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Impact of environment and crop management on the variance of maize (*Zea mays* L.) yield in different agroecological zones in Kenya

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Abstract

Addressing the limited understanding of how environmental factors and crop management affect maize (*Zea Mays* L.) grain yields across agroecological zones (AEZs) is essential in improving decision making and climate change adaptation planning in sub-Saharan Africa (SSA).

This study evaluated how environmental (seasonal climate factors, soil type) and crop management practices (irrigation, planting dates) affected rainfed and irrigated maize yields in semi-arid, sub-humid and humid agroecological zones (AEZs) in Kenya and identified critical thresholds that demarcated the transition between yield gains and losses.

We conducted field experiments in Maktau, Kishenyi and Kabete over four growing seasons (2024–2025), covering both long (LR) and short (SR) rains, applying full irrigation in LR2024 and S2024 and growth-stage based deficit irrigation in LR2025 and SR2025. A calibrated AquaCrop model was used to simulate early and delayed planting (local planting date ±15 and ±30 days) and corresponding rainfed alongside full and deficit irrigation strategies. We employed XGBoost models to estimate yield responses to seasonal environmental and crop management factors and utilised SHAP (Shapley Additive Explanations) values to quantify the influence of each predictor across the AEZs.

In semi-arid Maktau, yields gains were associated with seasonal irrigation of ~600 mm and yields declined at seasonal rainfall of ~150 mm, while in sub-humid Kishenyi, the corresponding critical thresholds were seasonal irrigation of ~400 mm and seasonal rainfall of 200 mm and in humid Kabete, ~200 mm of seasonal irrigation and ~600 mm seasonal rainfall. As for temperature sensitivity, yield gains were associated with seasonal mean maximum temperatures around 29°C, with losses clustered at temperatures above 30–31°C in semi-arid Maktau, while in sub-humid Kishenyi, yield losses concentrated at temperatures of ~27°C, while gains appear at ~22°C, and in humid Kabete, yield changes becoming increasingly negative above ~26°C. Early planting consistently produced higher yields across all AEZs, while delayed planting resulted in significant yield penalties.

This study highlights the complex AEZ-specific interplay between environmental, crop management and maize yield. The thresholds identified and interaction effects enables transition from broad interventions to targeted AEZs aligned strategies, that improve yield and enhance climate resilience in maize cropping systems.

Keywords: Agroecological zones, AquaCrop, irrigation, planting dates, smallholder, sub-Saharan Africa, XGBoost model

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