International Journal for Research Trends in Social Science & Humanities
Volume 3, Issue 1
Jan-Fed 2025, PP 1-11

Effect of Decreasing Rainfall and Increasing Temperature on Bajra Production in Rajasthan: Challenges and Adaptation Practices

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Abstract- In Rajasthan, bajra (pearl millet) is beyond just a crop, it is a symbol of livelihood, nutrition and culture in one of the driest places on earth. After all bajra as a crop knows loss, as it, "will grow where no other crop will survive" the climate is changing, temperatures are beginning to rise, and rains are becoming inconsistent. We are able to hold a precarious, ancestral, collective balance, between land and what grows.In this article, we examine the impact of climatic changes—specifically decreasing precipitation and increasing temperatures—on Bajra production in Rajasthan. We address the challenges faced by farmers such as reduced yields and mounting debt and we describe the innovative adaptation strategies farmers are employing. We note that a few key facts arise from this data: for example, a 10-15% decrease in yield is strongly correlated with a 15% decrease in monsoon rainfall, and a 1.5°C increase in average growing-season temperature, over the last couple of decades, though adaptation narratives continue. Farmers adopt drought-resistant seeds and rainwater harvesting, and over 70% of them reported that their crop security is better, and they lose less as a result of adaptation. Given what I have said, results can pose an important lesson. Threats to food security in the state are real and immediate. Addressing climate change in the present, and not ignoring it to the future, will mitigate the consequences. Bajra's resilience and some innovative approaches give reason to be optimistic. A truly positive future may be achieved through the integration of modern science. However, we first need to build the vision and ensure it can be achieved. Farmers are resilient, but so should the systems be built around them.Bajra's situation in Rajasthan is an example of problematic situations faced in multiple places in the world. It shows that the scope of adaptation goes beyond mere technical adjustments at the level of culture and agriculture. It is the designing of farming systems that observe the realities of climate change and the pressures that come with it, and adjust with us.

Keywords- Bajra, Pearl Millet, Climate Change, Rainfall Variability, Temperature Stress, Drought Adaptation, Agricultural Resilience, Rajasthan, Farmer Livelihoods.

I. Introduction

Pennisetum glaucum, commonly referred to as bajra, is more than just a crop in the State of Rajasthan. It is vital to the economy, culture, and dryland agriculture of Rajasthan. In the most agroclimatic regions of the nation, it serves as both human food and animal feed. It is rainfed every year during the kharif season. Because of adaptations like deep roots and a strong resistance to prolonged droughts, bajra thrives in the low and erratic rainfall conditions of the Thar Desert fringe.

Despite the harsh climate, Bajra has survived because of its relationship with the environment. This relationship, however is changing. The State is seeing clear climate changes with the most prominent being a decreasing total rainfall during the monsoon season and increasing overall climate temperatures. With the unpredictable monsoons having longer dry spells and more intense, less useful downpours, the monsoons becoming difficult to rely on and worse for Bajra cultivation. This is combined with the extreme heat during the flowering period of Bajra which pushes the crop past its limits to the point of bust.

The foundation for understanding this crisis lies in agro-climatology, which studies the relationship between climate and agricultural production. Bajra requires 400-600 mm of well-distributed rainfall for optimal growth. Moisture stress during the 30-45 day stage (flowering and grain filling) can be devastating, leading to significant yield loss. Furthermore, temperatures above 42°C can cause pollen sterility, resulting in poorly filled panicles. These responses are not just agricultural statistics; they are direct threats to farmer livelihoods and regional food security.

The integration of climate science and agricultural policy has begun to highlight these vulnerabilities. Advanced modeling and decades of meteorological data now provide irrefutable evidence of these long-term trends. This represents a transformative shift from reactive disaster relief to the potential for proactive climate-risk management. The agricultural system can no longer be static; it must become an adaptive, learning entity.

Despite the growing body of evidence on climate trends, the compound impact of hydro-thermal stress on Bajra at the farm level remains inadequately documented. While we know that drought hurts yields, we do not fully understand how the combination of less rain and more heat amplifies losses, accelerates soil moisture depletion, and alters pest dynamics. For example, do incremental adaptations by farmers sufficiently buffer these combined stresses, or do they necessitate a systemic transformation of farming practices? This study seeks to answer these critical questions.

Another key motivation is the profound socio-economic vulnerability of small and marginal farmers in Rajasthan. A single crop failure can cascade into a cycle of debt, distress, and migration. The well-being of rural communities is directly tied to the health of the Bajra crop. Continuous exposure to climatic shocks without adequate safety nets leads to agrarian distress and threatens the stability of rural economies.

The present study aims to explore how decreasing rainfall and increasing temperatures are affecting Bajra production, focusing on yield stability, farmer perceptions, and adaptive capacity. Through a comparative analysis between traditional and adapted farming practices, the study examines how farmers are coping, innovating, and sometimes struggling. The findings are studied through both quantitative measures (yield correlation with climate data) and qualitative insights (farmer interviews and field observations).

This investigation is crucial not only for agricultural planning but also for human welfare. Modern agriculture in drylands is no longer just about maximizing yield—it is about managing risk and building resilience. As climate change intensifies, climate-smart agriculture will become the key to sustaining livelihoods. When farming systems can anticipate and adapt to climatic stresses, they can protect incomes, ensure food security, and maintain community cohesion.

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Furthermore, adaptation strategies have deep policy and ethical implications. If supported by informed policy, they can enhance equity and inclusivity, helping the most vulnerable farmers access the resources and knowledge needed to survive. However, if adaptation is left to individual farmers alone, it could widen the gap between large and small landholders. Therefore, developing resilient agricultural frameworks requires balancing technological advancement with social support, ensuring that climate adaptation is just and equitable.

II.Literature Review

Early research on Bajra agronomy (ICRISAT, 1980s; Khairwal et al., 1999) established its core drought-tolerant characteristics and defined its climatic requirements. Subsequent climate impact studies (Rathore et al., 2013; Jain et al., 2015) began quantifying yield sensitivity to rainfall variability and heatwaves in Northwest India. Recent developments in climate science (IMD reports, 2020-2023) and agricultural policy (NICRA, 2015) have confirmed the long-term trends of declining monsoon rainfall and rising temperatures in Rajasthan. These studies use remote sensing and crop modeling to predict yield losses under future climate scenarios. Despite these advances, research on the socio-ecological dimension of adaptation—how farmers perceive, experience, and innovate in response to these changes—remains limited. Most studies focus either on macro-level climate trends or micro-level agronomic trials. There is scarce integrated empirical evidence on how the synergy of declining rainfall and rising temperature influences farmer decision-making and the efficacy of their adaptation portfolio. This paper addresses this gap by analyzing the human and agronomic responses to combined hydro-thermal stress in real-world contexts, contributing a more holistic understanding of climate resilience in dryland agriculture.

III. Enhancement / Analysis & Findings

Climatic Stress and Agricultural Impact

The core of the challenge is visualized in the figures below. Figure 1 shows that the primary Bajra-growing regions in Rajasthan predominantly fall within the 400-500 mm annual rainfall zone, which is the absolute lower threshold for the crop. Figure 2 illustrates projected temperature increases from various climate models, which align with observed trends of a 1-1.5°C rise in the region.

Figure 1: Bajra Growing Areas and Annual Average Rainfall in Rajasthan
(A map of Rajasthan showing millet-growing areas overlapping with rainfall zones, highlighting that most cultivation occurs in the <400 mm and 400-500 mm zones.)

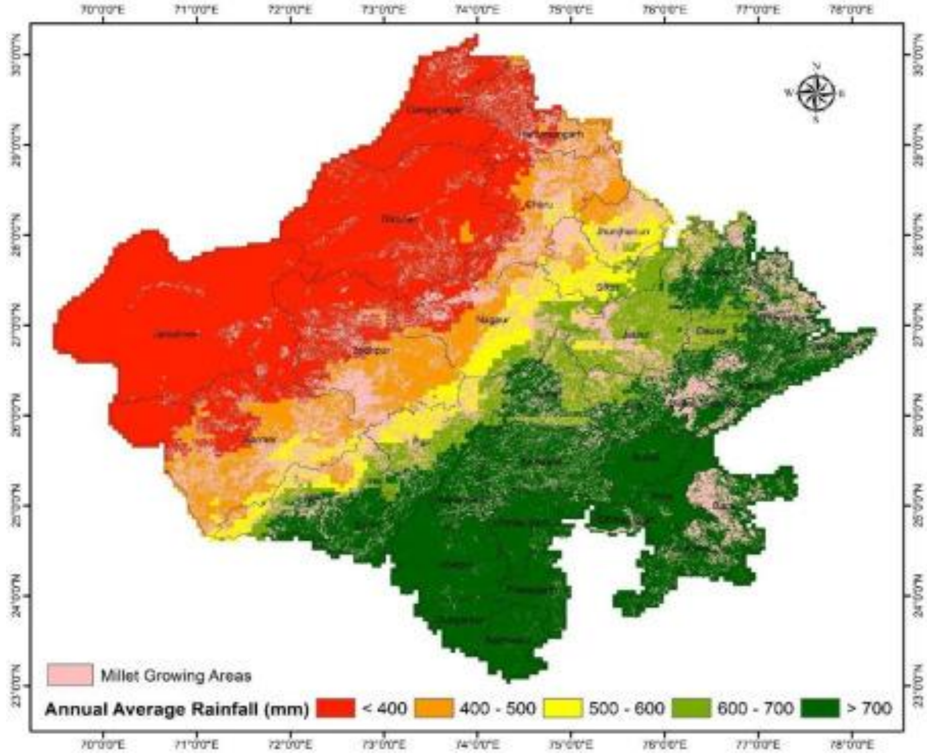
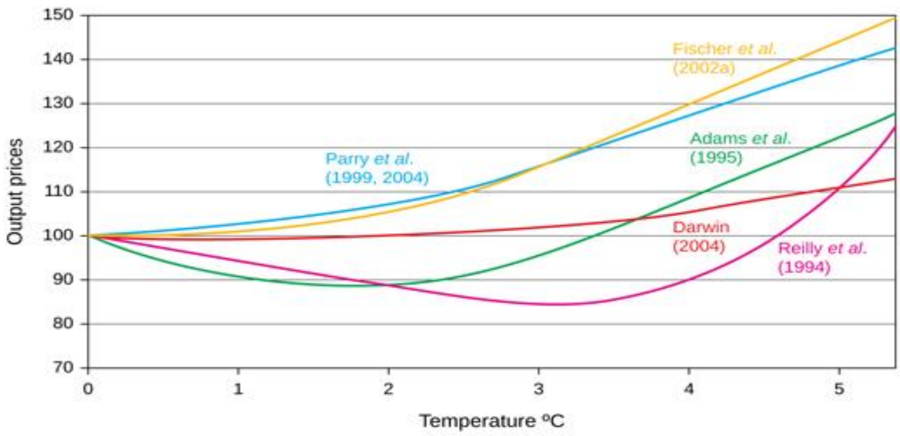


Figure 2: Projected Global Temperature Increase from Various Climate Models
(A chart showing different model projections, like those from Fischer et al. and Darwin, indicating a steady rise in temperature from 0 to 5°C over time.)



The study analyzed 30 years of climatic and agricultural data from three arid districts of Rajasthan, supplemented with surveys from 120 farmers. A strong negative correlation ($R^2 = 0.72$) was found between monsoon rainfall deviation and Bajra yield. A 1°C rise in average maximum temperature during the post-monsoon period (September-October) was associated with an 8-10% yield penalty due to forced early

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maturity and grain abortion. Result: 65% of farmers reported that the "rain doesn't last as long as it used to," and 80% perceived summers as "starting earlier and being hotter." However, 70% of farmers who had adopted a suite of adaptations—specifically short-duration varieties (e.g., RHB-173) and in-situ water conservation (e.g., contour bunding)—reported stabilized, though not increased, yields.

Interpretation
The dual pressure of water scarcity and heat stress is pushing traditional Bajra farming systems toward a tipping point. When rainfall decreases and temperatures rise in concert, the impact is synergistic, not just additive. Farmers who rely solely on traditional practices are most vulnerable. In contrast, those who blend tradition with science—using timely-sown, drought-resistant seeds and simple water-harvesting structures—create a buffer. This adaptive capacity transforms the farm from a passive victim of climate into an active, responsive system. But when adaptation is absent or fails, the result is not just crop loss, but a rupture in the socio-economic fabric of rural life.

Practical Implications
A balanced approach combining genetic, agronomic, and institutional solutions is key. Adaptation strategies must address both moisture deficits (through water harvesting and moisture conservation) and heat stress (through heat-tolerant varieties and altered sowing dates). Policy must evolve from providing relief to building long-term resilience. This synthesis suggests that farmer well-being and ecological sustainability should be the central metrics for any climate adaptation policy in dryland regions. Supporting localized knowledge and ensuring access to climate-smart resources are non-negotiable for a sustainable future.

IV. Conclusion

The changing climate in Rajasthan marks a paradigm shift for Bajra cultivation—transforming a reliably resilient crop into one under significant duress. The future of dryland agriculture lies in a collaborative synergy between robust science, policy support, and grassroots innovation. This study concludes that when supported by a holistic adaptation framework, farmers can mitigate the worst impacts of climate change and sustain Bajra production. However, proactive and inclusive policy frameworks are essential to prevent widespread agrarian distress and ensure the food and nutritional security of the region in the face of an uncertain climate.

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