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Stochastic Processes for Water-Risk Allocation in Rwanda: Asymptotic Analysis and Identifiability Checks

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Abstract

Water resource allocation in Rwanda is critical for sustainable development and economic growth. Stochastic models can provide a probabilistic framework to address uncertainties inherent in water resources management. We propose a stochastic differential equation model to represent the dynamics of water availability. The model incorporates rainfall data as a stochastic process driven by Gaussian white noise. We perform asymptotic analysis to understand long-term behaviour and identifiability checks to ascertain parameter estimability from observed data. Our asymptotic analysis reveals that the system's mean behaviour is stable under reasonable assumptions about rainfall variability, with significant fluctuations captured by our model. Identifiability tests indicate that key parameters affecting water availability can be reliably estimated from historical data. The developed stochastic process provides a robust framework for understanding and managing Rwanda's water resources under uncertainty. The results highlight the importance of accurately modelling both deterministic and probabilistic elements in water-risk allocation. Further research should focus on validating these models with real-world data from various regions within Rwanda, particularly during different seasons to enhance their applicability and reliability. The analytical core is $\hat{\{ y \}}t = mathcal\{F\}(xt;\theta)$ with $\hat{\{\theta\}} = argmin_{\theta} L(\theta)$, and convergence is established under standard smoothness conditions.

Keywords: *Geographical Information Systems, Markov Chains, Monte Carlo Methods, Stochastic Differential Equations, Time Series Analysis, Uncertainty Quantification, Variance Reduction Techniques*

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