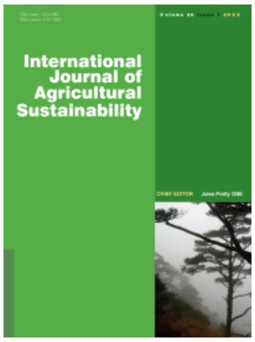

Taylor & Francis
Taylor & Francis Group

International Journal of Agricultural Sustainability

ISSN: 1473-5903 (Print) 1747-762X (Online) Journal homepage: www.tandfonline.com/journals/tags20

Linking soil fertility management practices to perceptions of soil fertility status among smallholder farmers in Kabarole District and Fort Portal City, Western Uganda

Cosmas Wacal , John Sekajugo , David Agole , Geoffrey Candia , Bruce Nyamweha , Collins Muhangi , Jacob Kaingo , Costa Gumisiriya , Joseph Okello , Jimmy Obala , Eriya Kule Birengesyo , Cecilia Kansiime , Ronald Buwa , Athanasius Ssekyanzi , Eva Tereka , John Patrick Kanahe Kagorora , Jack Turihohabwe & Alinaitwe Mukonyezi

To cite this article: Cosmas Wacal , John Sekajugo , David Agole , Geoffrey Candia , Bruce Nyamweha , Collins Muhangi , Jacob Kaingo , Costa Gumisiriya , Joseph Okello , Jimmy Obala , Eriya Kule Birengesyo , Cecilia Kansiime , Ronald Buwa , Athanasius Ssekyanzi , Eva Tereka , John Patrick Kanahe Kagorora , Jack Turihohabwe & Alinaitwe Mukonyezi (2026) Linking soil fertility management practices to perceptions of soil fertility status among smallholder farmers in Kabarole District and Fort Portal City, Western Uganda, International Journal of Agricultural Sustainability, 24:1, 2701501, DOI: 10.1080/14735903.2026.2701501

To link to this article: https://doi.org/10.1080/14735903.2026.2701501

Published online: 17 Jul 2026.

INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY
2026, VOL. 24, NO. 1, 2701501
https://doi.org/10.1080/14735903.2026.2701501

RESEARCH ARTICLE

OPEN ACCESS Check for updates

Linking soil fertility management practices to perceptions of soil fertility status among smallholder farmers in Kabarole District and Fort Portal City, Western Uganda

Cosmas Wacal[a], John Sekajugo[b], David Agole[c], Geoffrey Candia[a], Bruce Nyamweha[a], Collins Muhangi[a], Jacob Kaingo[a], Costa Gumisiriya[a], Joseph Okello[a], Jimmy Obala[a], Eriya Kule Birengesyo[c], Cecilia Kansiime[c], Ronald Buwa[a], Athanasius Ssekyanzi[a], Eva Tereka[c], John Patrick Kanahe Kagorora[a], Jack Turihohabwe[d] and Alinaitwe Mukonyezi[e]

[a]Department of Crop and Animal Production, Faculty of Agriculture and Environmental Sciences, Mountains of the Moon University, Fort Portal, Uganda; [b]Department of Environment, Natural Resources and Tourism, Faculty of Agriculture and Environmental Sciences, Mountains of the Moon University, Fort Portal, Uganda; [c]Department of Extension and Community Engagement, Faculty of Agriculture and Environmental Sciences, Mountains of the Moon University, Fort Portal, Uganda; [d]Department of Computer Science, Faculty of Science Technology and Innovations, Mountains of the Moon University, Fort Portal, Uganda; [e]Directorate of Information and Communication Technology, Mountains of the Moon University, Fort Portal, Uganda

ABSTRACT

Declining soil fertility remains a major constraint to agricultural productivity and livelihoods of smallholder farmers in Uganda. This study assessed the adoption of soil fertility management practices and their association with perceived soil fertility status among smallholder farmers in Kabarole District and Fort Portal City, Western Uganda. A cross-sectional survey was conducted among 300 randomly selected farmers. Descriptive statistics and binary logistic regression were used to analyze the relationship between perceived soil fertility status and adoption of management practices. Results showed that 77.3% perceived their soils as having low fertility, mainly due to continuous cropping, soil erosion, and deforestation. Conservation tillage (53%), mulching (46%), and manure application (35%) were the most adopted practices, although overall adoption remained low. Moreover, binary logistic regression revealed that conservation tillage (OR = 1.92, $p = 0.037$) and manure application (OR = 3.34, $p = 0.002$) were significantly associated with farmers reporting low soil fertility, whereas chemical fertilizers (OR = 0.36, $p = 0.022$) and intercropping (OR = 0.42, $p = 0.011$) were associated with fertile soils. These findings highlight the need to promote integrated soil fertility management practices and validate farmers' perceptions through laboratory soil analyses to guide evidence-based interventions.

ARTICLE HISTORY
Received 6 September 2025
Accepted 6 July 2026

KEYWORDS
Nutrient depletion; soil and water conservation; experiential learning; crop productivity; soil degradation

1. Introduction

Soil fertility decline is a major threat to agriculture and livelihoods in Sub-Saharan Africa (SSA), including Uganda, where over 60% of the population relies on smallholder agriculture (Sanchez, 2002; Tindwa et al., 2019; UBOS (Uganda Bureau of Statistics), 2024). Declining soil fertility is evidenced by the low nutrient levels across farming systems in the Rwenzori region, Western Uganda. In Uganda,it is estimated that 38.1 kg/ha of nitrogen (N), 16.5 kg/ha of phosphorus (P) and 32.2 kg/ha of potassium result in a total of 86.8 kg/ha are lost per year (IFDC International Fertilizer Development Center, 2017), and fertilizer use remains among the lowest globally, at less than 2 kg/ha/year (Wacal et al., 2023). As a result, food insecurity persists, especially in rural areas where livelihoods depend on agriculture (Apanovich & Mazur, 2018; Tindwa et al., 2019). Addressing soil fertility decline is therefore imperative for sustainable crop production and ultimately, for achieving long-term food security.

CONTACT Cosmas Wacal cwacal@gmail.com Department of Crop and Animal Production, Faculty of Agriculture and Environmental Sciences, Mountains of the Moon University, P.O. Box 837, Fort Portal, Uganda

Evidence from research indicates that smallholder farmers should adopt a combination of soil fertility management practices aimed at reducing nutrient mining, soil erosion, and building organic matter stock (Abdallah, 2024; Mupambwa et al., 2022; Tittonell et al., 2008). Usually, these practices include nutrient replenishment, such as chemical fertilizer application, local adaptations, such as contour ploughing, terracing, mulching, crop rotation, intercropping, and agroforestry, among others (Homeshwari-Devi et al., 2024; Shekhar et al., 2024). The adoption and implementation of these soil management practices are essential for maintaining soil fertility, improving crop productivity, and ensuring the long-term sustainability of agricultural systems. For instance, the application of chemical fertilizers and manure plays a significant role in replenishing essential plant nutrients that are often depleted through continuous cropping and nutrient mining. Chemical fertilizers and manure provide readily available nutrients such as nitrogen (N), phosphorous (P), and potassium (K), which significantly increase crop growth and yield when applied appropriately (Bhatt et al., 2019). In SSA, fertilizer use has been shown to improve nutrient availability in soils with low inherent fertility and enhance crop productivity when combined with other soil fertility management practices (Ichami et al., 2019; Sanchez, 2002).

Furthermore, soil and water conservation measures such as contour ploughing, conservation tillage, terracing, mulching, crop rotation, intercropping, and agroforestry play a critical role in maintaining soil fertility and preventing land degradation in agricultural systems (Ahuchaogu et al., 2022). Contour ploughing, which involves ploughing along the natural contours of the land, reduces runoff velocity, minimizes soil erosion, and enhances water infiltration; thereby conserving soil nutrients and moisture in the sloping landscape (Farahani et al., 2016). Similarly, terracing reduces slope length and gradient, helps control soil erosion and retains water and nutrients within fields, particularly in hilly and mountainous areas (Rutebuka et al., 2021). Moreover, practices such as mulching contribute to soil and water conservation, improving organic matter and soil structure as the residues decompose. In addition, crop rotation and intercropping enhance soil fertility and resource use efficiency by improving nutrient cycling, promoting biological nitrogen fixation in legume-based systems, and reducing pests and disease pressure (Al-Musawi et al., 2025). On the other hand, agroforestry further strengthens soil and water conservation by integrating trees with crops or livestock, which enhances nutrient recycling through litterfall, improves soil organic matter, reduces soil erosion, and creates favourable microclimatic conditions while providing additional farm products such as fuelwood, fodder and fruits (Nagar et al., 2022; Sileshi et al., 2020). Overall, these practices contribute to improved soil fertility and sustainable agricultural productivity.

Despite the promotion of these soil fertility management practices in SSA Uganda, their adoption remains significantly low (Anang et al., 2021; Mugwe et al., 2009; Woniala & Nyombi, 2014). For instance, a study conducted in Eastern Uganda around Mt. Elgon by Woniala and Nyombi (2014) showed that there is still low adoption of manure (1.3%), chemical fertilizer application (24.1%), mulching (11.4%) and cover cropping (6.3%). The authors also reported low adoption of soil erosion control measures linked to soil fertility management, including the use of retention ditches, terracing, fanya juu and fanya chini trenches, and contour bands. Furthermore, a study conducted in Ghana by Kwadzo and Quayson (2021) reported that the adoption of minimum tillage, crop rotation, chemical fertilizers and the integration of leguminous crops as soil fertility management practices was 26.66%. Similar evidence from Zambia shows that the adoption of soil fertility practices remains uneven, with manure application adopted by 4.75% of farmers, intercropping by 3.87%, minimum tillage by 1.32%, and residue retention/mulching by 33.91% (Chikopela et al., 2024). In terms of agroforestry, technologies such as alley cropping and improved fallow practices have been promoted to enhance soil fertility through biological nitrogen fixation and organic matter addition. However, adoption has been relatively low. More still, a study from Kenya indicates that moderate adoption of soil and water conservation practices, including minimum tillage and terraces, among smallholder farmers showed that 65.33% of farmers had adopted the soil and water conservation practices, while 34.67% had not adopted them. The study further found that the implementation of these practices was limited by a lack of capital (76.53%), high labour costs (62.24%), a lack of technical knowledge (34.69%), inadequate infrastructure (17.35%) and insecure land tenure (1.02%) (Rotich et al., 2024). Furthermore, chemical fertilizer usage varies widely across SSA but remains relatively low compared to global averages. For example, a study of maize farmers in Western Uganda found that only 32% of the farmers used inorganic fertilizers because of high input costs and limited access to credit (Midamba et al., 2025). Overall, these studies indicate that there is still low adoption of soil fertility management practices, which has exacerbated low crop productivity.

While the adoption of soil fertility management practices has been extensively emphasized across farming systems in SSA, including Uganda, farmers' understanding and interpretation of soil fertility decline varies considerably across contexts (Akinbode et al., 2024; Kenfack Essougong et al., 2020; Musinguzi et al., 2015). Some studies report that farmers rely primarily on observable indicators such as crop performance, soil colour, and weed composition to assess soil fertility, rather than scientific soil testing or nutrient balance (Alela et al., 2024; Berazneva et al., 2016). Through the use of practices such as manure application, mulching, agroforestry, intercropping and fertilizer use, farmers observe changes in crop performance and soil conditions, shaping their perceptions of soil fertility over time. These perceptions reflect not only observable soil characteristics but also farmers' experiences with management practices and their effects on crop productivity. Understanding how farmers interpret soil fertility status based on soil fertility management interventions that align with farmers' knowledge and practices is paramount. Although, several studies in Africa have examined the adoption level and determinants of the adoption of soil fertility management practices, such as socio-economic characteristics, farm size, access to extension, and institutional factors, few have explicitly analyzed how farmers' perceptions of soil fertility status shape their management decisions (Aura, 2016; Bonabana-Wabbi et al., 2016; Houndete & Djego, 2023; Mponela et al., 2016; Wawire et al., 2021). This knowledge gap is particularly evident in the ecologically fragile Rwenzori sub-region of Western Uganda, where soil erosion, nutrient depletion, and land fragmentation are widespread, yet empirical evidence linking farmers' perceptions to management decisionsremains limited.

In this study, we take a broader perspective that farmers rely on experiential knowledge derived from the implementation of soil management practices to evaluate the condition of their soils. Changes in crop vigour, yield performance, and soil physical properties following the application of soil fertility management practices may influence how farmers interpret whether soil fertility is fertile or less fertile. Examining the relationship between soil fertility management practices and farmers' perceptions of soil fertility status provides valuable insights into how farmers assess soil conditions within their farming systems and how management experiences shape these perceptions. We use a model based on experiential learning theory, which suggests that individuals develop knowledge and perceptions through direct experience and observation of outcomes in their environment. According to this theory, learning occurs through a cyclical process involving experience, reflection, conceptualization, and experimentation (Kolb, 1984). In agricultural systems, farmers observe the performance of crops under different soil management practices and use these observations to interpret the condition and productivity of their soils. Consequently, the soil fertility management practices implemented by farmers may shape how they perceive the status and trends of soil fertility over time. We therefore used a binary logistic regression model to examine the association between these practices and farmers' perceived soil fertility status.

This study, therefore, aimed to determine the adoption of soil fertility management practices and examine their association with farmers' perceptions of soil fertility status, particularly whether farmers perceived their soils as fertile or less fertile at the time of the survey in the Kabarole District and Fort Portal city, Western Uganda. The study highlights that farmers' experiential knowledge may be associated with both the perceived soil fertility status and the management practices implemented on their farms in Uganda, underscoring the need for participatory, farmer-centred extension systems that integrate local knowledge with scientific recommendations. Aligning agricultural policies and extension services with farmers' experiences is crucial for improving adoption, restoring soil fertility, and enhancing sustainable agricultural productivity.

2. Methodology

2.1. Site location

This study was conducted in Kabarole District and Fort Portal city in Western Uganda, which are located at coordinates 0°39'16.0"N, 30° 16' 28.0"E (Latitude: 0.654444; Longitude: 30.274444) (Figure 1). Kabarole District has a population of 230,368 people, while Fort Portal City has a population of 137,549 (UBOS (Uganda Bureau of Statistics), 2024). Kabarole District is located in Western Uganda and is bordered by

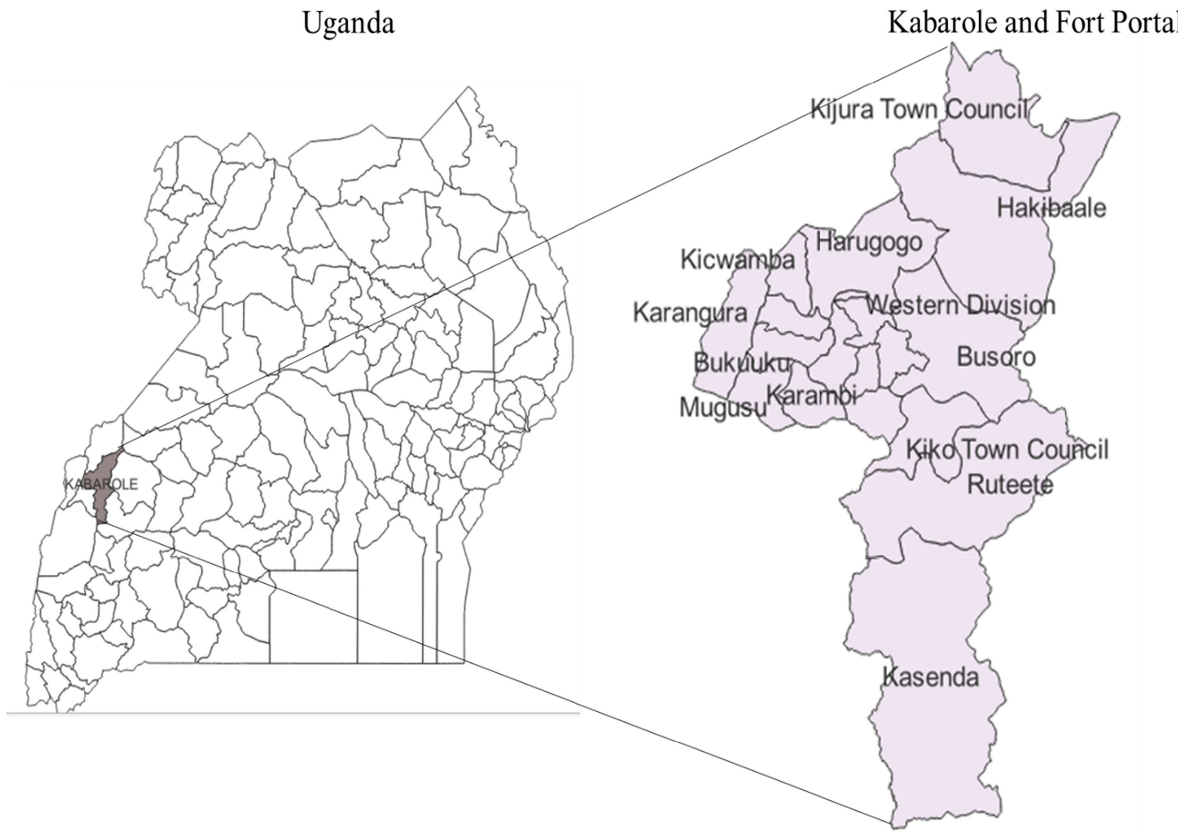

Figure 1. Map of the study area (Kabarole District and Fort Portal City).

Kamwenge district in the north, Bundibugyo district in the northwest, Kasese to the west, and Kyenjojo to the East. Fort Portal City serves as the main town for Kabarole District, situated approximately 300 km from Kampala, the capital city of Uganda.

Both Kabarole District and Fort Portal City experience a bimodal rainfall pattern characterized by a humid tropical environment, with the first rainy season occurring in March, April and May, while the second rainy season occurs in September, October and November (UBOS (Uganda Bureau of Statistics), 2024). The annual mean rainfall ranges from 1000 to 2000 mm, and the dominant soils of the study area are Andosols and Ferralsols, with the two locations also experiencing relatively moderate temperatures averaging between 22.5°C and 25.5°C, respectively (Kabarole District Local Government, 2023).

2.2. Research design

This study used a cross-sectional survey research design while adopting the quantitative research method to gather data from smallholder farmers in Kabarole district and Fort Portal City. Precisely, data was collected through a household survey, where structured interviews were conducted with farmer respondents, and observations of farmlands were made. The questionnaire captured key information on farmers' sociodemographic characteristics, including age, gender, education level, and household composition, among others. It also collected from characteristics, such as farm size, land under perennial crops, land ownership, and major farming enterprises. In addition, the tool assessed farmers' perceptions of crop yield reduction and their perception of the status of soil fertility. Furthermore, the questionnaire examined farmers' perceptions of the major causes of soil fertility decline, alongside the soil fertility management practices adopted, including both agronomic and soil and water conservation measures. These components provide a comprehensive basis for analyzing the relationship between farmers' practices and their perceptions of soil fertility dynamics.

2.3. Sample size and sampling techniques

A total of 300 smallholder farmers were sampled and surveyed across the sub-counties of Kabarole District and Fort Portal City. The sample was distributed to ensure adequate representation of farmers within the study area. The data collected focused on soil fertility management practices and farmers' perceptions regarding soil fertility. The selected sample size was considered sufficient to generate meaningful insights into prevailing practices and perceptions among smallholder farmers in the study area.

2.3.1 Sampling techniques

To ensure representativeness, the district and city was stratified by sub-county (Table 1). Within each sub-county, proportional random sampling was applied using farmer lists obtained from local extension offices. This sampling procedure ensured proportional representation across the district and minimized systematic bias, thus making the findings generalizable to smallholder farmers in Kabarole District and Fort Portal City.

2.4. Informed consent statement

Participation in this study was voluntary. All the respondents were fully informed about the purpose of the research, the procedure involved, and their right to withdraw at any point without any consequences. The principle of informed consent was explained verbally and reiterated on the questionnaire before data collection.

2.5. Data analysis

The data collected were analyzed using descriptive and inferential statistics using the SPSS Version 25 statistics software. The descriptive statistics included frequencies, percentages and graphical summaries to describe the distribution of responses among farmers.

To examine the relationship between soil fertility management practices and farmers' perceptions of soil fertility status, a binary logistic regression model was estimated (Equation (1)). The model was used to identify the soil fertility management practices associated with farmers' perceived soil fertility status at the time of the survey. Farmers' perceptions of soil fertility are often shaped by their farming experiences and the observed outcomes of management practices implemented on their farms.

In the binary logistic regression model, the dependent variable was farmers' perceived fertility status, which was coded as 1 if the farmer perceived the soil as having low fertility status and 0 if the farmer perceived the soil as fertile. The independent variables consisted of soil fertility management practices implemented by farmers, including conservation tillage, application of manure, agroforestry, mulching, terracing, contour ploughing, and application of chemical fertilizers, intercropping, cover cropping, vegetative strips and trenches.

Table 1. Sampling frame.

Sub-counties/division	Sample
Busoro	22
Hakibale	14
Harugongo	12
Kabasi	24
Kabende	39
Kasenda	25
Kichwamba	19
Kijura	16
Kiko Town Council	19
Mugusu	39
Fort Portal North division	25
Ruteete	12
Rwengaju	19
Karangura	15
Total	300

The binary logistic regression model was specified as follows:

$$Logit\ (Y) = \ln\left(\frac{P}{1-P}\right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon_i \ldots\ldots\ldots \quad (1)$$

where:

Y = dependent variable (perception of soil fertility), where 1 = low fertility and 0 = fertile;
α = intercept
$\beta_1,\ldots\beta_n$ = coefficients of the explanatory variables
$X_1\ldots X_n$ = soil fertility management practices
P = probability that a farmer perceives the soil as having low fertility status
1-P = probability that a farmer perceives the soil as fertile
ln = natural log
ε_i = error term
The explanatory variables included:
X_1 = conservation tillage
X_2 = application of manure
X_3 = agroforestry
X_4 = mulching
X_5 = terracing
X_6 = contour ploughing
X_7 = application of chemical fertilizers
X_8 = intercropping
X_9 = cover cropping
X_{10} = vegetative strips
X_{11} = trenches

3. Results

3.1. Sociodemographic characteristics of farmers

The results of the sociodemographic characteristics of the respondents are shown in Table 2. The results show that 56.0% of the respondents were female, while the rest were male (44.0%). In addition, the majority (70.7%) of the respondents were within the age bracket of 18–45 years. The results also revealed that most respondents (75.3%) were married, with the largest share (60.7%) belonging to households of 1–5 members.

In terms of education, 45.7% of the respondents had attained primary education, followed by 35.3% with secondary education, while only 6.3% had attained tertiary education level. Furthermore, the results show that the majority (77.3%) of the respondents reported being entirely dependent on farming as their main occupation. Overall, the sociodemographic findings indicate that female farmers are mainly engaged in agricultural production, and that most farmers are in a youthful age, confirming that the women in Uganda drive agriculture. In addition, there has been a drive to support youth engagement in agriculture due to the widespread unemployment in the formal job sectors. Thus, interventions such as soil fertility management technologies should be scaled down to farmers who include the majority as women and youths.

3.2. Farm characteristics

The results for the farm characteristics are indicated in Table 3. The results show that the majority (73.3%) of respondents cultivate less than 2 acres of land, with only 0.7% owning more than 10 acres. Most farmers (71.3%) dedicate 0.5–1 acre to perennial crop production. In addition, the predominant land tenure system is freehold (49.3%), followed by customary (41.7%), while a small proportion of farmers hold either leasehold (6.0%) or mailo (2.7%) tenure systems.

Furthermore, the results reveal that 66.3% of the respondents are engaged in both crop and livestock farming enterprises, whereas only 0.3% practice livestock-only farming, and one-third (33.3%) focus on only

Table 2. Sociodemographic characteristics of farmers.

Variable	Category	Frequency (*n*)	Percent (%)
Gender	Male	132	44.0
	Female	168	56.0
	Total	300	100.0
Age	18–35	105	35.0
	36–45	107	35.7
	46–60	54	18.0
	60 and above	34	11.3
	Total	300	100.0
Marital status	Single	46	15.3
	Married	226	75.3
	Widow	21	7.0
	Divorced	7	2.3
	Total	300	100.0
Family size	1–5	182	60.7
	6–10	108	36.0
	11–15	10	3.3
	Total	300	100.0
Education	Primary	137	45.7
	Secondary	106	35.3
	Tertiary	19	6.3
	None	38	12.7
	Total	300	100.0
Main occupation	Entirely farmer	232	77.3
	Professional job	27	9.0
	Casual labourer	15	5.0
	Others	26	8.7
	Total	300	100.0

Table 3. Farm characteristics.

Variable	Category	Frequency (*n*)	Percent (%)
Agricultural land	Less than 2 acres	220	73.3
	5–10 acres	78	26.0
	10 acres and above	2	0.7
	Total	300	100.0
Land under perennial crops	0.5–1 acres	214	71.3
	1.5–2 acres	64	21.3
	2.0–3 acres	11	3.7
	3 acres and above	11	3.7
	Total	300	100.0
Land ownership	Leasehold	18	6.0
	Freehold	148	49.3
	Mailo	8	2.7
	Customary	125	41.7
	Others	1	0.3
	Total	300	100.0
Major farming enterprises	Livestock	1	0.3
	Crops	100	33.3
	Both livestock and crops	199	66.3
	Total	300	100.0
labour	Hired labour	10	3.3
	Family labour	174	58.0
	Both hired and family labour	116	38.7
	Total	300	100.0

crop production. To manage these enterprises, the majority of the respondents depend on family labour (58%) to perform farm activities, whereas 38.7% combine both family and hired labour for carrying out farm activities.

3.3. Major crops cultivated and perception on yield

The results of the proportion of respondents cultivating various crops are shown in Figure 2. Among the crops commonly cultivated, banana is the most reported crop, being grown by over 85% of farmers, followed by beans (80%), cassava (70%), and maize (65%). The moderately cultivated crops included sweet potatoes (55%) and potatoes (45%). There were fewer than 40% of the respondents engaged in coffee and vegetable farming.

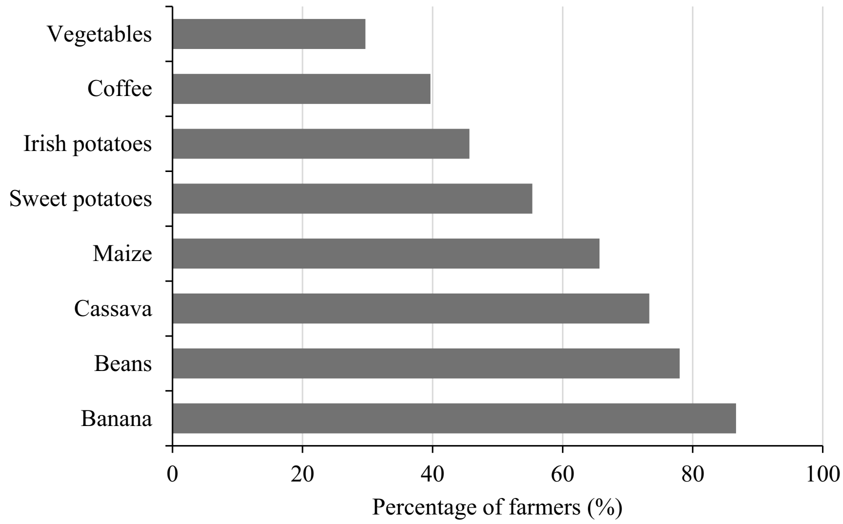

Figure 2. Proportion of smallholder farmers growing various crops.

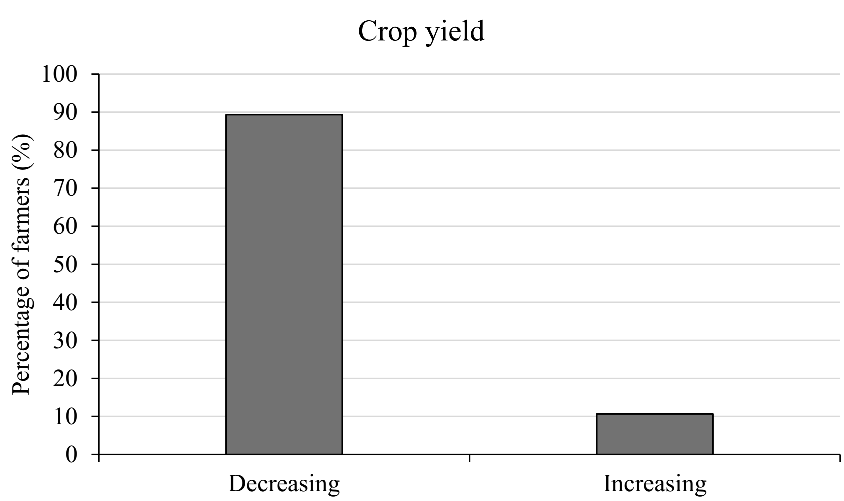

Figure 3. Proportion of smallholder farmers' perception on crop yield.

In terms of crop yield, the majority of the respondents (89.3%) reported declining crop yields, while only 10.7% indicated an increase (Figure 3).

When probed on the causes of crop yield decline, most frequently reported causes by the respondents included soil exhaustion (88.3%), soil erosion (75.3%), drought (58%), crop pests and diseases (44%), poor yielding varieties (31%) and poor quality seeds (26.7%) (Figure 4). On the other hand, a lack of labour for weeding (17%) and excessive use of chemical fertilizers (12.7%) were treated as less important causes of crop yield decline.

3.4. Status of soil fertility

The results further revealed that 77.3% of the respondents perceived their soils as having low fertility status, while (22.7%) perceived their soils as fertile (Figure 5). Furthermore, the results indicate that farmers perceive natural processes and human activities as major contributors to the decline in soil fertility (Table 4). Precisely, most farmers agreed (48.67%) while 51.0% strongly agreed that soil erosion caused by heavy rainfall leads to significantly higher losses in terms of soil fertility. Several respondents agreed that ploughing along the slope (49.00%), overgrazing (54.00%), deforestation (46.33%) and bush burning

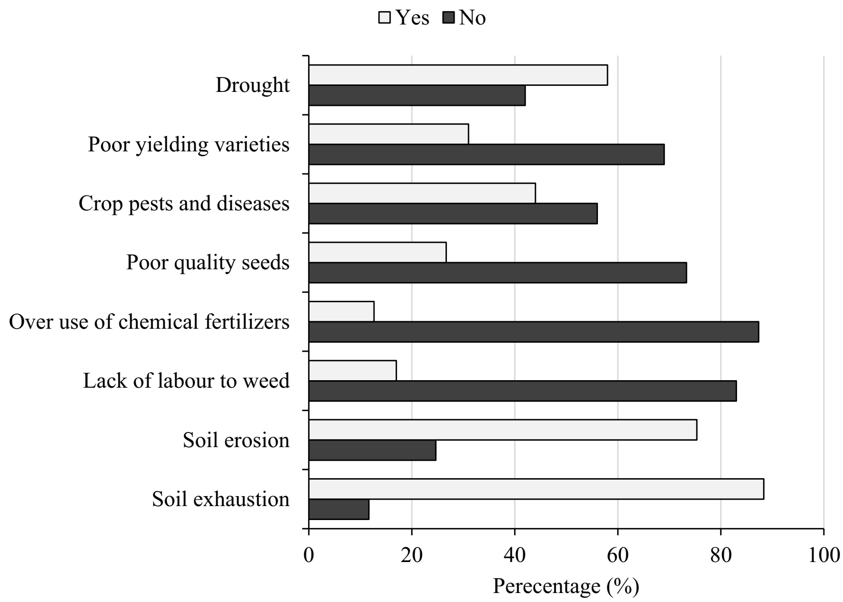

Figure 4. Perceived causes of crop yield declines among respondents.

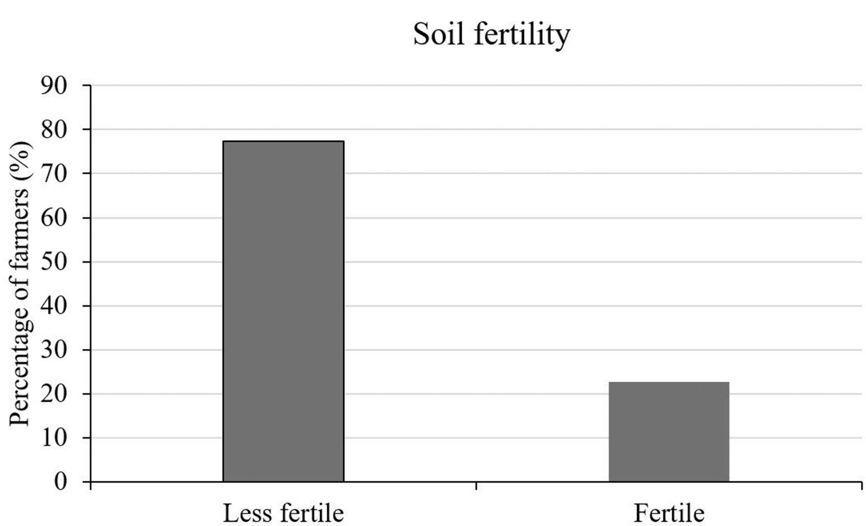

Figure 5. Perceived status of soil fertility among respondents.

Table 4. Perception on the major causes of soil fertility loss.

	Agree		Strongly agree		Disagree		Strongly disagree	
Causes of soil fertility loss	*n*	%	*n*	%	*n*	%	*n*	%
Heavy rainfall erosion	146	48.67	153	51.00	1	0.33	0	0.00
Ploughing along slopes	147	49.00	132	44.00	20	6.67	1	0.33
Overgrazing	162	54.00	84	28.00	49	16.33	5	1.67
Deforestation	139	46.33	101	33.67	55	18.33	5	1.67
Bush burning	146	48.67	93	31.00	59	19.67	2	0.67
Continuous cropping/over cultivation	79	26.33	215	71.67	5	1.67	1	0.33
Mining	40	13.33	31	10.33	137	45.67	92	30.67
Waste pollution	51	17.00	22	7.33	124	41.33	103	34.33

(48.67%) are also major contributors to soil fertility decline in the region. On the other hand, a significant number of respondents ($n = 215$) strongly agreed (71.67%) that continuous cropping (also over-cultivation) significantly decreases soil fertility in the study area. In contrast, mining and waste pollution were not widely perceived as major causes of the decline in soil fertility in the study area.

3.5. Management practices adopted by farmers

The various soil fertility management practices adopted by farmers in the study area are shown in Figures 6 and 7. The results revealed relatively low adoption rates of soil fertility management practices in Kabarole and Fort Portal City. The most commonly practiced management technologies on a moderate scale included conservation tillage (53%), mulching (46%) and intercropping (36%). Contrarily, there was limited adoption of manure application (35%), construction of trenches (26%), and cover cropping (19.7%) as key soil management technologies. Similarly, a limited number of respondents reported using chemical fertilizers (9.7%), agroforestry (11.3%), contour ploughing (12.7%), terracing (13.3%) and vegetative strips (12%) in soil fertility management.

3.6. Relationship between the perceived status and soil fertility management practices

The results of the relationship between the perceived status of soil fertility and the adoption of management practices are shown in Table 5. The binary logistic regression analysis was conducted to examine which soil fertility practices are likely to be adopted by farmers who perceive the soil fertility status. The binary logistic regression analysis examined associations between farmers' perceived soil fertility status and the soil fertility management practices implemented on their farms. Conservation tillage (OR = 1.92; $p = 0.037$) and manure application (OR = 3.34; $p = 0.002$) were positively associated with respondents reporting low soil fertility status. These results indicate that conservation tillage and manure application were more commonly reported among farmers who perceived their soils as having low fertility status.

In contrast, the application of chemical fertilizers ($p = 0.022$) is associated with lower odds (0.36 times) and has a negative effect on the soil fertility status, implying that farmers who perceive their soils as fertile are those applying chemical fertilizers. Similarly, intercropping ($p = 0.011$) also shows a significant negative association, with an odds ratio of 0.42, indicating that farmers practicing intercropping perceived that their soil fertility improved at the time of the survey. This implies that the application of chemical fertilizers and intercropping are adopted by farmers, who now perceive that their soils are fertile. On the contrary, other

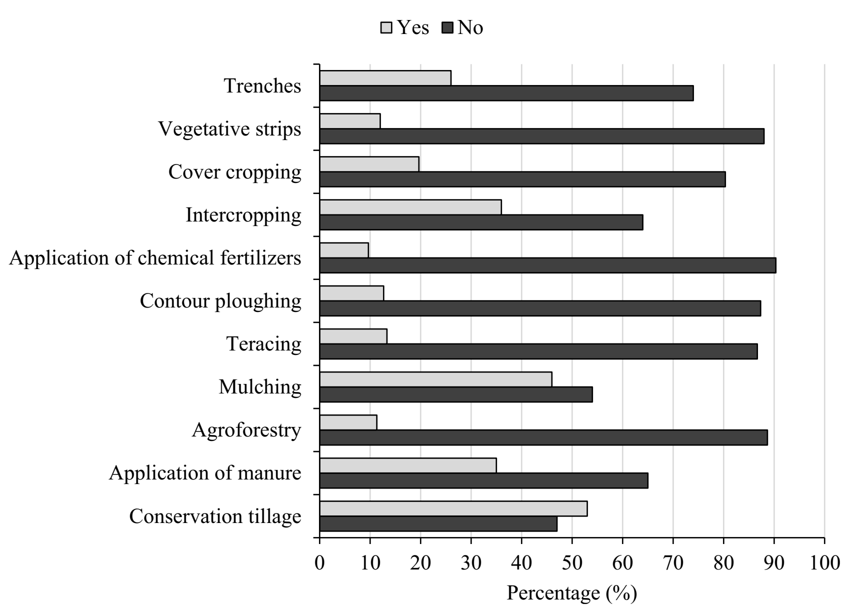

Figure 6. Proportion of farmers implementing various soil fertility management practices.

Figure 7. Trenches (above) and mulching (below) in banana plantations by farmers.

Table 5. Binary logistic regression analysis indicating the relationship between the perceived status and soil fertility management practices.

Independent variables	B	S.E.	Wald	Sig.	Exp(B)
Conservation tillage	0.65069	0.311967	4.350399	0.037*	1.916862
Application of manure	1.205522	0.38881	9.613368	0.001932**	3.338501
Agroforestry	−0.736	0.56082	1.722289	0.189399	0.479027
Mulching	0.563067	0.342956	2.695524	0.10063	1.75605
Terracing	−0.85432	0.63829	1.791468	0.180747	0.425571
Contour ploughing	−0.15045	0.57169	0.069256	0.792423	0.860322
Application of chemical fertilizers	−1.01371	0.44211	5.25737	0.021854*	0.36287
Intercropping	−0.85693	0.337897	6.431616	0.011211*	0.424464
Cover cropping	−0.5171	0.470134	1.209756	0.27138	0.59625
Vegetative strips	0.470068	0.597638	0.61865	0.431549	1.600103
Trenches	0.421766	0.450411	0.876846	0.349067	1.524651
Constant	−0.16743	0.621065	0.072673	0.787484	0.845839

The dependent variable (perception of soil fertility), where 1 = declining and 0 = improving.

practices, such as agroforestry, terracing, mulching, contour ploughing, vegetative strips, cover cropping, and trenches, did not show statistically significant effects on the perception of soil fertility status ($p > 0.05$).

4. Discussion

This study examined smallholder farmers' perceptions of soil fertility status, their causes of crop yield decline, and how these perceptions relate to their adoption of soil fertility management practices. Specifically, this study aimed to analyze the adoption of soil fertility management practices and examine their association with farmers’ perceptions of soil fertility status, particularly whether soil fertility is perceived as less fertile or fertile following the implementation of specific practices. The results showed that the majority of farmers reported declining crop yields attributed to low soil fertility resulting from soil degradation factors such as soil exhaustion due to continuous cropping/over-cultivation, soil erosion due to heavy rainfall, ploughing along slopes, deforestation and bush burning. The results also revealed that farmers reporting low soil fertility status were more likely to report the use of practices such as conservation tillage and manure application. This finding demonstrates a significant association between farmers' perceived soil fertility status and the management practices reported at the time of the survey.

In this study, the dominance of women and youth among smallholder farmers, most of whom depend on agriculture and operate on small landholdings with family labour, has important implications for soil fertility management (Table 2). These characteristics suggest that interventions must be deliberately designed to align with the socio-economic realities and decision-making structures within such farming systems. This finding is consistent with that of Galabuzi et al. (2021), who reported that largely women and youths are engaged in soil fertility management practices such as agroforestry to restore degraded farmland in Eastern Uganda. In fact, the role of women in decision making of soil fertility management practices is very important and has been emphasized in the adoption of fertilizer application, manure usage and other soil and water conservation practices focusing on increased soil fertility (Mponela et al., 2022).

Furthermore, the findings indicated that a large proportion of the respondents depend on family labour, which could influence the level of adoption of soil fertility management practices. Similar research has reported that in SSA, several families rely on family labour to produce the largest share of their crops on the farm, and it is common to find mostly women and youthful children engaged in the farm activities (Moyo, 2016). However, this over-reliance on women and family labour impacts soil fertility management in several ways, influencing both the adoption of soil fertility techniques and the sustainability of agricultural practices. Unfortunately, women often lack access to resources such as cash and credit, which are essential for acquiring fertilizers and other inputs (Gladwin, 2002; Sullivan, 2002). Therefore, the empowerment of women in decision-making can lead to increased adoption of certain soil fertility practices (Mponela et al., 2021). In terms of family labour, particularly from women, it is crucial in managing smallholder farms, but the dependency ratio can negatively impact the application of organic amendments, as more dependents per worker reduce the likelihood of adopting such practices (Mponela et al., 2021).

Furthermore, the predominance of staple crops such as cassava, maize, and sweet potatoes alongside widespread reports of declining yields and deterioration in perceived soil fertility underscores the strong linkage between crop choice and soil fertility dynamics in smallholder systems (Figure 2). These crops, while they are central to household food security, are often associated with continuous cultivation and limited nutrient replenishment, which accelerates soil nutrient mining and long-term productivity decline.

The limited engagement in high-value but input-sensitive enterprises, such as vegetables and coffee, further suggests that farmers may be constrained by market access, perishability concerns, and input requirements. This has implications for soil fertility management, as staple-based systems tend to prioritize subsistence over investment in soil-improving practices. Consequently, farmers may be less inclined to adopt external inputs or diversified nutrient management strategies, reinforcing cycles of low-input, low-output agriculture.

Farmers' attribution of yield decline primarily to soil exhaustion, erosion, and drought reflects a strong awareness of the biophysical drivers of soil degradation (Figure 4). This perception aligns with empirical evidence linking nutrient depletion and soil erosion to declining crop productivity in Uganda (Karamage et al., 2017; Nyabonga et al., 2022). In addition to soil erosion, farmers practice continuous cropping without nutrient addition from external sources such as crop residue return, biochar application and other sources of organic amendments, which negatively affect crop production (Kayuki et al., 2017; Wacal et al., 2023). Overall, the result is in agreement with those of Nabyonga et al. (2022), who reported that soil fertility losses perceived by farmers as soil exhaustion and manifested in the form of soil erosion are associated with crop yield declines. It is estimated that the nutrient losses of 38.1 kg/ha *N*, 16.5 kg/ha P_2O_5, and K_2O 32.2 kg/ha lead to a total of 86.8 kg/ha per year occur on farmers' fields and negatively affect crop yields in Uganda, posing a major threat to food security (IFDC International Fertilizer Development Center, 2017). Furthermore, drought associated with limited water availability for plant growth has posed a challenge in Uganda leading to large crop yield gaps (Epule & New, 2019). Therefore, crop yields have been significantly lower than the potential attributed to soil fertility loss and climate change-related challenges such as drought, pests and diseases (Epule et al., 2021).

Furthermore, the widespread recognition of overgrazing, deforestation and bush burning as key drivers of soil fertility decline reflects farmer's string awareness of the land degradation process (Table 4). These practices contribute to the removal of vegetation cover, leaving soils exposed to erosion, nutrient depletion, and reduced organic matter. In particular, overgrazing and deforestation accelerate soil structure breakdown and limit natural regeneration, while bush burning further exacerbates nutrient losses and has broader environmental implications, including increased greenhouse gas emissions and climate change (Turyasingura et al., 2022). On the contrary, mining and waste pollution were not widely perceived as major threats, possibly because of limited mining activity or waste disposal issues in the area studied. This indicates that while farmers' perceptions are strong regarding traditional causes of soil degradation, extension services need to broaden awareness of less visible but increasingly important anthropogenic drivers. However, this may also indicate that soil degradation in the area is primarily driven by agricultural and land use practices rather than by industrial activities.

Morestill, the adoption of soil fertility management practices was generally low. Only a few practices, such as conservation tillage, mulching, and intercropping, showed moderate uptake, while manure application and trenching were used to a limited extent. Moreover, more sustainable and intensive practices, including agroforestry, terracing, contour ploughing, chemical fertilizer use, vegetative strips, and cover cropping, have rarely been adopted. These findings demonstrate that although farmers recognize that soil fertility has declined, the translation of this perception into the widespread adoption of improved practices remains limited. The adoption of soil fertility management practices is key in improving crop yields but also incomes for smallholder farmers. Research shows that farmers who adopt improved soil fertility management practices tend to have high crop yields and therefore higher incomes compared to their counterparts who have not fully adopted the practices (Vanlauwe et al., 2015; Yamano & Kijima, 2010). A research in Northern Ghana, indicated that the adoption of key soil fertility management practices, including crop rotation, inorganic fertilizers, and farmyard manure, resulted in an 86.52% increase in maize yield and a 51.29% increase in net income from maize production (Boansi et al., 2024). Furthermore, in Ethiopia, the adoption of soil fertility management practices led to a significant increase in land productivity and net crops directly translated into high incomes for farmers (Hörner & Wollni, 2022).

On the contrary, our findings suggest that the adoption of soil fertility management practices such as mulching, manure application, terracing, chemical fertilizer use and cover cropping, among others, was low as the case in other SSA. The adoption and utilization of these soil fertility management practices are hindered by several factors, ranging from socioeconomic, institutional and technical constraints. For instance, high labour demands and associated costs discourage smallholder adoption of practices such as composting, mulching, or conservation tillage in Africa (Mponela et al., 2016; Vanlauwe et al., 2015). In addition, a lack of access to extension services and training limits farmer knowledge of the soil fertility management practices, which eventually affect the level of adoption (Gwandu et al., 2014; Mutua-Mutuku et al., 2017).

The results further show that farmers who perceive that their soils are low in fertility are likely to adopt conservation tillage and the application of manure as key soil fertility improvement strategies, as established by the binary logistic regression model. The adoption of conservation tillage and manure application suggests responsiveness to restore lost soil fertility. Conservation tillage is a practice that helps farmers retain large quantities of crop residues, which eventually enhance soil aggregate stability and soil structure, organic carbon, as well as reducing erosion, and that is practically relevant for farmers aware of slope-related losses of fertility in the Rwenzori region (Beukes & Swanepoel, 2017; Mubiru et al., 2017). On the other hand, manure application enriches the soil with organic matter and nutrients (especially nitrogen, phosphorus, and potassium), which replenish depleted soils and improve their fertility, structure, build biodiversity and soil health (Vanlauwe et al., 2015), thus countering depletion and aligning with farmers' perceptions. These findings suggest that conservation tillage and manure application are commonly implemented among farmers reporting low soil fertility status and may represent locally preferred management options. This is because practices such as manure application, farmyard manure and possibly conservation tillage are affordable to farmers, unlike the expensive chemical fertilizers that are unaffordable or unavailable (Abebe et al., 2022; Rubagumya et al., 2023). These are normally observed as a low-cost substitute for soil fertility management practices in SSA, including Uganda, and therefore should be promoted among smallholder farmers.

In contrast, the regression analysis indicated that users of chemical/inorganic fertilizers (OR = 0.36) and intercropping (OR = 0.42) were more likely to perceive stable or improved fertility (Table 5). This association may reflect the interaction between management practices and farmers' assessments of soil conditions. However, the direction of this relationship cannot be determined using cross-sectional data. Usually, chemical fertilizers release nutrients faster than organic inputs, thereby improving crop performance within a short period (Wato et al., 2024). This makes smallholder farmers who use chemical fertilizers such as DAP (Diammonium phosphate), CAN (Calcium Ammonium Nitrate), and NPK (Nitrogen, Phosphorus and Potassium) among others, perceive improved fertility in their fields. Regrettably, the average application rate of chemical fertilizers in Sub-Saharan Africa including Uganda, has stagnated at 14 kg ha^{-1} signalling that only a handful of farmers are applying them in crop production (UBOS & Uganda Bureau of Statistics, 2019; World Bank, 2018). This is attributed to the high costs associated with chemical fertilizer purchase, yet the majority of Uganda farmers are resource-poor (Bonilla Cedrez et al., 2020). There is still a need to promote the use of chemical fertilizers for soil fertility improvement despite their associated cost. This can be achieved through government subsidies for chemical fertilizer imports and the promotion of local production industries.

Moreover, the results also reveal that farmers who perceive improved fertility with intercropping suggest that they integrate legumes such as beans, including cover crops that benefit the soil through biological nitrogen fixation, thereby improving soil fertility. Research indicates that legumes form symbiotic relationships with Rhizobium bacteria, fixing atmospheric nitrogen into a plant-usable form, enriching soil nitrogen for both the legume and the associated crops, e.g. cereals such as maize (Vanlauwe et al., 2015). This consequently reduces the need for chemical *N* fertilizers. Previous research in Uganda has shown that the adoption of cereal-legume intercropping systems is still low, i.e. approximately 10% (Ekepu & Tirivanhu, 2016), triggering the need for more training of farmers on this soil fertility management practice.

Overall, the study demonstrates that farmers' perceptions of soil fertility are significantly associated with their soil fertility management practices, thereby directly addressing the study objective. Farmers who perceive their soils are as having low fertility are more likely to adopt restorative practices, whereas those using certain inputs such as chemical fertilizers are more likely to perceive their soils as fertile suggesting that perceptions and management practices are closely interrelated. However, t

hese findings should be interpreted as associations rather than causal relationships because the cross-sectional design does not establish the direction of influence between perception and managment practices. In addition, the regression analysis did not include socio-economic characteristics such as age, education, and farm size, which may also influence farmers' perceptions and management decisions. Future studies should integrate socio-economic factors, laboratory-based soil analysis and longitudinal data to better understand the complex interactions among actual soil fertility status, farmers' perceptions, and soil fertility management practices.

5. Conclusions

This study explored the perception of smallholder farmers regarding the status of soil fertility status and their association with the adoption of soil fertility management practices. The findings indicate that most farmers perceive their soils as having low in fertility, primarily based ondeclining crop yields, which they attribute to soil exhaustion, erosion, and drought. The generally low adoption of soil management practices corresponded with these perceptions of declining soil fertility. Significant associations were observed between farmers' perceived soil fertility status and selected management practices, particularly conservation tillage and manure application while, farmers reporting fertile soils were more likely to use intercropping and chemial fertilizers. Despite farmers' awareness of declining soil fertility, the adoption of several important practices, including agroforestrty, contour ploughing, terracing, vegetative strips, and chemical fertlizer use, remains limited, highlighting a gap between farmers' knowledge, perceptions, and management practices. These findings underscore the need to strengthen the promotion o and adoption of integrated soil fertility management strategies among smallholder farmers. Future research should combine farmers' perception with laboratory-based soil analyses to better understand the drivers of soil fertility perceptions and management decisions, thereby informig more effective and context-specific interventions.

Acknowledgements

We thank all the farmers in the Kabarole district and Fort Portal City who responded to our questions and the enumerators for their valuable efforts during data collection.

Author contributions

CRediT: **Cosmas Wacal:** Conceptualization, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing; **John Sekajugo:** Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing; **David Agole:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing; **Geoffrey Candia:** Investigation, Methodology, Writing – review & editing; **Bruce Nyamweha:** Investigation, Methodology, Writing – review & editing; **Collins Muhangi:** Investigation, Methodology; **Jacob Kaingo:** Investigation, Methodology; **Costa Gumisiriya:** Investigation, Methodology; **Joseph Okello:** Investigation, Methodology; **Jimmy Obala:** Investigation, Methodology, Writing – review & editing; **Eriya Kule Birengesyo:** Investigation, Methodology, Writing – review & editing; **Cecilia Kansiime:** Methodology, Project administration, Writing – review & editing; **Ronald Buwa:** Methodology, Writing – review & editing; **Athanasius Ssekyanzi:** Investigation, Methodology; **Eva Tereka:** Investigation, Methodology; **John Patrick Kanahe Kagorora:** Investigation, Methodology, Writing – review & editing; **Jack Turihohabwe:** Investigation, Methodology; **Alinaitwe Mukonyezi:** Methodology, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The Government of Uganda through the Mountains of the Moon University Research and Innovation Funds (MMURIF-2, 2024/2025), financially supported this study.

Data availability statement

The data supporting the results presented in this study can be obtained from the corresponding author on request. The data are not publicly available to protect the personal privacy of the respondents.

Ethical approval

The Committee of Graduate Studies, Research, Ethics and Publications (CGSREP) of the Mountains of the Moon University waived ethical review and approval for this study since it did not involve human clinical trials or animal experiments, and all participation was voluntary. All subjects gave verbal informed consent and were assured of confidentiality and anonymity.

References

Abdallah, A. (2024). Smallholder adoption of soil and water conservation techniques in Ghana. *African Journal of Agricultural Research*, *9*(5), 539–546. https://doi.org/10.5897/AJAR2013.7952

Abebe, T. G., Tamtam, M. R., Abebe, A. A., Abtemariam, K. A., Shigut, T. G., Dejen, Y. A., & Haile, E. G. (2022). Growing use and impacts of chemical fertilisers and assessing alternative organic fertiliser sources in Ethiopia. *Applied and Environmental Soil Science*, *2022*, 14738416–14. https://doi.org/10.1155/2022/4738416

Ahuchaogu, I. I., Ehiomogue, P. O., & Udoumoh, U. I. (2022). Effects of soil and water conservation measures on the environment: A review. *Poljoprivredna Tehnika*, *47*(3), 42–55. https://doi.org/10.5937/PoljTeh2203042A

Akinbode, S. O., Folorunso, O., Olutoberu, T. S., Olowokere, F. A., Adebayo, M., Azeez, S. O., Hammed, S. G., & Busari, M. A. (2024). Farmers' perception and practice of soil fertility management and conservation in the era of digital soil information systems in southwest Nigeria. *Agriculture*, *14*(7), 1182. https://doi.org/10.3390/agriculture14071182

Alela, B., Katya Kule, E., Midamba, D. C., & Mugonola, B. (2024). Determinants of adoption of integrated soil fertility management practices among coffee producers in mid-Northern Uganda. *Cogent Social Sciences*, *10*(1. 2417807. https://doi.org/10.1080/23311886.2024.2417807

Al-Musawi, Z. K., Vona, V., & Kulmány, I. M. (1966). Utilizing different crop rotation systems for agricultural and environmental sustainability: A review. *Agronomy*, *15*(8), 2025

Anang, B. T., Amesimeku, J., & Fearon, J. (2021). Drivers of adoption of crop protection and soil fertility management practices among smallholder soybean farmers in tolon district of Ghana. *Heliyon*, *7*(5. e06900. https://doi.org/10.1016/j.heliyon.2021.e06900

Apanovich, N., & Mazur, R. E. (2018). Determinants of seasonal food security among smallholder farmers in south-central Uganda. *Agriculture & Food Security*, *7*(1), 1–10. https://doi.org/10.1186/s40066-018-0237-6
Aura, S. (2016). Determinants of the adoption of integrated soil fertility management technologies in mbale division, Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, *16*(1), 10697–10710. https://doi.org/10.18697/ajfand.73.15735
Berazneva, J., McBride, L., Sheahan, M., & Guerena, D. (2016). Perceived, measured, and estimated soil fertility in east Africa: Implications for farmers and researchers.
Beukes, D., & Swanepoel, C. (2017). The effects of conservation tillage practices and fertiliser management on soil structural properties at an experimental farm. *South African Journal of Plant and Soil*, *34*(1), 19–26. https://doi.org/10.1080/02571862.2016.1155763
Bhatt, M. K., Labanya, R., & Joshi, H. C. (2019). Influence of long-term chemical fertilizers and organic manures on soil fertility-A review. *Universal Journal of Agricultural Research*, *7*(5), 177–188. https://doi.org/10.13189/ujar.2019.070502
Boansi, D., Owusu, V., & Donkor, E. (2024). Impact of integrated soil fertility management on maize yield, yield gap and income in Northern Ghana. *Sustainable Futures*, *7*, 100185. https://doi.org/10.1016/j.sftr.2024.100185
Bonabana-Wabbi, J., Mogoka, H., Semalulu, O., Kirinya, J., & Mugonola, B. (2016). Adoption of integrated soil fertility management by groundnut farmers in eastern Uganda. *Journal of Development and Agricultural Economics*, *8*(4), 86–94. https://doi.org/10.5897/JDAE2014-0627
Bonilla Cedrez, C., Chamberlin, J., Guo, Z., & Hijmans, R. J. (2020). Spatial variation in fertiliser prices in sub-saharan Africa. *PloS One*, *15*(1. e0227764
Chikopela, L., Kalinda, T. H., Ng'ombe, J. N., & Kuntashula, E. (2024). Cultivating sustainability: Adoption and intensity of soil fertility management technologies among rural farms in Zambia. *World Development Sustainability*, 5, 100174.
Ekepu, D., & Tirivanhu, P. (2016). Assessing socio–economic factors influencing adoption of legume-based multiple cropping systems among smallholder sorghum farmers in soroti, Uganda. *South African Journal of Agricultural Extension*, *44*(2), 195–215.
Epule, T. E., & New, M. G. (2019). Vulnerability of crop yields to variations in growing season precipitation in Uganda. *SN Applied Sciences*, *1*(8), 899. https://doi.org/10.1007/s42452-019-0912-7
Epule, T. E., Dhiba, D., Etongo, D., Peng, C., & Lepage, L. (2021). Identifying maize yield and precipitation gaps in Uganda. *SN Applied Sciences*, *3*(5), 537. https://doi.org/10.1007/s42452-021-04532-5
Farahani, S. S., Fard, F. S., & Asoodar, M. A. (2016). Effects of contour farming on runoff and soil erosion reduction: A review study. *Elixir Agriculture*, *101*(1), 44089–44093.
Galabuzi, C., Agaba, H., Okia, C. A., Odoul, J., & Muthuri, C. (2021). Women and youths participation in agroforestry: What counts and what doesn't around mount elgon, Uganda? *Journal of Mountain Science*, *18*(12), 3306–3320. https://doi.org/10.1007/s11629-021-6812-5
Gladwin, C. H. (2002). Gender and soil fertility in Africa. *African Studies Quarterly*, *6*(1 & 2), 1–26.
Gwandu, T., Mtambanengwe, F., Mapfumo, P., Mashavave, T. C., Chikowo, R., & Nezomba, H. (2014). Factors influencing access to integrated soil fertility management information and knowledge and its uptake among smallholder farmers in Zimbabwe. *The Journal of Agricultural Education and Extension*, *20*(1), 79–93. https://doi.org/10.1080/1389224X.2012.757245
Homeshwari-Devi, M., Haokip, I. C., & Kalidas-Singh, S. (2024). Impact of traditional land management practices on soil fertility and crop productivity, *Sustainable Land Management In India*. 179–200. Springer. Singapore.
Hörner, D., & Wollni, M. (2022). Does integrated soil fertility management increase returns to land and labour? Plot-level evidence from Ethiopia. *Agricultural Economics*, *53*(3), 337–355. https://doi.org/10.1111/agec.12699
Houndete, C. J., & Djego, G. J. (2023). Farmers' perceptions and characterization of local knowledge on soil fertility management by maize farmers in central Benin. *European Scientific Journal, ESJ*, *20*, 67 Retrieved from. https://eujournal.org/index.php/esj/article/view/17074
Ichami, S. M., Shepherd, K. D., Sila, A. M., Stoorvogel, J. J., & Hoffland, E. (2019). Fertilizer response and nitrogen use efficiency in African smallholder maize farms. *Nutrient Cycling In Agroecosystems*, *113*(1), 1–19. https://doi.org/10.1007/s10705-018-9958-y
IFDC International Fertilizer Development Center. (2017). Feed the Future Soil Fertility Technology (SFT) Adoption Policy Reform and Knowledge Management Project. Semi-Annual Performance Report. 2017; April 1 2017 – September 30 2017.
Kabarole District Local Government2023). *District Profile and Background Information*. Uganda: Kabarole District.
Karamage, F., Zhang, C., Liu, T., Maganda, A., & Isabwe, A. (2017). Soil erosion risk assessment in Uganda. *Forests*, *8*(2), 52. https://doi.org/10.3390/f8020052
Kayuki, K. C., Angella, N., & Musisi, K. F. (2017). Optimizing fertilizer use within the context of integrated soil fertility in Uganda., In Fertilizer use optimization in sub-Saharan Africa (pp. 193–209). GB: CABI.
Kenfack Essougong, U. P., Slingerland, M., Mathé, S., Vanhove, W., Tata Ngome, P. I., Boudes, P., Giller, K. E., Woittiez, L. S., & Leeuwis, C. (2020). Farmers' perceptions as a driver of agricultural practices: Understanding soil fertility management practices in cocoa agroforestry systems in Cameroon. *Human Ecology*, *48*(6), 709–720. https://doi.org/10.1007/s10745-020-00190-0
Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. Prentice-Hall. Englewood Cliffs, New Jersey.

Kwadzo, M., & Quayson, E. (2021). Factors influencing adoption of integrated soil fertility management technologies by smallholder farmers in Ghana. *Heliyon*, *7*(7), e07589. https://doi.org/10.1016/j.heliyon.2021.e07589

Midamba, D. C., Agbolosoo, J. A., Ouya, F. O., & Kwesiga, M. (2025). The contribution of Socio-Economic factors to adoption of inorganic fertilizers among maize farmers in Western Uganda. Discover Sustainability, 6(1), 683.

Moyo, S. (2016). Family farming in sub-saharan Africa: Its contribution to agriculture. *Food Security And Rural Development (No. 150). Working paper.*

Mponela, P., Manda, J., Kinyua, M., & Kihara, J. (2022). Participatory action research, social networks, and gender influence soil fertility management in Tanzania. *Systemic Practice and Action Research*, *36*(1), 141–163. https://doi.org/10.1007/s11213-022-09601-3

Mponela, P., Tamene, L., Ndengu, G., Magreta, R., Kihara, J., & Mango, N. (2016). Determinants of integrated soil fertility management technologies adoption by smallholder farmers in the chinyanja triangle of Southern Africa. *Land Use Policy*, *59*, 38–48. https://doi.org/10.1016/j.landusepol.2016.08.029

Mponela, P., Villamor, G. B., Snapp, S., Tamene, L., Le, Q. B., & Borgemeister, C. (2021). The role of women empowerment and labour dependency on adoption of integrated soil fertility management in Malawi. *Soil Use and Management*, *37*(2), 390–402. https://doi.org/10.1111/sum.12627

Mubiru, D. N., Namakula, J., Lwasa, J., Otim, G. A., Kashagama, J., Nakafeero, M., Coyne, M. S., & Nanyeenya, W. (2017). Conservation farming and changing climate: More beneficial than conventional methods for degraded Ugandan soils. *Sustainability*, *9*(7), 1084. https://doi.org/10.3390/su9071084

Mugwe, J., Mugendi, D., Mucheru-Muna, M., Merckx, R., Chianu, J., & Vanlauwe, B. (2009). Determinants of the decision to adopt integrated soil fertility management practices by smallholder farmers in the central highlands of Kenya. *Experimental Agriculture*, *45*(1), 61–75. https://doi.org/10.1017/S0014479708007072

Mupambwa, H. A., Nciizah, A. D., & Nyambo, P. (2022). Can organic soil fertility management sustain farming and increase food security among African smallholder farmers?, *In Food Security For African Smallholder Farmers* (pp. 89–112). Singapore: Springer Nature Singapore.

Musinguzi, P., Ebanyat, P., Tenywa, J. S., Basamba, T. A., Tenywa, M. M., & Mubiru, D. (2015). Precision of farmer-based fertility ratings and soil organic carbon for crop production on a ferralsol. *Solid Earth*, *6*(3), 1063–1073. https://doi.org/10.5194/se-6-1063-2015

Mutua-Mutuku, M., Nguluu, S. N., Akuja, T., Lutta, M., & Bernard, P. (2017). Factors that influence adoption of integrated soil fertility and water management practices by smallholder farmers in the semi-arid areas of eastern Kenya. *Tropical and Subtropical Agroecosystems*, *20*(1), 141–153.

Nabyonga, L., Basamba, T. A., Nyakoojo, C., & Ssenku, J. E. (2022). Impediments to agricultural production in Uganda and measures to enhance soil fertility utilizing organic soil amendments: A review. *Cogent Food & Agriculture*, 8(1), 2113051.

Nagar, B., Rawat, S., Pandey, R., Kumar, M., & Alatalo, J. M. (2022). Fuelwood and fodder consumption patterns among agroforestry-practicing smallholder farmers of the lower Himalayas, India. *Environment, Development and Sustainability*, *24*(4), 5594–5613. https://doi.org/10.1007/s10668-021-01673-w

Rotich, B., Maket, I., Kipkulei, H., Ocansey, C. M., Justine, P. N., MohammedZein, M. A., Csorba, Á., & Michéli, E. (2024). Determinants of soil and water conservation practices adoption by smallholder farmers in the central highlands of Kenya. *Farming System*, *2*(2. 100081. https://doi.org/10.1016/j.farsys.2024.100081

Rubagumya, I., Komakech, A. J., Kabenge, I., & Kiggundu, N. (2023). Potential of organic waste to energy and bio-fertiliser production in sub-saharan Africa: A review. *Waste Disposal & Sustainable Energy*, *5*(3), 259–267. https://doi.org/10.1007/s42768-022-00131-1

Rutebuka, J., Uwimanzi, A. M., Nkundwakazi, O., Kagabo, D. M., Mbonigaba, J. J. M., Vermeir, P., & Verdoodt, A. (2021). Effectiveness of terracing techniques for controlling soil erosion by water in Rwanda. *Journal of Environmental Management*, *277*. 111369. https://doi.org/10.1016/j.jenvman.2020.111369

Sanchez, P. A. (2002). Soil fertility and hunger in Africa. *Science*, *295*, 2019–2020. https://doi.org/10.1126/science.1065256

Shekhar, M., Shivashankar, E., & Pandey, S. K. (2024). Crop rotation and intercropping techniques, *Modern Concept in Agronomy*, IND Global Publication House. https://doi.org/10.5281/zenodo.11051201

Sileshi, G. W., Mafongoya, P. L., & Nath, A. J. (2020). Agroforestry systems for improving nutrient recycling and soil fertility on degraded lands, *Agroforestry for Degraded Landscapes: Recent Advances and Emerging Challenges-Vol. 1*. 225–253. Springer Singapore. Singapore. https://doi.org/10.1007/978-981-15-4136-0_8

Sullivan, A. J. (2002). Gender, household composition, and adoption of soil fertility technologies: A study of women rice farmers in Southern Senegal. *African Studies Quarterly*, *6*(1 & 2), 157–174.

Tindwa, H. J., Semu, E., Shelukindo, H. B., & Singh, B. R. (2019). Soil degradation with reference to nutrient mining and soil fertility decline in sub-saharan Africa, *Soil Degradation and Restoration in Africa*. 24–38. CRC Press. https://doi.org/10.1201/b22321-2

Tittonell, P., Corbeels, M., Van Wijk, M. T., Vanlauwe, B., & Giller, K. E. (2008). Combining organic and mineral fertilizers for integrated soil fertility management in smallholder farming systems of Kenya: Explorations using the crop-soil model FIELD. *Agronomy Journal*, *100*(5), 1511–1526. https://doi.org/10.2134/agronj2007.0355

Turyasingura, B., Ayiga, N., & Benzougagh, B. (2022). Re-thinking on land degradation and its impacts on livelihoods of the farmers in Kanungu District, Uganda.

UBOS (Uganda Bureau of Statistics). (2024). Statistical Abstract. Kampala, Uganda.

UBOS, Uganda Bureau of Statistics. (2019). Annual agricultural survey 2019 report. Kampala Uganda.
Vanlauwe, B., Descheemaeker, K., Giller, K. E., Huising, J., Merckx, R., Nziguheba, G., Wendt, J., & Zingore, S. (2015). Integrated soil fertility management in sub-saharan Africa: Unravelling local adaptation. *Soil*, *1*(1), 491–508. https://doi.org/10.5194/soil-1-491-2015
Wacal, C., Basalirwa, D., Byalebeka, J., Tsubo, M., & Nishihara, E. (2023). Low cost maize stover biochar as an alternative to inorganic fertilizer for improvement of soil chemical properties, growth and yield of tomatoes on degraded soil of Northern Uganda. *BMC Plant Biology*, *23*(1), 473. https://doi.org/10.1186/s12870-023-04468-5
Wato, T., Negash, T., Andualem, A., & Bitew, A. (2024). Significance of organic and inorganic fertilizers in maintaining soil fertility and increasing crop productivity in Ethiopia: A review. *Environmental Research Communications*, *6*(10), 102002. https://doi.org/10.1088/2515-7620/ad79be
Wawire, A. W., Csorba, Á., Tóth, J. A., Michéli, E., Szalai, M., Mutuma, E., & Kovács, E. (2021). Soil fertility management among smallholder farmers in mount Kenya east region. *Heliyon*, *7*(3), e06488. https://doi.org/10.1016/j.heliyon.2021.e06488
Woniala, J., & Nyombi, K. (2014). Soil fertility management by smallholder farmers and the impact on soil chemical properties in sironko district, Uganda. *Research Journal of Agriculture and Forestry Sciences*, 6063 ISSN, 2320.
World Bank. (2018). *World Development Indicators*. Washington, D.C.: The World Bank Group. https://data.worldbank.org/indicator.
Yamano, T., & Kijima, Y. (2010). The associations of soil fertility and market access with household income: Evidence from rural Uganda. *Food Policy*, *35*(1), 51–59. https://doi.org/10.1016/j.foodpol.2009.09.005