



# Topological Data Analysis for Agricultural Yield Prediction in Rwanda: Monte Carlo Estimation with Variance Reduction Techniques

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## Abstract

This study addresses a current research gap in Mathematics concerning Topological Data Analysis for agricultural yield prediction in Rwanda: Monte Carlo estimation with variance reduction in Rwanda. The objective is to formulate a rigorous model, state verifiable assumptions, and derive results with direct analytical or practical implications. A theorem-driven mathematical framework was developed under explicit regularity assumptions, with stability and convergence analysis of the proposed estimator. The main results show stability of the proposed functional under bounded perturbations and convergence of the estimator to a well-defined limit, characterised by  $R(x) = \operatorname{argmin}_{\theta} L(\theta; x)$ . The findings provide a reproducible analytical basis for subsequent theoretical and applied extensions. Stakeholders should prioritise inclusive, locally grounded strategies and improve data transparency. Topological Data Analysis for agricultural yield prediction in Rwanda: Monte Carlo estimation with variance reduction, Rwanda, Africa, Mathematics, methodology paper This work contributes a formal specification, transparent assumptions, and mathematically interpretable claims.

**Keywords:** *African Geography, Topological Data Analysis, Monte Carlo Method, Variance Reduction Techniques, Random Field Theory, Spatial Statistics, Geometric Measure Theory*

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