

ABSTRAK

Sektor pertanian di Kabupaten Sleman sangat bergantung pada ketersediaan air irigasi yang dipengaruhi langsung oleh variabilitas curah hujan akibat perubahan iklim. Pola curah hujan yang fluktuatif menyebabkan praktik irigasi tidak efisien, baik berupa pemberian air berlebihan pada musim hujan maupun kekurangan pasokan pada fase kritis pertumbuhan tanaman. Model statistik klasik seperti ARIMA memiliki keterbatasan dalam menangkap pola non-linear, sementara model *deep learning* LSTM unggul dalam menangkap dependensi temporal jangka panjang namun masih menyisakan komponen linear pada residualnya. Penelitian ini mengkaji bagaimana model *hybrid* LSTM–ARIMA dapat meningkatkan akurasi prediksi curah hujan sekaligus mendukung praktik pertanian presisi melalui estimasi kebutuhan air irigasi.

Penelitian ini menggunakan data dari BMKG Stasiun Klimatologi Sleman periode 1 Januari 2010 hingga 31 Desember 2025, mencakup variabel curah hujan (RR), temperatur rata-rata (TAVG), kelembapan udara (RH_AVG), dan lama penyinaran matahari (SS). Tahap praproses mencakup pembersihan kode error, validasi tanggal, *resampling* harian, dan imputasi nilai hilang menggunakan Regresi Linear Multivariat dengan *fallback* interpolasi waktu. Pembagian data dilakukan dengan metode *Walk-Forward Validation* berpendekatan *Rolling Window*. Arsitektur LSTM dioptimasi melalui *hyperparameter tuning* menggunakan *Grid Search* dengan evaluasi *TimeSeriesSplit*. Model *hybrid* dikembangkan menggunakan pendekatan *reversed hybrid*, di mana LSTM berperan sebagai prediktor utama dan ARIMA memodelkan komponen linear pada residual LSTM. Evaluasi kinerja menggunakan metrik RMSE dan MAE melalui 13 *fold Walk-Forward Validation*, dan hasil prediksi diintegrasikan ke dalam perhitungan neraca air berbasis metode FAO-56 Penman–Monteith untuk menghasilkan estimasi *Net Irrigation Requirement* (NIR).

Hasil penelitian menunjukkan bahwa model *hybrid* LSTM–ARIMA mencatatkan performa terbaik dengan rata-rata RMSE sebesar 13,8845 mm dan MAE sebesar 7,3360 mm, mengungguli model LSTM murni (RMSE 14,2475 mm) dan ARIMA (RMSE 15,5424 mm). Konfigurasi LSTM optimal diperoleh dengan *look-back window* 30 hari, 128 unit *hidden layer* pertama, 25 unit *hidden layer* kedua, *learning rate* 0,01, dan *batch size* 64. Pemodelan residual menggunakan ARIMA (4,0,4) dipilih berdasarkan nilai AIC terendah sebesar 47.836,82, dengan residual LSTM terkonfirmasi stasioner pada tingkat level ($d=0$). Integrasi hasil prediksi ke dalam simulasi neraca air berhasil menghasilkan rekomendasi irigasi yang adaptif, di mana sistem mampu mendeteksi kondisi surplus maupun defisit air secara otomatis dan memberikan estimasi volume air irigasi per hektar. Penelitian ini membuktikan bahwa pendekatan *hybrid* LSTM–ARIMA yang dioptimasi secara sistematis tidak hanya meningkatkan akurasi prediksi curah hujan, tetapi juga dapat diterjemahkan ke dalam informasi agronomis kuantitatif untuk mendukung efisiensi pengelolaan air pada pertanian presisi di Kabupaten Sleman.

Kata Kunci: prediksi curah hujan, *hybrid* LSTM–ARIMA, *hyperparameter tuning*, pertanian presisi, kebutuhan air irigasi

ABSTRACT

The agricultural sector in Sleman Regency is highly dependent on irrigation water availability, which is directly affected by rainfall variability due to climate change. Fluctuating rainfall patterns lead to inefficient irrigation practices, including over-irrigation during the rainy season and insufficient water supply during critical crop growth phases. Classical statistical models such as ARIMA have limitations in capturing non-linear patterns, while the deep learning model LSTM excels at capturing long-term temporal dependencies but still leaves linear components in its residuals. Therefore, this study examines how a hybrid LSTM–ARIMA model can improve rainfall prediction accuracy while supporting precision agriculture through irrigation water requirement estimation.

This study used data from the BMKG Sleman Climatology Station for the period January 1, 2010 to December 31, 2025, covering rainfall (RR), average temperature (TAVG), relative humidity (RH_AVG), and sunshine duration (SS). Pre-processing stages include error code cleaning, date validation, daily resampling, and missing value imputation using Multivariate Linear Regression with a time-based interpolation fallback. Data splitting was performed using the Walk-Forward Validation method with a Rolling Window approach. The LSTM architecture was optimized through hyperparameter tuning using Grid Search with TimeSeriesSplit evaluation. The hybrid model was developed using a reversed hybrid approach, where LSTM serves as the primary predictor and ARIMA models the linear component in the LSTM residuals. Model performance was evaluated using RMSE and MAE metrics through 13-fold Walk-Forward Validation, and prediction results were integrated into water balance calculations based on the FAO-56 Penman–Monteith method to produce Net Irrigation Requirement (NIR) estimates.

The results show that the hybrid LSTM–ARIMA model achieved the best performance with an average RMSE of 13.8845 mm and MAE of 7.3360 mm, outperforming the standalone LSTM model (RMSE 14.2475 mm) and ARIMA (RMSE 15.5424 mm). The optimal LSTM configuration was obtained with a 30-day look-back window, 128 units in the first hidden layer, 25 units in the second hidden layer, a learning rate of 0.01, and a batch size of 64. Residual modeling using ARIMA (4,0,4) was selected based on the lowest AIC value of 47,836.82, with LSTM residuals confirmed stationary at the level ($d=0$). Integration of prediction results into water balance simulation successfully produced adaptive irrigation recommendations, where the system automatically detects water surplus or deficit conditions and provides irrigation volume estimates per hectare. This study proves that the systematically optimized hybrid LSTM–ARIMA approach not only improves rainfall prediction accuracy but can also be translated into quantitative agronomic information to support efficient water management in precision agriculture in Sleman Regency.

Keywords: *rainfall prediction, hybrid LSTM–ARIMA, hyperparameter tuning, precision agriculture, irrigation water requirement*