Agricultural Vulnerability and Risk to Climatic Threats: Insights from the State of West Bengal, India

Abstract

Climate change is a significant global challenge that affects ecosystems, food systems, and livelihoods worldwide. In India, where nearly half the population depends on agriculture, even subtle shifts in climatic parameters can have profound socioeconomic impacts. Despite India's agroclimatic diversity, most studies focus on a few climatic parameters (typically temperature and rainfall), often overlooking how multiple dimensions, such as climate-induced hazards, exposure, sensitivity, and adaptive capacity, interact to shape agricultural vulnerability and risk at finer spatial scales. West Bengal, with its diverse physiography, agroclimatic regimes, and socioeconomic conditions, offers an ideal setting for analyzing climate dynamics, agricultural risk, and identifying evidence-based adaptation pathways. To accomplish this, the present study examines long-term daily climatic data (1951–2020) for five key parameters: maximum and minimum temperatures, precipitation, reference evapotranspiration, and solar radiation across the Kharif (Monsoon), Rabi (Winter), and Zaid (Summer) cropping seasons. Climate dynamics were characterized using fractal-based measures of variability and persistence, along with analyses of trend and magnitude of change. A context-specific indicator framework, representing hazard, exposure, sensitivity, and adaptive capacity, was developed and integrated using both the data-driven objective and expert-informed subjective methods to construct a composite risk index. Results show widespread warming, increasing evaporative demand, and rising seasonal variability. Western and southwestern Gangetic West Bengal exhibit high variability and drying trends, whereas parts of Sub-Himalayan West Bengal are facing emerging seasonal stress. The districts of Purulia, Paschim Medinipur, and Darjeeling have emerged as risk hotspots, whereas several eastern and central districts in Gangetic West Bengal display moderate to low risk levels. While component indices demonstrate robustness across methods, the overall risk is dynamic and sensitive to minor changes in risk components. Adaptation pathways were derived from district-level cross-model risk transitions, directing incremental interventions in low-risk areas and systemic or transformational measures in moderate- and high-risk districts. Overall, this study provides actionable evidence for spatially differentiated and climate-resilient agricultural strategies in West Bengal. The findings align with India's National and State Action Plans on Climate Change and global Sustainable Development Goals, particularly SDG 2 (Zero Hunger) and SDG 13 (Climate Action).

Keywords: Climate Dynamics, Agriculture, Indicators, Vulnerability, Risk, Adaptation Pathways, West Bengal