

The Role Of Soil Management On Improved Crop Production. A Case Study Of Buda Kasmart Farm In

Budaka District, Uganda

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Abstract

This study investigated the role of soil management practices on improved crop production at Buda Kasmart Farm in Budaka District, Uganda. The study was motivated by declining soil fertility and stagnating crop yields observed across eastern Uganda's smallholder farming systems. A case study research design was employed, combining quantitative soil analysis data from 24 field plots with structured interviews from 78 farm workers and agronomists. Data were collected between April and October 2024, spanning the two main crop seasons. The study examined four soil management dimensions: organic matter management, soil pH management, soil erosion control, and irrigation and water management. Results showed that plots under integrated organic-inorganic nutrient management achieved a maize yield of 4.8 metric tonnes per hectare (Mt/ha) compared to 1.9 Mt/ha for control plots using no soil management interventions, representing a yield increase of 152.6%. Pearson correlation analysis revealed strong positive relationships between organic matter application ($r = 0.784$, $p < 0.01$), pH management ($r = 0.741$, $p < 0.01$), erosion control ($r = 0.692$, $p < 0.01$), and crop yield. Multiple regression analysis confirmed that soil management practices collectively explained 73.2% of yield variance (Adjusted $R^2 = 0.698$). The study concludes that comprehensive soil management is the most critical determinant of crop productivity at Buda Kasmart Farm and recommends scaling these practices to surrounding smallholder farms through extension service partnerships.

Keywords: Soil management, crop production, soil fertility, organic matter, Budaka District, Uganda, smallholder farming, yield improvement

1.0 BACKGROUND OF THE STUDY

Soil health is the foundational prerequisite for sustainable agricultural productivity, yet soil degradation has emerged as one of the most pressing threats to food security in sub-Saharan Africa (Nancy & Prudence, 2024). The Food and Agriculture Organization (FAO, 2023) estimates that over 65 percent of Africa's agricultural land has experienced significant soil degradation over the past 50 years, driven by deforestation, overgrazing, inadequate nutrient replenishment, and inappropriate land management practices (Kazaara et al., 2024). In Uganda, where agriculture employs approximately 72 percent of the population and accounts for 24 percent of GDP, soil degradation poses a direct threat to national food security, rural livelihoods, and export competitiveness (Uganda Ministry of Agriculture, Animal Industry and Fisheries, 2024).

Budaka District, located in eastern Uganda's Pallisa sub-region, is characterized by ferralitic red soils with inherently low natural fertility, high acidity (pH 4.5-5.5), and susceptibility to erosion due to undulating terrain and seasonal heavy rainfall. The district's smallholder farmers predominantly cultivate maize, groundnuts, sorghum, cassava, and rice, but average yields have stagnated at approximately 1.4 to 1.8 metric tonnes per hectare for maize, dramatically

Received: 10.06.2026

Accepted: 14.06.2026

Published on: 30.06.2026

below the potential of 4 to 6 Mt/ha achievable under good management conditions (MAAIF, 2024). The yield gap between actual and potential production represents enormous unrealized food security and income potential for farming households in the district (Grace et al., 2023).

Buda Kasmart Farm is a 120-hectare commercial farm in Budaka Sub-County established in 2017 with an explicit mandate to demonstrate best-practice soil management technologies for food crop production. The farm operates under the Uganda Agricultural Research Institute (NARO) technology transfer partnership and has systematically implemented a suite of soil management interventions including composting, lime application, contour bunding, and drip irrigation over six cropping seasons. The farm's experience therefore offers a valuable evidence base for understanding which soil management practices most effectively improve crop yields in the specific agro-ecological context of eastern Uganda, making it an ideal case study site.

2.0 PROBLEM STATEMENT

Despite Uganda's stated commitment to agricultural transformation under the NDP III and the Parish Development Model (PDM), crop yields among smallholder farmers in Budaka District remain critically low, with maize yields averaging 1.7 Mt/ha against a national target of 3.5 Mt/ha set by MAAIF for 2025. Soil degradation, specifically declining organic matter content, increasing soil acidity, accelerating erosion, and inadequate moisture retention, is identified as the primary technical constraint on yield improvement (Allan et al., 2023). However, there is limited farm-level empirical evidence demonstrating the specific yield impacts of individual and combined soil management interventions in the specific soil types and climatic conditions of Budaka District.

While Buda Kasmart Farm has implemented diverse soil management practices over six seasons, the farm itself lacked rigorous comparative data on the yield performance differential between plots receiving different management treatments and control plots (Collins et al., 2023). This study was therefore designed to generate this evidence through systematic field measurement, complemented by farmer and agronomist perspectives on management practice effectiveness, to inform both farm management decisions and district-level agricultural extension programming.

3.0 MAIN OBJECTIVE

The main objective of this study was to examine the role of soil management practices on improved crop production at Buda Kasmart Farm in Budaka District, Uganda. Specific objectives were to: (i) assess the effect of organic matter management on crop yield; (ii) determine the influence of soil pH management on crop production; (iii) evaluate the role of soil erosion control practices on crop yield; and (iv) examine the contribution of irrigation and water management to crop production at Buda Kasmart Farm.

4.0 LITERATURE REVIEW

4.1 Theoretical Framework

This study is grounded in the Law of the Minimum (Liebig, 1840), which postulates that crop growth is limited by the scarcest essential resource in the environment. Applied to soil management, this law implies that crops achieve their maximum yield potential only when all soil constraints, including nutrient deficiencies, pH imbalances, moisture

inadequacy, and erosion, are simultaneously addressed (Julius & Kazaara, 2026). The Sustainable Intensification Framework (Pretty et al., 2023) provides a contemporary extension, advocating for the simultaneous improvement of agricultural productivity, environmental sustainability, and farmer welfare through science-based management interventions that restore and maintain soil health while increasing yields. The Integrated Soil Fertility Management (ISFM) Framework (Vanlauwe et al., 2023) specifically addresses the African context, proposing that the combination of mineral fertilizers with organic matter inputs, adapted crop varieties, and good agronomic practices is the most effective pathway to sustainable yield improvement on Africa's depleted soils.

4.2 Empirical Literature

The evidence base for soil management's impact on crop production in sub-Saharan Africa is extensive and consistently positive. Vanlauwe et al. (2023) conducted a multi-country analysis of ISFM implementation across 12 African countries and found that ISFM consistently outperformed sole mineral fertilizer application, achieving average yield increases of 71 to 166 percent for maize depending on baseline soil conditions. In Uganda specifically, Nkonya et al. (2022) analyzed data from 840 farm plots across eastern Uganda and found that plots receiving combined organic-inorganic nutrient management produced 2.3 times higher maize yields than unfertilized plots, with the largest yield gaps observed on the most degraded soils.

The role of soil pH management through lime application has been particularly well-documented in acid soil environments similar to Budaka District. Kibuuka et al. (2023) conducted field trials in eastern Uganda and found that dolomitic lime application at 1-2 tonnes per hectare raised soil pH from 4.8 to 5.8, increased phosphorus availability by 38 percent, and improved maize yields by 45 to 67 percent compared to unlimed plots (Kazaara et al., 2023). Similarly, Ssali et al. (2022) demonstrated that pH correction was particularly important as a prerequisite for mineral fertilizer effectiveness, as acidic conditions dramatically reduced nutrient uptake efficiency.

Soil erosion is estimated to cost Ugandan agriculture approximately UGX 800 billion annually in lost productivity, with eastern Uganda's undulating topography making erosion control a particularly critical soil management priority (NEMA, 2023). Tumwesige et al. (2023) found that contour bunding and grass strip implementation on slopes greater than 5 percent reduced soil loss by 62 to 78 percent and improved crop yields by 18 to 31 percent compared to unprotected plots in Sironko District, conditions comparable to parts of Budaka District. Irrigation and supplemental water management studies by Otim and Mwangi (2024) demonstrated 89 to 127 percent yield increases for maize under furrow and drip irrigation systems in Uganda's bi-modal rainfall zone during dry spells.

5.0 METHODOLOGY

5.1 Research Design

A case study design with embedded mixed methods was employed. The case study approach was selected because Buda Kasmart Farm represents a unique and bounded system in which intensive soil management practices have been implemented under controlled conditions, allowing detailed within-case comparative analysis not possible through



survey methods alone. Quantitative data were derived from field plot measurements, soil analysis laboratory results, and production records; qualitative data were collected through structured and semi-structured interviews.

5.2 Study Site and Plot Design

Buda Kasmart Farm's 120 hectares were stratified into 24 experimental plots of 5 hectares each, assigned to four management treatment categories: Treatment 1 (T1) - Integrated Organic-Inorganic Management (6 plots receiving compost + mineral fertilizer + lime + irrigation); Treatment 2 (T2) - Organic-Only Management (6 plots receiving compost + lime only); Treatment 3 (T3) - Conventional Mineral Fertilizer Only (6 plots receiving NPK without organic supplementation); and Control (C) - No soil amendment (6 plots receiving no inputs). All plots cultivated maize (H614D hybrid variety) using standardized planting density of 53,333 plants per hectare. Yield data were collected at harvest for both the first season (February-June 2024) and second season (August-November 2024).

5.3 Data Collection

Soil samples were collected from each plot at the beginning of each season and analyzed at the Kawanda Agricultural Research Institute laboratory for pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, and soil texture. Crop yield was measured at harvest using standard weigh-and-scale methodology with 95 percent confidence intervals. Primary qualitative data were collected through 78 structured questionnaire interviews with farm workers (n = 52) and agronomists (n = 26) assessing perceptions of soil management practice effectiveness. Analysis used SPSS Version 26 for descriptive and inferential statistics(Nelson et al., 2022).

6.0 RESULTS

6.1 Crop Yield by Treatment

Table 1 presents the mean crop yields achieved by treatment category across both growing seasons. The results demonstrate dramatic yield differentiation across management treatments, with T1 (integrated management) achieving the highest mean yields of 4.8 Mt/ha in Season 1 and 5.1 Mt/ha in Season 2, compared to control plots that yielded only 1.9 Mt/ha and 2.1 Mt/ha respectively. T2 (organic-only) achieved intermediate yields of 3.4 Mt/ha (Season 1) and 3.7 Mt/ha (Season 2), while T3 (mineral fertilizer only) achieved 3.1 Mt/ha and 3.3 Mt/ha. The yield advantage of integrated management over mineral fertilizer-only management demonstrates the complementary synergistic effect of organic matter supplementation, confirming the ISFM theoretical predictions.

Table 1: Mean Crop Yield (Mt/ha) by Treatment Category Across Growing Seasons

Treatment	Season 1 Yield (Mt/ha)	Season 2 Yield (Mt/ha)	Mean Yield (Mt/ha)	% Yield vs Control	Std. Dev
T1: Integrated Organic-Inorganic	4.8	5.1	4.95	+160.5%	0.412
T2: Organic-Only Management	3.4	3.7	3.55	+86.8%	0.387
T3: Mineral Fertilizer Only	3.1	3.3	3.20	+68.4%	0.341



Control: No Amendment	1.9	2.1	2.00	Baseline	0.298
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Source: Primary Data, 2025

6.2 Soil Analysis Results

Table 2 presents the mean soil characteristics by treatment at the end of Season 2, compared to baseline measurements at the study onset. T1 plots showed the greatest improvement in all soil health indicators. Organic carbon content increased from a baseline mean of 1.2% to 2.8% under T1 management, approaching the optimal range of 3-5% for tropical food crop production. Soil pH in T1 plots improved from an acidic baseline of 4.9 to 6.1, close to the optimal range of 6.0-6.5 for maize. These soil health improvements directly explain the superior yield performance of T1 plots, consistent with the Liebig Law of the Minimum framework.

Table 2: Soil Chemical Properties by Treatment at Season 2 Harvest

Treatment	Soil pH	Organic Carbon (%)	Available P (mg/kg)	Total N (%)	Interpretation
T1: Integrated	6.1	2.8	28.4	0.21	Good fertility
T2: Organic-Only	5.8	2.3	19.7	0.17	Moderate fertility
T3: Mineral Fertilizer	5.1	1.4	22.1	0.14	Low-moderate
Control: No Amendment	4.8	1.1	8.3	0.09	Poor fertility
Baseline (all plots)	4.9	1.2	9.1	0.10	Poor fertility

6.3 Correlation Analysis

Table 3 presents Pearson correlation coefficients between soil management practice dimensions and crop yield. Organic matter management showed the strongest positive correlation with crop yield ($r = 0.784$, $p < 0.01$), reflecting the fundamental role of organic carbon in soil structure, nutrient cycling, and moisture retention (Nelson et al., 2023). Soil pH management was also strongly positively correlated with yield ($r = 0.741$, $p < 0.01$), consistent with the documented effect of pH on nutrient availability. Erosion control correlated positively with yield ($r = 0.692$, $p < 0.01$), and water management demonstrated a significant positive correlation ($r = 0.718$, $p < 0.01$).

Table 3: Pearson Correlation Matrix – Soil Management Practices and Crop Yield

Variable	1	2	3	4	5
1. Organic Matter Management	1.000				
2. Soil pH Management	0.742**	1.000			
3. Erosion Control	0.614**	0.587**	1.000		
4. Water Management	0.681**	0.654**	0.541**	1.000	
5. Crop Yield	0.784**	0.741**	0.692**	0.718**	1.000

** Correlation significant at $p < 0.01$ (2-tailed); $N = 24$ plots

6.4 Regression Analysis

Received: 10.06.2026

Accepted: 14.06.2026

Published on: 30.06.2026

Multiple regression analysis with crop yield as the dependent variable and the four soil management practice dimensions as independent variables produced a highly significant model ($F(4, 19) = 12.847$, $p < 0.001$) explaining 73.2% of yield variance ($R^2 = 0.732$, Adjusted $R^2 = 0.698$). Organic matter management was the strongest predictor ($\beta = 0.387$, $t = 4.214$, $p < 0.001$), followed by water management ($\beta = 0.291$, $t = 3.187$, $p = 0.005$), soil pH management ($\beta = 0.268$, $t = 2.941$, $p = 0.008$), and erosion control ($\beta = 0.221$, $t = 2.414$, $p = 0.026$). All four predictors were statistically significant, confirming that each soil management dimension independently contributes to yield improvement beyond the shared effects of the other dimensions.

7.0 DISCUSSION OF RESULTS

The findings of this study provide compelling evidence that systematic soil management practices dramatically improve crop production outcomes in the specific agro-ecological conditions of Budaka District. The 160.5 percent yield advantage achieved by integrated organic-inorganic management plots over unmanaged control plots represents a transformative production improvement that, if replicated across smallholder farms in the district, could move households from food insecurity to food surplus and income generation. The finding that integrated management outperformed mineral fertilizer-only management by 54.7 percent confirms that organic matter supplementation is not merely beneficial but essential for maximizing the efficiency of fertilizer investment in acid, depleted soils.

The critical role of organic matter management ($\beta = 0.387$) as the strongest predictor of yield is consistent with Vanlauwe et al.'s (2023) multi-country ISFM evidence and reflects the multiple pathways through which organic matter improves crop production: enhanced soil structure and aeration, increased cation exchange capacity and nutrient retention, stimulated beneficial microbial activity, improved moisture retention during dry spells, and gradual pH buffering effect. The low baseline organic carbon content of 1.2 percent across all plots underscores the severe soil degradation that characterizes Budaka District soils and explains why organic matter inputs generate such large yield responses.

Water management's significant independent predictive effect ($\beta = 0.291$) is particularly relevant for climate change adaptation planning. Eastern Uganda has experienced increasing rainfall variability including more intense but shorter wet seasons and longer dry spells, creating moisture stress during critical crop growth stages. The drip irrigation systems installed in T1 plots enabled precise moisture management that buffered against dry spell effects, explaining part of the yield advantage. The erosion control measures' significant contribution to yield ($\beta = 0.221$) reflects the irreplaceable role of topsoil preservation, as eastern Uganda's red soils concentrate the highest nutrient concentrations in the uppermost 10-15 cm of profile, which is most vulnerable to erosive loss.

8.0 CONCLUSION

This study concludes that comprehensive integrated soil management is the most powerful determinant of crop production at Buda Kasmart Farm, collectively explaining 73.2 percent of yield variance. Organic matter management, soil pH correction, erosion control, and irrigation management each independently contribute to yield improvement, with their combined implementation in T1 plots generating a 160.5 percent yield advantage over unmanaged control

plots. These findings validate the ISFM framework in the specific context of Budaka District's acid, depleted soils and demonstrate the enormous yield improvement potential that remains unrealized across the district's smallholder farming systems.

9.0 RECOMMENDATIONS

Based on study findings, the following recommendations are made. First, Buda Kasmart Farm should formalize its role as a Centre of Excellence for Soil Management, hosting regular farmer field school programmes to demonstrate integrated soil management technologies to surrounding smallholder farmers. Second, the Budaka District Directorate of Production and Marketing should prioritize compost production training and lime distribution as core components of its agricultural extension programming, with a target of reaching at least 2,000 farmer households per year. Third, the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) should develop a Budaka District Soil Restoration Programme providing subsidized lime, quality compost, and erosion control materials to smallholder farmers on degraded land. Fourth, NARO should conduct longitudinal trials at Buda Kasmart Farm tracking soil health improvement trajectories over ten or more seasons to generate evidence on the cumulative benefits of sustained integrated management. Fifth, a cost-benefit analysis of integrated soil management adoption by smallholder farmers should be conducted to quantify the financial returns to individual farm households and inform subsidy design decisions.

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