

Statistical Forecasting Rainfall Model for the Distribution of Agricultural Production and Disaster Preparedness

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Abstract

This paper focuses the importance of accurate rainfall forecasting for agriculture, disaster preparedness, and reducing economic and human losses, mostly in the data scarce. The issues had arisen in the 81st United Nations General Assembly in New York in September 2026. The August 26, 2026, flood was given as a warning from the Himalayas to the world about accelerating climate risks and global greenhouse-gas emissions with deaths (1,453 & 6,000+ missing) in Nepal and 3.5 billion people affected globally. The link between climate predictions and agriculture highlights the crucial role of accurate forecasts in shaping the future of food security. The study proposes the application of advanced machine learning (ML) algorithms, including random forest (RF), support vector regression (SVR), artificial neural network (ANN), and Markov Chain model. The stochastic model to analyze and predict the distributional patterns of annual rainfall has a first-order reliance on discrete state and time. X_t denote the rainfall state at time t , taking values from a finite state space $S = \{s_1, s_2, \dots, s_n\}$. The model assumes the Markov property: $P(X_{t+1} = j \mid X_t = i, X_{t-1}, \dots, X_0) = P(X_{t+1} = j \mid X_t = i) = p_{ij}$. The long-run behavior of rainfall distribution is examined through the stationary distribution π , satisfying: $\pi P = \pi$, $\sum \pi_i = 1$ and parameters are estimated using maximum likelihood estimation. Model validation is performed using goodness-of-fit tests and predictive accuracy measures and reveal persistent rainfall patterns and probabilistic transitions between drought, normal, and wet years, which are critical for agricultural planning and risk management. This Markov chain model provides a robust probabilistic tool for forecasting rainfall regimes and supports decision-making in crop selection, irrigation planning, and climate adaptation strategies. The model was applied to the analysis of Kathmandu's yearly rainfall meteorological data from six stations at different elevations from 2005–2023. The findings, 14% of the yearly rainfall will be low, 34% will be moderate and well-spread, 47% will be high, and 5% will be moderate and poorly dispersed. Farmers and the government might utilize the model's information about rainfall in connection to crop cultivation to design strategies for high crop output in the surrounding area. These advanced techniques hold the potential to significantly improve the accuracy of rainfall prediction, offering hope for more reliable forecasts.

Keywords: Markov Chain, Rainfall, Crop Production, Transition Probability, Stochastic Modeling, Stationary Distribution