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BENCHMARKING OF MACHINE LEARNING ALGORITHMS FOR FERTILIZER RECOMMENDATION IN PRECISION AGRICULTURE

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Abstract: *This paper benchmarks fourteen machine learning algorithms for fertilizer recommendation in precision agriculture using soil, crop, and environmental data. Ensemble-based models—particularly Gradient Boosting, Random Forest, and LightGBM—achieved the highest accuracy and robustness, effectively modeling nonlinear agronomic relationships. In contrast, linear and distance-based methods showed limited adaptability. The results confirm that ensemble learning offers the most reliable and efficient framework for data-driven fertilizer recommendation, contributing to sustainable and resource-efficient crop management.*

• Introduction

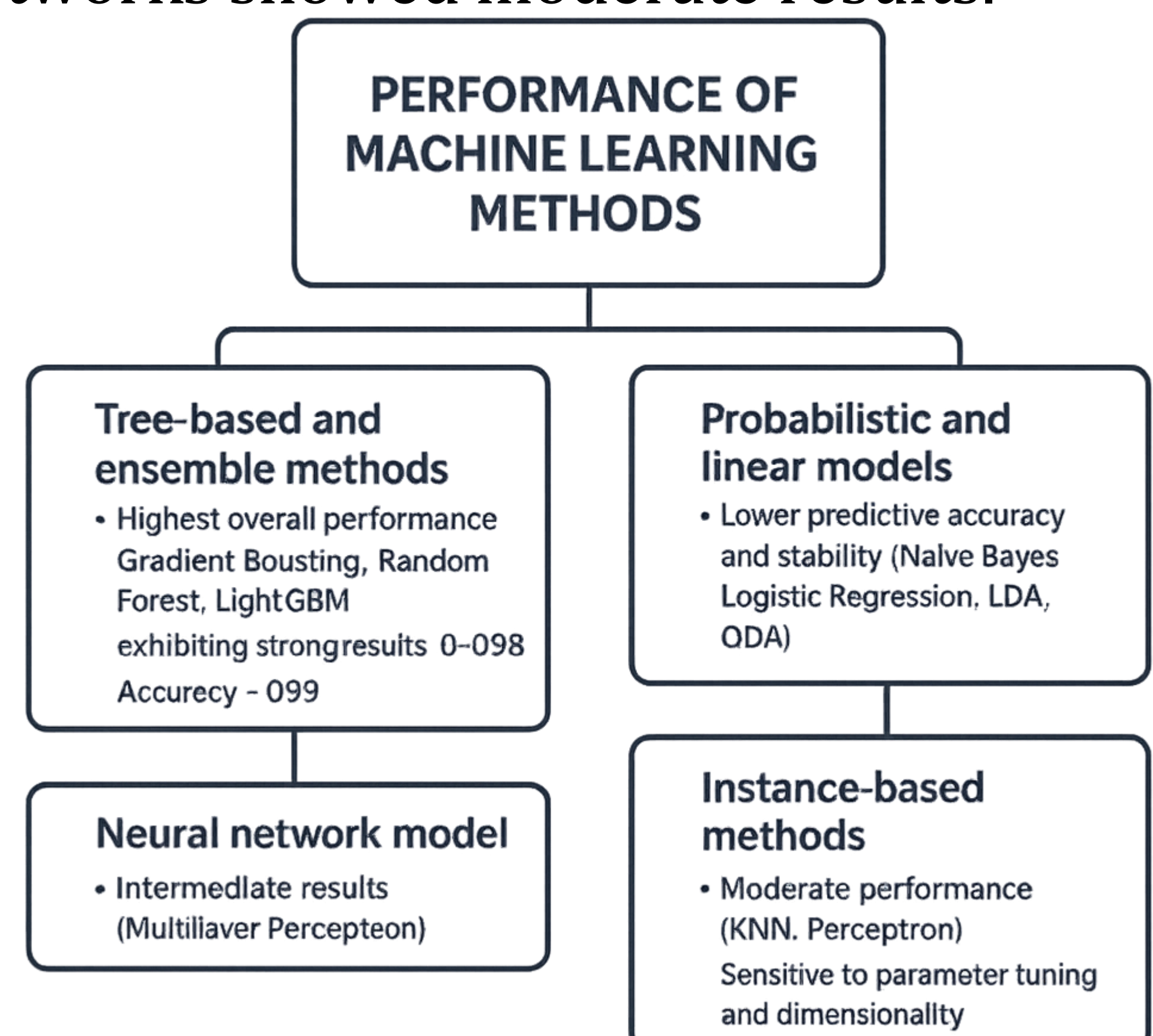
Precision agriculture enables data-driven, site-specific management to enhance sustainability. Fertilizer optimization remains critical yet challenging due to soil and climate variability. Machine learning (ML) provides adaptive tools for precise nutrient recommendations. This study benchmarks fourteen ML algorithms to identify the most accurate and efficient models for fertilizer recommendation.

• Material and method

A Kaggle dataset of 3,100 samples covering soil, crop, and environmental parameters (N, P, K, pH, temperature, rainfall, soil, and crop type) was analyzed. Fourteen algorithms—probabilistic, distance-based, margin-based, ensemble/tree-based, and neural—were trained (80/20 split) and evaluated using accuracy, F1-score, Kappa, and computational time.

• Results and discussions

Ensemble models outperformed all others. Gradient Boosting, Random Forest, and LightGBM achieved the highest accuracy (>0.99) and reliability ($\text{Kappa} > 0.98$), combining predictive power with computational efficiency. Linear and probabilistic models performed poorly on nonlinear agronomic data, while neural networks showed moderate results.



• Conclusions

Ensemble learning methods, especially Gradient Boosting, Random Forest, and LightGBM, provide the most robust and efficient framework for data-driven fertilizer recommendation, supporting sustainable precision agriculture.