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Phenology and soil moisture dynamics under conservation practices in rainfed sub-humid maize systems

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Abstract

Drought stress driven by intra-seasonal rainfall variability and rising evaporative demand limits maize productivity in rainfed sub-humid systems of sub-Saharan Africa. This study evaluated the effects of Conservation Soil Water Management Practices (CSWMPs) such as straw mulch, half-moon pits, and permanent planting basins on seasonal, phenological, and depth-wise soil moisture dynamics over three maize growing seasons. Volumetric soil moisture (θnow) was monitored at 0 – 40 cm depth using FDR probes and linked to soil water storage, deficit to field capacity (Dr), available water, and soil physical properties.

Soil moisture increased from planting to vegetative stages, peaked during tasseling to silking (up to 0.43 m^3 m^{-3}), and declined towards maturity. The CSWMPs consistently maintained significantly higher soil moisture than the control ($p \leq 0.05$), with half-moon pits showing the greatest retention during critical growth stages. Enhanced moisture was observed within the root-active zone (10 – 30 cm) and sustained in deeper layers (30 – 40 cm), improving buffering against dry spells. Mixed-effects modeling revealed crop growth stage ($\chi^2 = 50.65 - 86.23$, $p < 0.001$) and soil water storage ($p < 0.001$) as key determinants of θnow, while Dr alone was not significant but interacted strongly with phenology ($p < 0.001$). Bulk density and saturated hydraulic conductivity significantly influenced soil moisture ($p < 0.001$), whereas static thresholds (field capacity, permanent wilting point) were less explanatory.

Overall, the CSWMPs improved infiltration, reduced evaporative losses, and enhanced soil structural functioning, thereby increasing phenology-specific water availability. These results demonstrate that conservation-oriented soil water management strengthens maize resilience and stabilizes yields under increasing climatic variability.

Keywords: Climate-resilient agriculture, Hydraulic properties, Maize phenology, Soil moisture dynamics, soil water management

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