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## Multivariate SPC of Smart Greenhouses for Berry Production: A Hybrid SPC–ML Framework — Moroccan Case Study

Berry greenhouses in the Souss-Massa region of Morocco sustain high-value exports of strawberries, blueberries, and raspberries, but their yield and fruit quality are highly sensitive to microclimate deviations. Dense IoT sensor networks generate high-dimensional, autocorrelated, and non-stationary data that violate classical Shewhart, CUSUM, and MEWMA assumptions.

We propose a hybrid Statistical Process Monitoring framework combining a regularized autoencoder, trained on in-control periods, with an adaptive MEWMA chart on reconstruction residuals. The approach is validated on several months of real greenhouse data (temperature, humidity, CO<sub>2</sub>, soil moisture, PAR, fertigation) and benchmarked against Hotelling's T<sup>2</sup>, PCA-MSPC, and isolation forests. Results show faster drift detection, better out-of-control ARL, and clearer interpretability through residual contribution plots. We discuss explainable AI and standardization for SPM in precision agriculture.

### Special/ Invited session

### Classification

Both methodology and application

### Keywords

SPM; Smart Greenhouses; MEWMA; Autoencoder; Precision Agriculture.

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**Track Classification:** Statistical Process Monitoring