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# Influence of Sustainable Soil Management Practices on Maize Productivity among Smallholder Farmers in Nyanza District

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*Abstract:* **Maize productivity among smallholder farmers in Nyanza District, Rwanda, remains below its potential despite ongoing agricultural interventions. Low yields are largely attributed to soil degradation, declining fertility, soil acidity, and inadequate organic matter. While Sustainable Soil Management (SSM) practices have been promoted to address these challenges, their adoption and contribution to maize productivity remain inadequately documented. This study examined the influence of SSM practices on maize productivity among smallholder farmers in Nyanza District. Specifically, it assessed the effects of physical, chemical, and biological soil management practices, including terracing, liming, organic manuring, agroforestry, and Integrated Soil Fertility Management (ISFM), on maize yield, grain quality, and household income. A descriptive and correlational research design was employed. Data were collected from 398 smallholder farmers selected using Yamane's formula and 62 purposively selected key informants, including agronomists and Social Economic Development Officers. Quantitative data were analyzed using descriptive and inferential statistics, while qualitative data were analyzed thematically. The findings revealed that organic manure was the most widely adopted SSM practice (71.9%), whereas lime application and ISFM showed relatively low adoption due to high costs and limited farmer awareness. Maize productivity remained low to moderate, with 43.7% of farmers producing between 1.1 and 2.0 tons per hectare and only 13.1% achieving yields above 3.0 tons per hectare. Regression analysis demonstrated that SSM practices significantly influenced maize productivity ($R^2 = 0.55$, $p < 0.001$). ISFM ($\beta = 0.29$), liming ($\beta = 0.24$), and terracing ($\beta = 0.18$) emerged as the strongest predictors of improved maize yields. Qualitative findings identified high input costs, inadequate extension services, and limited technical knowledge as major barriers to adoption. The study concludes that sustainable improvements in maize productivity require integrated soil fertility management approaches rather than reliance on isolated agricultural inputs. It recommends expanding subsidies for lime and soil amendments, strengthening agricultural extension services, and enhancing farmer training to promote wider adoption of SSM practices and support Rwanda's Crop Intensification Program (CIP).**

*Keywords:* **sustainable, soil management, maize productivity, smallholder farmers, Nyanza District.**

## 1. INTRODUCTION

Globally, the rising food demand of an estimated 9.7 billion people by 2050 has intensified pressure on land resources, resulting in widespread land overexploitation. Consequently, nearly 33% of global soils are now moderately to severely degraded due to erosion, nutrient depletion, and chemical pollution (Food and Agriculture Organization [FAO], 2022). In response to topsoil degradation driven by intensive mono-cropping systems, the United States has increasingly adopted Climate-Smart Agriculture practices. Within this approach, conservation methods such as no-till farming and cover cropping have improved maize drought resilience by 12% (Zulauf & Bown, 2023). Similarly, China's Zero Growth in Chemical Fertilizer Action Plan demonstrates that integrated soil-crop management systems can simultaneously enhance

productivity and sustainability by increasing maize yields by 10.8% while reducing nitrogen fertilizer use by 14.7% (Cui et al., 2018).

At the continental level, severe soil degradation across Sub-Saharan Africa (SSA) continues to undermine efforts toward achieving the Malabo Declaration targets of tripling intra-African trade and halving poverty. Smallholder farmers frequently cultivate soils that are severely depleted of essential macronutrients, particularly nitrogen, phosphorus, and potassium (NPK). In response, Integrated Soil Fertility Management (ISFM) interventions in semi-arid regions of Kenya—combining organic manure with low-cost mineral fertilizers—have successfully quadrupled maize yields (Njeru et al., 2022). Likewise, large-scale soil and water conservation structures such as terracing and stone bunds in the Ethiopian highlands have reduced runoff and increased wheat yields by 15% (Adimassu et al., 2017). Despite these demonstrated biophysical gains, the widespread adoption of sustainable soil management (SSM) practices across SSA remains constrained by high input costs, fragmented input supply chains, and weak agricultural extension systems.

In Rwanda, agriculture remains the backbone of macroeconomic stability and rural livelihoods, contributing approximately 25% of national GDP and employing over 60% of the active labour force. Within this sector, maize is prioritized under national land consolidation programs as a strategic staple crop for food security, import substitution, and animal feed industries. At the household level, maize production plays a central role in smallholder welfare, both as a dietary staple and a cash income source. Revenue from maize sales enables rural households to meet essential needs, including school fees, household asset accumulation, and healthcare access through Mutuelle de Santé. As a result, fluctuations in maize productivity have direct implications for poverty reduction and household nutritional security.

However, Rwanda's predominantly hilly and undulating topography makes it highly vulnerable to water-induced soil erosion, leading to an estimated loss of 25 million tonnes of fertile topsoil annually. Although national programs such as the Crop Intensification Program (CIP) and the Strategic Plan for Agricultural Transformation (PSTA IV) have increased overall crop production, heavy dependence on synthetic fertilizers without adequate organic integration has contributed to severe soil acidification in several provinces (Ministry of Agriculture and Animal Resources [MINAGRI], 2021). To address this challenge, the government has promoted integrated land management strategies, including radical terracing combined with the Girinka program, which supplies organic manure through livestock distribution. These combined landscape and organic interventions form a critical pillar in efforts to reduce nutrient leaching and restore soil fertility balance.

In Nyanza District, smallholder maize production remains an important driver of local economic activity; however, it is increasingly threatened by land fragmentation and erratic rainfall patterns. Many farmers continue to rely on traditional tillage practices on steep slopes without adequate soil conservation measures, resulting in severe erosion and loss of soil fertility. Although cooperative structures have improved access to improved hybrid seed varieties, a significant productivity gap persists due to underlying soil degradation. Therefore, there is a clear empirical need to examine the specific effects of targeted sustainable soil management (SSM) practices—namely agroforestry, composting, and agricultural liming—on maize productivity (quintals per hectare) among smallholder farmers in Nyanza District, in order to support both district-level economic development and household livelihood improvement.

## 2. METHODOLOGY

### 2.1 Research Design

The study used a descriptive and correlational research approach to look at the impact of sustainable soil management (SSM) methods on maize productivity among smallholder farmers in Nyanza District.

### 2.2 Target Population

The target population for this study consisted of 79,312 individuals and households engaged in maize production and agricultural oversight within the ten administrative sectors of Nyanza District, namely Busasamana, Mukingo, Kigoma, Busoro, Cyabakamyi, Rwabicuma, Muyira, Kibirizi, Ntyazo, and Nyagisozi, as documented by NISR (2022) and the Nyanza District Agricultural Office Reports (2025/2026).

### 2.3 Study Area

The research was carried out in Nyanza District, one of the districts in Rwanda's Southern Province.

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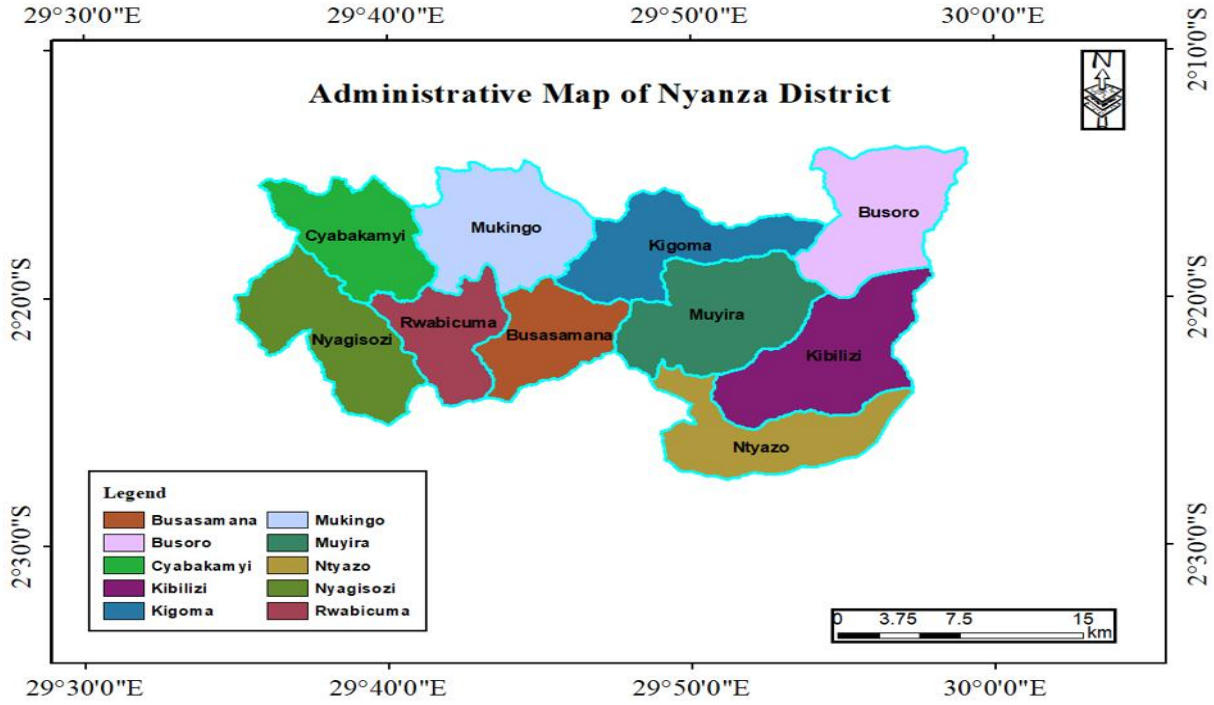


**Figure 1: Administrative map of Nyanza district**

### 2.4 Sampling Method and Sample Size

**Sample size determination**

To ensure that the study findings could be generalized to the entire population of maize farmers in Nyanza District, the sample size was determined using the Yamane (1967) formula. Given a known population of 79,250 maize farmers and a margin of error of 5% at a 95% confidence level, the sample size was calculated as follows:

$$n = \frac{N}{1 + N(e^2)}$$

Where:

- **n** = Required sample size
- **N** = Total population of maize farmers (79,250)
- **e** = Margin of error (0.05)
- **1** = Statistical constant

Substituting the values into the formula:

$$n = \frac{79{,}250}{1 + 79{,}250(0.05)^2}$$
$$n = \frac{79{,}250}{1 + 198.125}$$
$$n = \frac{79{,}250}{199.125}$$
$$n = 397.98 \approx 398$$

Therefore, a sample size of 398 maize farmers was selected for the quantitative survey.

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To ensure adequate representation of all ten sectors of Nyanza District, proportional allocation was employed. The number of respondents selected from each sector was determined using the following formula:

$$n_i = \frac{N_i}{N} \times n$$

Where:

- $\mathbf{n_i}$ = Sample size for sector *i*
- $\mathbf{N_i}$ = Population of maize farmers in sector *i*
- **N** = Total population of maize farmers in the district (79,250)
- **n** = Total sample size (398)

This proportional allocation technique ensured that sectors with larger populations contributed a correspondingly larger number of respondents, thereby enhancing the representativeness of the sample.

In addition to the quantitative survey, 62 key informants were purposively selected for semi-structured interviews. These included Sector Agronomists, Socio-Economic Development Officers (SEDOs), and the District Agricultural Officer. Combining quantitative data from maize farmers with qualitative insights from key informants enabled the study to obtain a comprehensive understanding of sustainable soil management practices and maize productivity in Nyanza District.

**Sampling Techniques**

Respondents for this study in Nyanza District were selected using a multi-stage sampling technique.

**2.5 Data collection Instruments**

Structured questionnaires were provided during face-to-face interviews, as well as semi-structured interviews with important informants, primarily Sector Agronomists.

## 3. RESULTS AND DISCUSSION

### 3.1 Demographic details

The socio-demographic characteristics of the respondents are presented in Table 4.1. These characteristics include gender, age, education level, land size under maize cultivation, and land tenure status. Understanding these variables is important as they provide contextual background for interpreting the adoption of sustainable soil management practices and maize productivity levels among smallholder farmers in Nyanza District.

**Table 1: Socio-Demographic Characteristics of Respondents (n = 398)**

| Demographic Variable | Category | Frequency (n) | Percentage (%) | Cumulative (%) |
|---|---|---|---|---|
| **Gender** | Male | 242 | 60.8 | 60.8 |
| | Female | 156 | 39.2 | 100 |
| **Age of Respondent** | 18–35 | 102 | 25.6 | 25.6 |
| | 36–50 | 176 | 44.2 | 69.8 |
| | 51–65 | 88 | 22.1 | 91.9 |
| | Above 65 | 32 | 8 | 99.9 |
| **Education Level** | None | 74 | 18.6 | 18.6 |
| | Primary | 168 | 42.2 | 60.8 |
| | Secondary | 102 | 25.6 | 86.4 |
| | TVET | 36 | 9 | 95.4 |
| | University | 18 | 4.5 | 99.9 |
| **Land Size (Maize)** | < 0.5 ha | 96 | 24.1 | 24.1 |
| | 0.5–1.0 ha | 158 | 39.7 | 63.8 |
| | 1.1–2.0 ha | 104 | 26.1 | 89.9 |
| | > 2.0 ha | 40 | 10.1 | 100 |
| **Land Tenure Status** | Owned (with title) | 182 | 45.7 | 45.7 |
| | Rented/Leased | 124 | 31.2 | 76.9 |
| | Family land (no title) | 92 | 23.1 | 100 |

**Source: Primary data, 2026**

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The findings in Table 4.1 indicate that the majority of respondents were male (60.8%), while females accounted for 39.2%, suggesting that maize farming in Nyanza District is predominantly male-dominated, although women also play a significant role. In terms of age distribution, most farmers (44.2%) were aged between 36–50 years, indicating that the farming population is largely composed of economically active individuals. Regarding education level, the majority had attained primary education (42.2%), followed by secondary education (25.6%), while a smaller proportion had no formal education (18.6%), TVET (9.0%), or university education (4.5%). The results further show that most farmers cultivate small to medium land sizes, with 39.7% farming between 0.5–1.0 hectares and 26.1% between 1.1–2.0 hectares. This reflects the smallholder nature of maize farming in the district.

Finally, land tenure status indicates that 45.7% of respondents owned land with titles, while 31.2% rented land and 23.1% used family land without formal ownership. This suggests that land ownership security is moderate but still presents constraints that may influence investment in sustainable soil management practices.

### 3.2 Findings

#### 3.2.1 Adoption of Sustainable Soil Management Practices

This section presents the findings related to the first research objective, which is to assess the predominant sustainable soil management practices currently adopted by smallholder maize farmers in Nyanza District.

**Table 2: Adoption of Sustainable Soil Management Practices (n = 398)**

| Indicator | Category | Frequency (n) | Percentage (%) | Cumulative (%) |
|---|---|---|---|---|
| **Terracing (Radical/Progressi-ve)** | High Adoption (Often/Always) | 214 | 53.8 | 53.8 |
| | Low Adoption (Never/Rarely/ Sometimes) | 184 | 46.2 | 100 |
| **Lime Application (Ishwagara/ Travertine)** | High Adoption | 168 | 42.2 | 42.2 |
| | Low Adoption | 230 | 57.8 | 100 |
| **Organic Manure Use** | High Adoption | 286 | 71.9 | 71.9 |
| | Low Adoption | 112 | 28.1 | 100 |
| **Agroforestry/ Crop Rotation** | High Adoption | 198 | 49.7 | 49.7 |
| | Low Adoption | 200 | 50.3 | 100 |
| **Integrated Soil Fertility Management (ISFM)** | High Adoption | 176 | 44.2 | 44.2 |
| | Low Adoption | 222 | 55.8 | 100 |

**Source: Primary data, 2026**

The findings in Table 2 indicate that the most widely adopted sustainable soil management practice among smallholder farmers is organic manure use (71.9%), suggesting that farmers rely heavily on locally available soil fertility inputs.

**Figure 2: Organic Manure Use in Kigoma Sector, Nyanza District**

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The photo presented in Figure 2 shows the use of organic manure in Kigoma Sector. The findings indicate that organic manure use is the most widely adopted sustainable soil management practice among smallholder farmers, with a high adoption rate of 71.9%. This suggests that farmers in Kigoma Sector largely rely on locally available soil fertility inputs such as livestock manure and compost to enhance soil fertility, improve soil structure, and support increased maize production.

**Figure 3: Lime Application (Ishwagara/Travertine) in Kibirizi Sector, Nyanza District**

The photo presented in Figure 3 shows lime application (Ishwagara/Travertine) in Kibirizi Sector, Nyanza District. The findings indicate that lime application has a relatively low adoption rate of 42.2% among smallholder farmers. This suggests possible constraints such as the cost of lime, limited awareness, and inadequate access to soil testing and extension services, which may hinder its widespread use in improving soil acidity and fertility.

**Figure 4: Terracing (Radical/Progressive) in Mukingo Sector, Nyanza District**

The photo presented in Figure 4.3 shows terracing (radical and progressive) practices in Mukingo Sector, Nyanza District. The findings indicate that terracing is moderately adopted among smallholder farmers, with an adoption rate of 53.8%. This reflects ongoing government and extension service support aimed at promoting soil erosion control and improving land productivity on hilly landscapes.

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**Figure 5: Agroforestry / Crop Rotation in Muyira Sector, Nyanza District**

The photo presented in Figure 4.6 shows agroforestry and crop rotation practices in Muyira Sector, Nyanza District. The findings indicate that agroforestry and crop rotation have a moderate level of adoption among smallholder farmers, with a high adoption rate of 49.7%. This suggests that nearly half of the farmers integrate trees within crop fields or practice crop rotation to improve soil fertility, enhance soil structure, and promote long-term sustainable maize production.

**Table 3: Mean Scores of SSM Practices**

| Indicator | Mean | Std. Deviation | Interpretation |
|---|---|---|---|
| Terracing | 3.62 | 1.12 | High Adoption |
| Lime Application | 3.1 | 1.25 | Moderate Adoption |
| Organic Manure | 4.01 | 0.98 | High Adoption |
| Agroforestry | 3.45 | 1.1 | Moderate Adoption |
| ISFM | 3.28 | 1.15 | Moderate Adoption |

**Source: Primary data, 2026**

The results in Table 3 indicate varying levels of adoption of sustainable soil management practices among smallholder farmers in Nyanza District.

Organic manure use recorded the highest mean score (Mean = 4.01, SD = 0.98), suggesting strong and consistent adoption across respondents, followed by terracing (Mean = 3.62, SD = 1.12),

which also falls within the high adoption category. In contrast, lime application (Mean = 3.10, SD = 1.25), agroforestry (Mean = 3.45, SD = 1.10), and integrated soil fertility management (ISFM) (Mean = 3.28, SD = 1.15) were moderately adopted, indicating that these practices are used but not consistently by all farmers. The relatively higher standard deviations, particularly for lime application and ISFM, suggest variability in adoption levels, likely due to differences in access to inputs, knowledge, and extension services. Overall, the findings imply that while farmers are actively engaging in certain sustainable practices such as organic manure use and terracing, there remains a need to strengthen the adoption of other practices to achieve more comprehensive soil management.

**Institutional Support Influencing Adoption of SSM Practices**

**Table 4: Institutional Support to Smallholder Farmers (n = 398)**

| Indicator | Category | Frequency (n) | Percentage (%) | Cumulative (%) |
|---|---|---|---|---|
| **Frequency of Agronomist Visits** | Never | 64 | 16.1 | 16.1 |
| | 1–2 times | 172 | 43.2 | 59.3 |
| | 3–5 times | 110 | 27.6 | 86.9 |

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| | | | | |
|---|---|---|---|---|
| | More than 5 times | 52 | 13.1 | 100 |
| **Training on Soil Acidity Management** | Yes | 238 | 59.8 | 59.8 |
| | No | 160 | 40.2 | 100 |
| **Affordability of Lime (Ishwagara)** | Yes | 146 | 36.7 | 36.7 |
| | No | 182 | 45.7 | 82.4 |
| | Partially | 70 | 17.6 | 100 |

**Source: Primary data, 2026**

The findings in Table 4 indicate that institutional support for smallholder farmers in Nyanza District is moderate but not optimal for enhancing adoption of sustainable soil management practices.

The majority of farmers (43.2%) reported receiving 1–2 visits from Sector Agronomists per season, while only 13.1% received more than five visits. This suggests that extension service coverage is present but still limited in intensity. Regarding training, 59.8% of respondents reported having received training on soil acidity management, indicating that awareness creation on key soil fertility issues is relatively strong. However, 40.2% of farmers had not received such training, showing a remaining knowledge gap.

In terms of affordability, only 36.7% of farmers considered lime (Ishwagara) affordable, while 45.7% reported it as unaffordable. This indicates that cost remains a major barrier to the adoption of lime-based soil correction practices. Overall, the results suggest that institutional support, through extension services, training, and input affordability, plays a critical role in influencing the adoption of sustainable soil management practices among smallholder farmers.

### 3.2.2 Maize Productivity Levels

**Maize Productivity Levels**

This section presents the findings related to the second research objective, which is to assess the level of maize productivity (yield per hectare) among smallholder farmers in Nyanza District. Maize productivity was measured using three key indicators, including yield per hectare, yield trends compared to the previous season, and major constraints affecting production.

**Table 5: Maize Productivity Levels among Smallholder Farmers (n = 398)**

| Indicator | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Maize Yield (Tons/Ha) | Below 1.0 (Very low productivity) | 62 | 15.6 |
| | 1.1 – 2.0 (Low productivity) | 174 | 43.7 |
| | 2.1 – 3.0 (Moderate productivity) | 110 | 27.6 |
| | Above 3.0 (High productivity) | 52 | 13.1 |
| Yield Trend Compared to Previous Season | Significant decrease | 48 | 12.1 |
| | Slight decrease | 96 | 24.1 |
| | No change | 92 | 23.1 |
| | Slight increase | 110 | 27.6 |
| | Significant increase | 52 | 13.1 |
| Main Constraint to Productivity | Soil erosion | 106 | 26.6 |
| | Soil acidity | 132 | 33.2 |
| | Lack of fertilizer | 98 | 24.6 |
| | Pests and diseases | 62 | 15.6 |

**Source: Primary data, 2026**

The findings in Table 5 indicate that maize productivity among smallholder farmers in Nyanza District is generally low to moderate. The majority of respondents (43.7%) reported yields between 1.1 and 2.0 tons per hectare, while only 13.1% achieved high productivity levels above 3.0 tons per hectare. This suggests that most farmers are producing below the optimal maize yield potential for the region.

In terms of yield trends, a relatively balanced distribution was observed. While 27.6% of farmers reported a slight increase in yield and 13.1% reported a significant increase, a considerable proportion (36.2%) experienced either a slight or significant decrease in productivity. This indicates that maize productivity remains unstable across seasons, reflecting

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vulnerability to environmental and management-related factors. Regarding production constraints, soil acidity was identified as the most critical challenge (33.2%), followed by soil erosion (26.6%) and lack of fertilizer (24.6%). Pests and diseases also contributed to reduced productivity (15.6%). These findings suggest that soil-related constraints, particularly acidity and erosion, are the dominant factors limiting maize productivity in the district. Overall, the results show that maize productivity in Nyanza District remains constrained by both biophysical and input-related challenges, which highlights the importance of strengthening sustainable soil management practices to improve yields.

**Table 6: Mean Scores of Maize Productivity Indicators (n = 398)**

| Indicator | Mean | Std. Deviation | Interpretation |
|---|---|---|---|
| Maize Yield Level | 2.38 | 0.95 | Low to Moderate Productivity |
| Yield Trend Compared to Previous Season | 3.05 | 1.21 | Approximately No Change / Slight Increase |

**Source: Primary data, 2026**

The results presented in Table 6 indicate that maize productivity among smallholder farmers in Nyanza District is generally low to moderate. The mean score for maize yield level (Mean = 2.38, SD = 0.95) suggests that most farmers fall within the lower productivity categories, particularly between 1.1–2.0 tons per hectare, reflecting suboptimal agricultural output.

Similarly, the mean score for yield trend compared to the previous season (Mean = 3.05, SD = 1.21) shows that productivity has remained relatively stagnant, with a slight tendency toward improvement for some farmers, although not substantial enough to indicate strong overall growth.

The relatively high standard deviation in yield trend implies significant variation among farmers, meaning that while some experienced improvements, others faced declines or no change in production. Overall, these findings suggest that maize productivity in the study area remains constrained and unstable, highlighting the need for strengthened soil management practices and improved agricultural support services.

**Relationship between Sustainable Soil Management Practices and Maize Productivity**

This section presents findings related to the third research objective, which is to analyze the relationship between specific sustainable soil management (SSM) practices and maize productivity among smallholder farmers in Nyanza District. The analysis was conducted using perceived Influence of Sustainable Soil Management Practices on Maize Yield, correlation and regression results derived from the aggregated indices of SSM practices and maize productivity indicators.

**Perceived Influence of Sustainable Soil Management Practices on Maize Yield**

This section presents findings related to farmers' perceptions on the influence of sustainable soil management practices on maize yield in Nyanza District. The analysis is based on responses measured using a 5-point Likert scale (SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree).

**Table 7: Farmers' Perceived Influence of Sustainable Soil Management Practices on Maize Yield (n = 398)**

| Statement | SD n (%) | D n (%) | N n (%) | A n (%) | SA n (%) | Mean |
|---|---|---|---|---|---|---|
| Using lime has visibly increased my maize grain size/weight | 24 (6.0) | 42 (10.6) | 48 (12.1) | 170 (42.7) | 114 (28.6) | 3.77 |
| My maize yields are higher in plots with terraces compared to slopes | 22 (5.5) | 39 (9.8) | 46 (11.6) | 175 (44.0) | 116 (29.1) | 3.81 |
| Organic manure helps my maize survive even when rains are poor | 18 (4.5) | 35 (8.8) | 42 (10.6) | 186 (46.7) | 117 (29.4) | 3.88 |
| I see no difference in yield when I apply sustainable practices (reverse item) | 154 (38.7) | 128 (32.2) | 57 (14.3) | 42 (10.6) | 17 (4.2) | 2.15 |

**Source: Primary data, 2026**

The findings in Table 7 indicate that the majority of farmers perceive sustainable soil management practices as having a positive influence on maize yield in Nyanza District. This overall positive perception is further supported by relatively high mean scores across most indicators. For lime application, a combined 71.3% of respondents agreed or strongly agreed that it improves maize grain size and weight, with a mean score of 3.77, suggesting that farmers recognize its role in reducing soil acidity and enhancing nutrient availability.

Similarly, terracing recorded a mean of 3.81, with 73.1% of respondents agreeing or strongly agreeing that maize yields are higher in terraced plots compared to sloped areas, indicating strong perceived effectiveness of soil erosion control practices. Organic manure showed the highest perceived benefit with a mean of 3.88, where 76.1% of respondents agreed or strongly agreed that it helps maize survive during periods of poor rainfall, highlighting its importance in improving soil moisture retention and crop resilience.

Conversely, the reverse statement indicating no difference in yield when applying sustainable practices recorded a low mean of 2.15, with 70.9% of respondents disagreeing or strongly disagreeing, reinforcing the view that SSM practices positively influence maize productivity. Overall, the results confirm that farmers in the study area generally recognize sustainable soil management practices as beneficial to maize production, consistent with the quantitative regression findings.

## 4. STUDY IMPLICATIONS

The findings of this study have important policy, practical, and academic implications for improving maize productivity through sustainable soil management in Nyanza District.

From **a** policy perspective**,** the results emphasize the need to strengthen agricultural extension services, particularly by increasing the frequency and quality of agronomist visits. In addition, policies should focus on improving the affordability and accessibility of soil amendments such as lime (Ishwagara), given their significant contribution to productivity.

From a practical perspective, farmers should be encouraged to adopt integrated soil management practices, including terracing, organic manure application, liming, and crop rotation, rather than relying on single interventions. Strengthening Farmer Field Schools (FFS) would further enhance farmers' technical knowledge and practical application of sustainable soil management technologies.

From an academic perspective**,** the study adds to existing literature by providing empirical evidence on the combined effects of multiple sustainable soil management practices on maize productivity at the district level. It also highlights the importance of linking institutional support with adoption behavior and productivity outcomes.

The study underscores that improving maize productivity in the region requires not only the promotion of sustainable soil management technologies, but also addressing institutional, economic, and knowledge-related constraints affecting their adoption.

## 5. CONCLUSION

This study concludes that Sustainable Soil Management (SSM) practices play a significant role in enhancing maize productivity among smallholder farmers in Nyanza District. The findings reveal that while the adoption of practices such as organic manure application and terracing is relatively moderate, the uptake of lime application, agroforestry, and Integrated Soil Fertility Management (ISFM) remains low due to financial limitations, inadequate extension support, and limited technical knowledge among farmers.

The study further establishes that maize productivity in the district remains below its potential, with many farmers achieving only low to moderate yields. However, the regression analysis demonstrates that the adoption of integrated SSM practices, particularly ISFM, lime application, terracing, organic manure use, and crop rotation, has a statistically significant and positive effect on maize yield, crop quality, and household income.

Based on these findings, the study concludes that improving maize productivity in Nyanza District requires a comprehensive approach that promotes the wider adoption and integration of sustainable soil management practices. This should be supported by strengthened agricultural extension services, continuous farmer capacity building, increased access to soil amendments and fertilizers, and policies that facilitate the affordability and availability of agricultural inputs. Such interventions are essential for enhancing soil health, increasing maize productivity, and improving the livelihoods of smallholder farming households.

## 6. POLICY IMPLICATIONS AND RECOMMENDATIONS

This study generates important policy and practical implications for improving maize productivity through sustainable soil management (SSM) practices in Rwanda. The recommendations are grounded in empirical findings from both quantitative and qualitative data and are relevant to farmers, government institutions, extension service providers, development partners, and training agencies.

### 6.1 Strengthening Agricultural Extension Systems

Empirical results show limited extension coverage, with only 13.1% of farmers receiving more than five agronomist visits per season and 16.1% reporting no contact. This inadequate technical support constrains adoption of SSM practices. Policy efforts should therefore prioritize strengthening extension systems through increased staffing, regular farm visits, demonstration plots, and continuous technical advisory services to enhance farmers' adoption of improved soil management technologies.

### 6.2 Improving Access to Agricultural Inputs (Lime and Fertilizers)

The study established that lime application significantly improves maize productivity ($\beta = 0.24$); however, adoption remains low at 42.2%, largely due to affordability constraints, with 45.7% of farmers reporting high input costs. Policymakers and development partners should enhance input subsidy programs, streamline distribution systems, and improve market accessibility for lime and fertilizers to promote equitable access among smallholder farmers.

### 6.3 Promoting Integrated Soil Fertility Management (ISFM)

ISFM exhibited the strongest positive effect on maize productivity ($\beta = 0.29$), yet adoption remains suboptimal at 44.2%, with most farmers (71.9%) relying predominantly on organic manure. Agricultural policy should therefore emphasize integrated approaches combining organic manure, mineral fertilizers, and lime, supported by targeted awareness campaigns and practical demonstrations to enhance soil fertility and productivity.

### 6.4 Strengthening Soil Conservation and Erosion Control Measures

Soil acidity (33.2%) and erosion (26.6%) were identified as major productivity constraints, while terracing significantly improved yields ($\beta = 0.18$). There is a need for strengthened enforcement and expansion of soil conservation programs, including terracing, contour farming, and other erosion control measures, to reduce land degradation and sustain long-term agricultural productivity.

### 6.5 Enhancing Farmer Capacity Building and Training

Although 59.8% of farmers reported receiving some training on soil acidity management, adoption of key SSM practices remains limited, indicating persistent knowledge gaps. Continuous, practical, and farmer-centered training programs should be institutionalized through extension services, cooperatives, and NGOs to improve farmers' technical capacity and ensure effective implementation of sustainable soil management practices.

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