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Beyond single indicators: Composite indexing of soil fertility managements for maize intensification in northern Ghana

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Abstract

Closing maize yield gaps in sub-Saharan Africa demands intensification strategies that are productive, profitable, ecologically sound, and socially acceptable. This study evaluated soil fertility management practices: a Control (no fertiliser), two inorganic nitrogen rates (30 and 60 kg N ha^{-1}), two sole organic manure rates (2.5 and 5.0 t ha^{-1}), and two integrated combinations (30 kg N+5.0 t manure ha^{-1} and 60 kg N+2.5 t manure ha^{-1}) across four sustainability pillars in three districts of Northern Ghana (Mion, Savelugu and Tolon), using APSIM simulations (1980–2024) for two maize maturity classes. Long-term climate data confirmed rising temperatures and declining rainfall across all sites, underscoring the urgency of resilient intensification pathways. Sole 60 kg N ha^{-1} maximised gross margins (GHS 14,821 ha^{-1}, a 70 % gain over the Control and 70 % over the sole 5.0 t manure ha^{-1}) yet recorded the lowest biodiversity score (0.2) across sites. Conversely, sole 5.0 t manure ha^{-1} scored highest on biodiversity, yet no single fertility management strategy consistently excelled across all dimensions. The longer-maturing Obatanpa outperformed Abontem by a mean gross margin of GHS 2,706 ha^{1} across all treatments. Integrated treatments produced the lowest yield coefficients of variation, confirming their resilience under rainfall variability. Social acceptability diverged by location: Mion farmers favoured organic-inclusive treatments, Savelugu farmers preferred inorganic-dominant practices, and Tolon farmers showed the strongest aversion to high nitrogen without manure. A composite sustainability index aggregating all four pillar scores with equal weighting provided decisive resolution, with integrated treatments outperforming sole-input strategies across all sites. The 60 kg N+2.5 t manure ha^{-1} achieved the highest composite score at Mion (0.85), while 30 kg N + 5.0 t manure ha^{-1} excelled at Savelugu (0.79) and Tolon (0.80), far exceeding the Control (0.14–0.20). The score differential between these two integrated treatments suggests that, where inorganic fertiliser access is constrained, increasing manure to 5.0 t ha^{-1} while reducing mineral nitrogen to 30 kg N ha^{-1} can achieve equivalent sustainability outcomes. The composite index combines multiple performance indicators into one clear score, providing a site-specific tool to support farmers, extension agents, and policymakers in scaling integrated soil fertility management.

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