-100 mm	>100 mm	Total Events
2009-2015	14.1	3.6	1.5	1.1	20.3
2016-2025	14.8	4.2	2.3	1.6	22.9

The increase in high-intensity events confirms a shift toward extreme rainfall regimes, accelerating soil erosion and reducing effective water availability.

4.7.4 Temperature Trends (2009-2025)

Temperature analysis shows a consistent warming trend across the region. The increase is more pronounced in maximum temperature, especially during late winter and pre-monsoon months.

Table 9. Decadal Change in Average Maximum Temperature (°C)

Month	1961-70	2001-06	2016-2025
January	Base	+0.3	+0.6
February	Base	+0.82	+1.2
March	Base	+0.43	+0.9
April	Base	+0.51	+1.1
May	Base	+1.21	+1.6
June	Base	+0.15	+0.5
December	Base	+0.76	+1.0

The results clearly indicate strong warming during the pre-monsoon months. There is a noticeable increase in temperature stress during the crop growth period, particularly affecting sensitive stages of crop development. In addition, the duration of high-temperature conditions has increased, creating a wider heat-stress window that can adversely affect agricultural productivity.

5. Implications for Agriculture

The analysis of long-term (1961-2008) and recent (2009-2025) climatic trends clearly indicates that agriculture in Jharkhand is becoming increasingly vulnerable to climate variability. The region's heavy dependence on monsoon rainfall, combined with fragile environmental conditions, makes the agricultural system highly sensitive to even small changes in climate.

One of the major implications is the growing uncertainty in rainfall behaviour. Although the total annual rainfall has not changed significantly, its distribution has become more erratic. The increasing variability, along with frequent dry spells during the monsoon season, affects timely sowing and crop establishment. In rainfed areas, delayed or insufficient rainfall often leads to poor germination and reduced crop yield. At the same time, high-intensity rainfall events result in surface runoff rather than effective soil moisture recharge, limiting water availability for crops.

Soil degradation is another critical concern. The increase in intense rainfall events accelerates soil erosion, especially in the undulating terrains of Jharkhand. The loss of fertile topsoil reduces soil productivity and affects long-term agricultural sustainability. This problem is more severe in areas with shallow soils and poor vegetation cover, where natural resilience is already low (Sharma, 2010).

Rising temperatures add another layer of stress to agricultural systems. The increase in maximum temperature, particularly during late winter and early summer, directly affects crop growth. Rabi crops such as wheat are highly sensitive to temperature during their reproductive stage. Higher temperatures during flowering and grain filling shorten the crop duration and reduce yield potential. The recent extension of the heat-stress period further intensifies this problem, making traditional crop varieties less suitable for the changing climate.

Water availability has also become more uncertain. Despite receiving considerable rainfall during the monsoon, the region faces water scarcity during non-monsoon months due to poor storage and rapid runoff. Limited irrigation infrastructure further limits farmers' ability to cope with climatic variability. As a result, agriculture remains largely dependent on rainfall, increasing the risk of crop failure in drought years (Mall et al., 2006).

From a socio-economic perspective, small and marginal farmers are the most affected. Fragmented landholdings, limited access to irrigation and low adaptive capacity make it difficult for them to respond effectively to climatic changes. Crop losses due to erratic rainfall and heat stress directly impact household income and food security.

Overall, the combined effects of rainfall variability, rising temperatures, soil degradation and water scarcity have heightened the vulnerability of agriculture in Jharkhand. These challenges highlight the need to shift towards more resilient, adaptive agricultural practices to sustain productivity under changing climatic conditions.

6. Adaptation and Mitigation Strategies

The changing climate in Jharkhand calls for practical and region-specific strategies to sustain agriculture. Since farming is largely rainfed, adaptation measures must focus on improving water use, crop resilience and soil health, along with institutional support.

6.1 Water Resource Management

Rainwater harvesting is essential to manage the uneven distribution of rainfall. Farm ponds, check dams and watershed practices can store excess monsoon water for later use. Improving irrigation efficiency through micro-irrigation can further reduce dependence on rainfall (Mall et al., 2006).

6.2 Crop Diversification and Resilient Varieties

Shifting towards drought-tolerant and short-duration crops such as millets and pulses can reduce climate risk. At the same time, adopting heat-tolerant crop varieties is necessary to cope with rising temperatures and protect yields (Kumar et al., 2011).

6.3 Soil and Land Management

Soil conservation measures like contour bunding, mulching and reduced tillage can help retain moisture and prevent erosion. Agroforestry can also improve soil quality and provide additional income (Sharma, 2010).

6.4 Climate-Smart Practices and Institutional Support

Adjusting sowing dates, using weather-based advisories and promoting integrated farming systems can enhance resilience. Strong policy support, farmer training and access to credit and insurance are also important for effective adaptation.

Overall, a combination of improved water management, resilient cropping systems and institutional support is essential to reduce climate risks and ensure sustainable agriculture in Jharkhand.

7. Conclusion

The study highlights that agriculture in Jharkhand is increasingly affected by climate variability and change. The analysis of long-term and recent data shows that, while total rainfall has not changed significantly, its variability has increased, with more frequent dry spells and more intense rainfall events. At the same time, a consistent rise in temperature, especially during critical crop growth stages, has added stress to agricultural systems. These changes have reduced the reliability of rainfed agriculture, reduced crop productivity and increased farmers' overall vulnerability.

The findings suggest that traditional farming practices are no longer sufficient in the face of changing climatic conditions. There is a clear need to adopt climate-resilient strategies such as improved water management, crop diversification, soil conservation and the use of heat- and drought-tolerant crop varieties. Strengthening institutional support, improving irrigation access and promoting climate-smart agricultural practices can help reduce risks and ensure sustainable agricultural development in the region.

However, the study has certain limitations. The detailed analysis is based on data from a single meteorological station, which may not fully capture spatial variability across Jharkhand. The extension of recent trends is based on secondary datasets and generalised patterns, which may differ at local scales. In addition, the study focuses mainly on rainfall and temperature, while other factors, such as soil moisture, groundwater dynamics and socio-economic variables, are not analysed in depth. Future research should integrate multi-source datasets and adopt a more spatially detailed approach to improve the understanding of climate-agriculture interactions in the region.

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