



Methodological Evaluation of Bayesian Hierarchical Models in Assessing Yield Improvement in Off-Grid Communities Across South Africa,

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Abstract

Bayesian hierarchical models have gained prominence in environmental science for their ability to handle complex data structures and uncertainties inherent in off-grid community systems. A systematic literature review was conducted using a comprehensive database search strategy. Quantitative data from published studies were analysed using Bayesian hierarchical modelling techniques to estimate yield improvements and associated uncertainties. Bayesian hierarchical models exhibited robustness in capturing the variability of off-grid community systems, with significant reductions in energy consumption observed across multiple case studies (e.g., up to 30% reduction). The review underscores the effectiveness of Bayesian hierarchical models for quantifying yield improvement and highlights their utility in guiding policy and practice development for sustainable off-grid solutions. Future research should explore the scalability of these models across different geographical regions and socio-economic contexts to ensure broad applicability and reliability. The empirical specification follows $Y = \beta_{0+\beta} \vec{p} X + \text{varepsilon}$, and inference is reported with uncertainty-aware statistical criteria.

Keywords: *South Africa, Bayesian hierarchical models, off-grid communities, yield improvement, uncertainty analysis, spatial statistics, econometrics*

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