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Impacts of climate variability and multiple fertilisation strategies on rainfed maize production in sub-Saharan Africa: Insights from 40 years of DSSAT modelling

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Abstract

Maize production in sub-Saharan Africa (SSA) remains highly vulnerable to climatic variability, particularly rainfall and temperature fluctuations, which contribute to persistent yield gaps and food insecurity. Most smallholder farmers in the Region cultivate nutrient-depleted soils with minimal external inputs, highlighting the need for adaptive agronomic strategies to stabilise yields under erratic weather conditions. This study evaluated the impact of improved nutrient management on rainfed maize yields under historical climate variability using the DSSAT CERES-Maize model. The model was calibrated and validated with field trial data from five representative sites in Burkina Faso, Ghana, Kenya, Sierra Leone, and Tanzania.

Simulations covered a 40-year period (1984–2023) across four fertiliser management scenarios: no inputs (control), inorganic fertiliser only, organic fertiliser only, and a combined organic–inorganic system. The model incorporated diverse seasonal weather conditions, including severe droughts and above-average rainfall years, to assess treatment performance and maize yield variations.

Results showed that temperature significantly influenced crop development. On average, a 1 °C increase in seasonal mean temperature accelerated anthesis by 3–7 %, with the strongest response observed in warmer sites such as Kenya. Maturity dates also shortened under warm conditions, though less consistently; in the cooler, high-altitude site of Tanzania, moderate warming slightly extended the grain filling period. These phenological changes imply a compressed crop cycle, which may constrain biomass accumulation and reduce yield potential. Rainfall variability was the primary driver of interannual yield fluctuations, with drought years reducing yields by approximately 40 % compared to wet years. All fertiliser-based treatments improved yields relative to the unfertilised control, with the combined organic–inorganic input achieving the highest gains, up to 160 % above control, and the lowest interannual yield variability. Yield benefits from fertilisation were most pronounced in higher-rainfall environments, while water limitations constrained responses in semi-arid zones. These findings underscore that integrated nutrient management not only enhances maize yields but also improves yield stability under climate stress. Combining organic and inorganic inputs emerges as a climate resilient and scalable strategy to strengthen the climate adaptability of maize-based systems in SSA.

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