# AI-Driven PSO-Optimized Hybrid Framework for Sustainable Rainfall Prediction to Support Agricultural Planning in Monsoonal Regions: A Case Study of Hyderabad

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## ABSTRACT

In Pakistan's monsoonal regions, accurate short-term precipitation forecasting is essential for climate-resilient decision-making, environmental sustainability, and agricultural biotechnology. Irrigation scheduling, crop disease prevention, fertilizer planning, and flood-aware agriculture management are all directly impacted by rainfall uncertainty. For reliable day-ahead rainfall categorization in Hyderabad, Sindh, this study suggests an AI-enabled, big-data-driven hybrid computing architecture optimized by Particle Swarm Optimization (PSO). A rich environmental dataset pertinent to sustainable climate-smart agriculture is represented by the framework's 20 heterogeneous meteorological predictors, which include temperature, humidity, wind dynamics, barometric pressure, IMERG satellite rainfall, and radiation/UV indices. The model uses a nested 5×5 TimeSeriesSplit with a 14-day temporal embargo to guarantee accurate forecasting and avoid temporal leakage, allowing for rigorous chronological examination. To lessen class imbalance without tainting test data, data preprocessing techniques include uniform scaling, mutual- information-based feature selection, and the selective use of SMOTE exclusively on training folds. Two hybrid ensembles a KNN+LR model and a PSO-optimized hybrid system—are added to the baseline classifiers (Random Forest, K-Nearest Neighbors, Logistic Regression, and Support Vector Classifier). Adaptive learning from intricate monsoonal climate patterns is made possible by PSO's joint optimization of soft-voting ensemble weights, the LR regularization parameter (C), and the KNN neighborhood size (k). Over ten temporally ordered evaluation runs (2 seeds × 5 folds), the PSO-optimized hybrid continuously outperforms all baseline approaches, obtaining ACC = 0.859, F1 = 0.869, ROC-AUC = 0.936, and PR-AUC = 0.947. This work presents a useful early-warning rainfall prediction system that helps sustainable agricultural planning and environmental monitoring in monsoonal cities like Hyderabad by combining intelligent optimization, hybrid learning, and rigorous time-aware evaluation.

**Keywords:** Agricultural Biotechnology, Rainfall, PSO optimized, Environmental Sustainability.

## METHODOLOGY

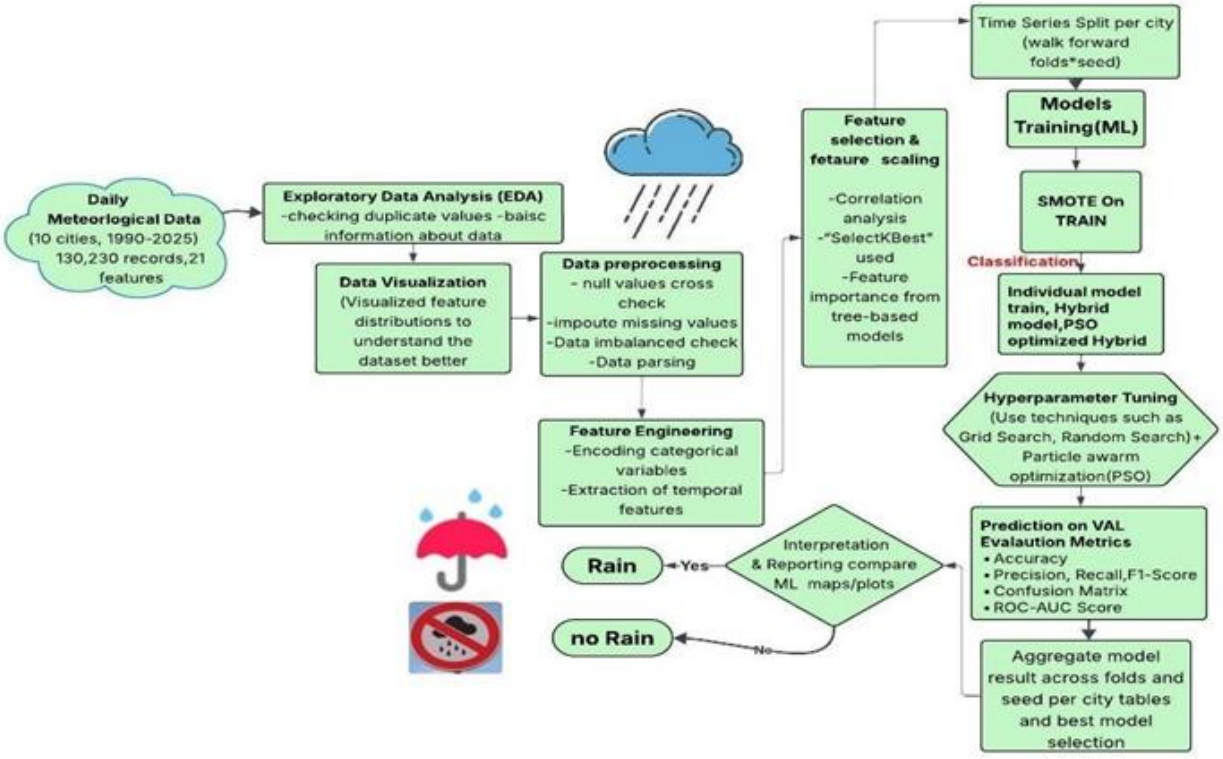


**Figure 1.** Proposed methodology.

## CONCLUSION

Using Hyderabad as a case study, this study suggests an AI-driven, PSO-optimized hybrid rainfall forecast system to help sustainable agricultural planning in monsoonal regions. Reliable day-ahead rain/no-rain forecasting is made possible by the PSO-optimized KNN–Logistic Regression hybrid model as shown in Figure **1**, which consistently outperforms baseline classifiers under stringent time-aware validation. The framework offers a scalable and deployable early-warning system for irrigation scheduling, crop risk reduction, flood preparedness, and climate-resilient agricultural planning in semi-arid and monsoonal cities by addressing temporal leakage, class imbalance, and operational relevance.

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