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Evaluation of Various Soil and Water Conservation Practices Using Qualitative Criteria by Diverse Stakeholders in the River Katonga Micro-Catchment of South-Central Uganda

Matabaro Wivine Adidja[1*], Joseph Ssekandi[1], Akalu Teshome[2]

[1]Faculty of Agriculture, Uganda Martyrs University, Nkozi, Uganda
[2]Stichting Wageningen Research (SWR), Addis-Ababa, Ethiopia
Email: *adidjamatabaro@gmail.com

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Abstract

This study evaluated various SWC practices utilizing qualitative criteria by engaging farmers, environmental experts, and local leaders in Mityana, Butambala, and Lwengo. The Multi-Criteria Analysis (MCA) process was used and included determining objectives, identifying alternatives, establishing evaluation criteria, determining the effects of alternatives, and aggregating and ranking the alternatives. Data collection employed qualitative and quantitative methods, including surveys (200 farmers), key informant interviews (20 local leaders and environmental experts), and 12 focus group discussions. The most commonly used SWC practices are trenches/ditches, mulches/cover crops, grass bunds/hedgerows, and agroforestry/tree planting ($p < 0.01$). Farmers utilize a range of criteria to evaluate the SWC practices' performance. The evaluation criteria used by farmers for these SWC methods are classified into economic, ecological, social, and other criteria. The most important criteria included minimizing soil loss, maximizing water retention, enhancing soil fertility, and increasing crop yields ($p < 0.01$). The preferences, rankings, and uses of SWC practices are influenced by gender dynamics, age, land acreage, level of education, and household structures. The study provides insights into the preferences and effectiveness of SWC practices, highlighting the influence of various socio-economic factors on decision-making concerning soil and water conservation in the River Katonga micro-catchment. Policymakers and practitioners are urged to give attention to farmers' preferences, experiences, and local conditions when developing SWC strategies and programmes. Further research is needed to determine soil, runoff, and nutrient losses from these SWC practices to enhance their effectiveness and inform sustainable land management strategies.

Keywords

Soil and Water Conservation (SWC), Multi-Criteria Analysis (MCA), Farmer Preferences, Katonga Micro-Catchment, Uganda

1. Introduction

Soil and Water Conservation (SWC) is essential for the sustainable management of ecosystems, especially in areas susceptible to land degradation and water scarcity, such as the Katonga Micro-catchment [1]. Effective SWC practices control soil erosion, enhance water retention, increase agricultural productivity, and enhance livelihoods and income; this is crucial for food security, environmental stability, and poverty reduction in several developing countries [2]-[4]. However, these practices' success mostly depends on their adoption by local communities and stakeholders, as the latter's perceptions and experiences considerably influence the long-term implementation and effectiveness of the SWC interventions and play a vital role in land use decisions [5] [6].

The River Katonga micro-catchment in Uganda is an indispensable agricultural and ecological area facing increasing several environmental and socio-economic challenges related to land degradation (soil erosion, overgrazing, deforestation, droughts, reduced water retention and water scarcity, floods and infertile soils), declining agricultural productivity, increasing pest and disease outbreaks, limited livelihood options, reduced income, increased population growth etc. [1] [7]. In response to this, several SWC practices have been introduced and implemented by governmental agencies, non-governmental organizations, and local communities to address these issues. These practices involve trenches/ditches, mulching/cover crops, grass bunds/hedgerows, afforestation/tree planting, terracing, contour bunds, drainage ways, stone wall/bunds, live fences, woodlots, irrigation, manure/fertilizer, ploughing, and digging holes [1]. These interventions aim at mitigating the adverse effects of land degradation and water scarcity, but their success mostly depends on local stakeholders' perceptions, acceptance, and practical feasibility. The effectiveness of these interventions is not solely determined by their technical performance but by the qualitative perceptions of different stakeholders such as farmers, local leaders, and environmental experts [8]-[10].

This study focuses on evaluating the different SWC practices used in the River Katonga micro-catchment by utilizing qualitative criteria from various stakeholders, comprising farmers, community leaders, NGOs, and government officials. While technical evaluations of SWC practices every so often dominate the literature, there is limited understanding of how local stakeholders perceive and prioritize these soil and water conservation strategies, particularly in terms of their social acceptability, economic feasibility, and long-term sustainability [5] [11] [12]. This gap in knowledge undermines the potential for sustainable environmental management, as the success of SWC interventions depends largely on local buy-in and adaptation to community contexts [13] [14]. Therefore, the incorporation of stakeholder perspectives is increasingly acknowledged as an essential component in determining the long-term sustainability and adoption of these practices [15] [16]. Understanding the preferences of stakeholders and the social, economic, and environmental factors that influence these preferences is key to improving the design and implementation of SWC interventions in the Katonga micro-catchment [17] [18]. Moreover, understanding the perspectives of different stakeholders is fundamental for the success of SWC practices.

Previous studies have highlighted the need for participatory methods in environmental conservation, arguing that top-down methods often fail due to a lack of community involvement and consideration of local knowledge systems [19] [20]. By evaluating SWC practices through the lens of stakeholder perceptions, this study contributes to the wider discourse on sustainable land management and highlights the importance of incorporating local knowledge into conservation efforts.

This study seeks to address the gap in knowledge by evaluating SWC practices through a participatory method that integrates qualitative input from stakeholders who are the most affected by these interventions. This study will offer insights into the strengths and weaknesses of different conservation practices as perceived by the stakeholders, help realize which conservation practices are most accepted and practically viable within the local context, and then provide recommendations for improving SWC efforts in the area. The integration of local knowledge and qualitative criteria will ensure that SWC practices are not only technically effective but also socially acceptable and economically feasible for long-term success [21] [22]. This research utilizes Multi-Criteria Analysis (MCA) methods to assess the effectiveness of SWC practices, utilizing qualitative criteria identified by stakeholders within the River Katonga micro-catchment. The significance of MCA alongside its integration with Cost-Benefit Analysis (CBA) to evaluate SWC projects, considering both monetary and non-monetary aspects, has been widely investigated by [23] [24]. The availability of conflicting objectives, numerous SWC alternatives, and farmers' decision-making process and adoption of soil and water conservation (SWC) measures is often hindered by a range of evaluation criteria that they utilize [25] [26]. It is important to note that investment objectives of farmers frequently diverge from those of researchers and extension workers, as they have additional objectives beyond minimizing soil erosion and maximizing the SWC measures' financial benefits [21] [27]; these objectives often conflict, leading to the fact that there is no single soil and water conservation (SWC) measure that can offer the best outcome for all farmers. Therefore, it is essential to assess the objectives and criteria of farm households when making decisions about SWC practices, taking into consideration their economic, ecological, and social implications or impacts. To effectively identify and analyze the diverse and often conflicting objectives and goals, Multi-Criteria Analysis (MCA) emerges as a more appropriate tool [28] [29]. Additionally, MCA methods serve as a suitable modeling approach for addressing the economic and environmental evaluation issues [30] [31].

This study aims to evaluate different SWC practices utilizing qualitative criteria by the different stakeholders based on the perceived economic, ecological, and social impacts.

2. Materials and Methods

2.1. Study Area

The study was undertaken in the Katonga micro-catchment in South-Central Uganda (**Figure 1**). This catchment was chosen because it is part of the larger River Katonga Basin, which plays an important role in the hydrological balance of South-Central Uganda. Its connection to Lake Victoria, the largest freshwater body on the African continent, makes it essential for understanding conservation practices that impact both local and downstream water systems [32] [33] and specific experiences with existing SWC initiatives [1].

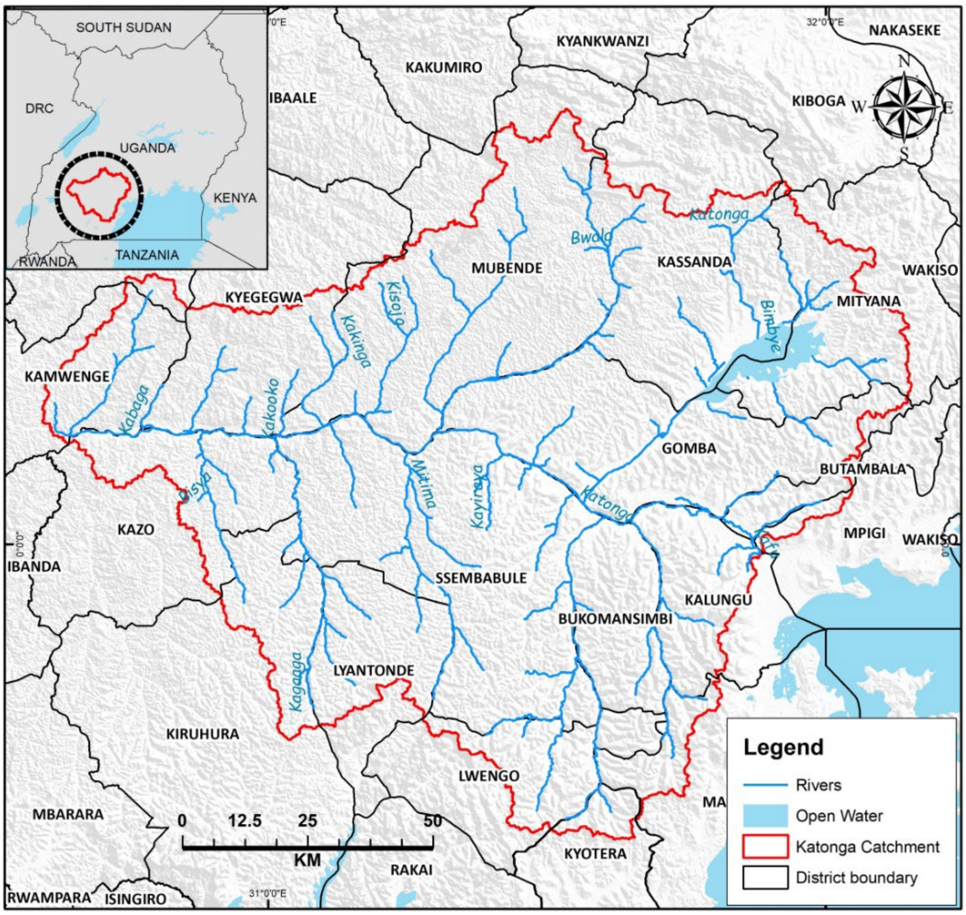

Figure 1. Map of the Katonga micro-catchment study area in South-Central Uganda.

In addition, the micro-catchment has diverse biophysical and socio-economic characteristics (Table 1). The dominant farming system in the micro-catchment is a mixed crop-livestock farming system.

Table 1. Socio and physical characteristics of the Katonga micro-catchment.

Features	Attributes
Size of the catchment	2478 km^2
Altitude	1108 - 1581 m.a.s.l.
Mean annual rainfall Average/annual rainfall	800 - 1300 mm
Dominant soil types	Acric ferralsols, luvisols, gleyic arenosols, planosols, dystric regosols
Degradation status	Highly degraded
Soil pH	4.5 - 6.8
Soil types	Acric ferralsols, luvisols, gleyic arenosols, planosols, and dystric regosols
Landscape	Rocky outcrops and steep slopes
Land cover types	Rainfed farmland, isolated central and local forest reserves, a wildlife reserve, wetlands, forest plantations, and irrigated farmland.
Dominant Livelihoods	Limited livelihood options; Rainfed subsistence farming, livestock rearing, fishing, and to a lesser extent, tourism
Dominant crops in farming	Maize, bananas, beans, and coffee
Dominant livestock	Cattle, goats, and sheep
Productivity	Low/declining
Population	3,020,638 (high population density)
Number of households	678,076
All-weather road	Poor/bad roads
Distance to district town (km)	10 to over 30

Source: [1] [34].

2.2. Data Collection

Farmers, local leaders, and environmental experts serve as the primary stakeholders in soil and water conservation (SWC) initiatives in the Katonga micro-catchment, as highlighted by [12] and [35]. Both qualitative and quantitative data were gathered from these stakeholders in 2023, utilizing a combination of focus group discussions, surveys, and key informant interviews. A total of twelve (12) focus group discussions were held, utilizing a checklist, with two discussions conducted in each sub-county of the study area. Each focus group included 20 farmers who were invited to share their insights. A recording tool was employed during these discussions to capture direct quotations of participants' views. Following the focus group discussions, individual household surveys were carried out to verify the information collected using a semi-structured questionnaire. A total of 200 farm households were randomly selected and interviewed for the surveys. The number of interviewed households was estimated using the [36] equation: Z (1.96) is the score at the 0.95 level of significance from the normal curve. P is the proportion of households involved in agricultural activities (85%), Q = 1 − P = 15%, d (0.05) is the precision desired, maximum value of relative sampling error. The total number of households that were to be interviewed according to Bryan's formulae was 196, which was rounded to 200. Households were randomly selected from 6 sub-counties, namely Maanyi, Bulera, Ngado, Budde, Kkingo, and Malongo in the River Katonga Sub-catchment; these sub-counties were randomly selected from three (3) districts of the Sub-catchment with the most agricultural land use and high slopes based on criteria such as accessibility, security, and health conditions. Each of the 3 districts were randomly selected in the Northern (1), Eastern (1), and Southern (1) regions of the sub-watershed, respectively. Land use and slope distribution were obtained from GIS-generated satellite images (Figure 2 and Figure 3).

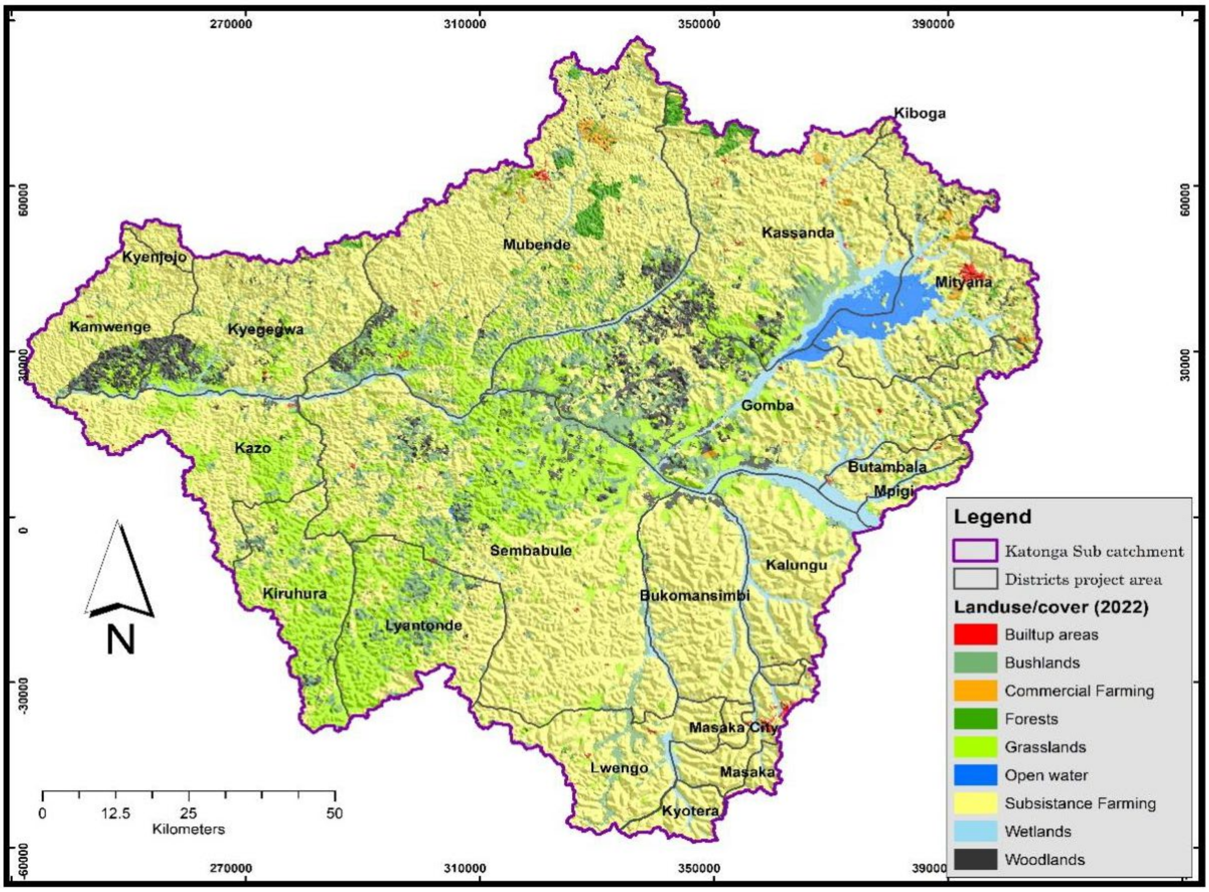

Figure 2. Land use/cover distribution in Katonga micro-catchment.

Agricultural land use areas were located in the Northern, Eastern and Southern regions of the micro-watershed (Figure 2). In addition, 20 key informants' interviews were conducted using an interview guide, involving district and sub-county agricultural and environmental officers and extension workers. The key informants were randomly selected from the leading staff and public extension service workers operating in each of the districts and sub-counties. The SWC alternatives and the evaluation criteria were identified from the previous studies [1] [12] [37]-[39]. The SWC alternatives and the evaluation criteria were presented for discussion with the farmers and the experts. During the focus group discussions, some SWC alternatives and criteria were removed, since they were either not very relevant or not commonly practiced. Similarly, some SWC alternatives and criteria were added, since they were either very relevant or commonly practiced; for example, digging holes and ploughing were added as relevant methods in all the districts and sub-counties of the Katonga micro-catchment. Additionally, minimizing weeding and increasing income were also added as relevant evaluation criteria to the area, while maximizing ox-plowing convenience was not relevant. Thus, in this study, the assignment of weightings to criteria was achieved through a collaborative consensus among the group, based on the farmers' classifications. A fixed point scoring method was utilized, as outlined by [40] and [12], an approach that obliges the decision-maker to allocate a fixed number of points among various criteria, with the higher point score indicating that the particular criterion has greater importance assigned to it. The fixed point scoring technique serves as the most direct method of collecting weighting information from the decision-maker, as supported by [12] and [41].

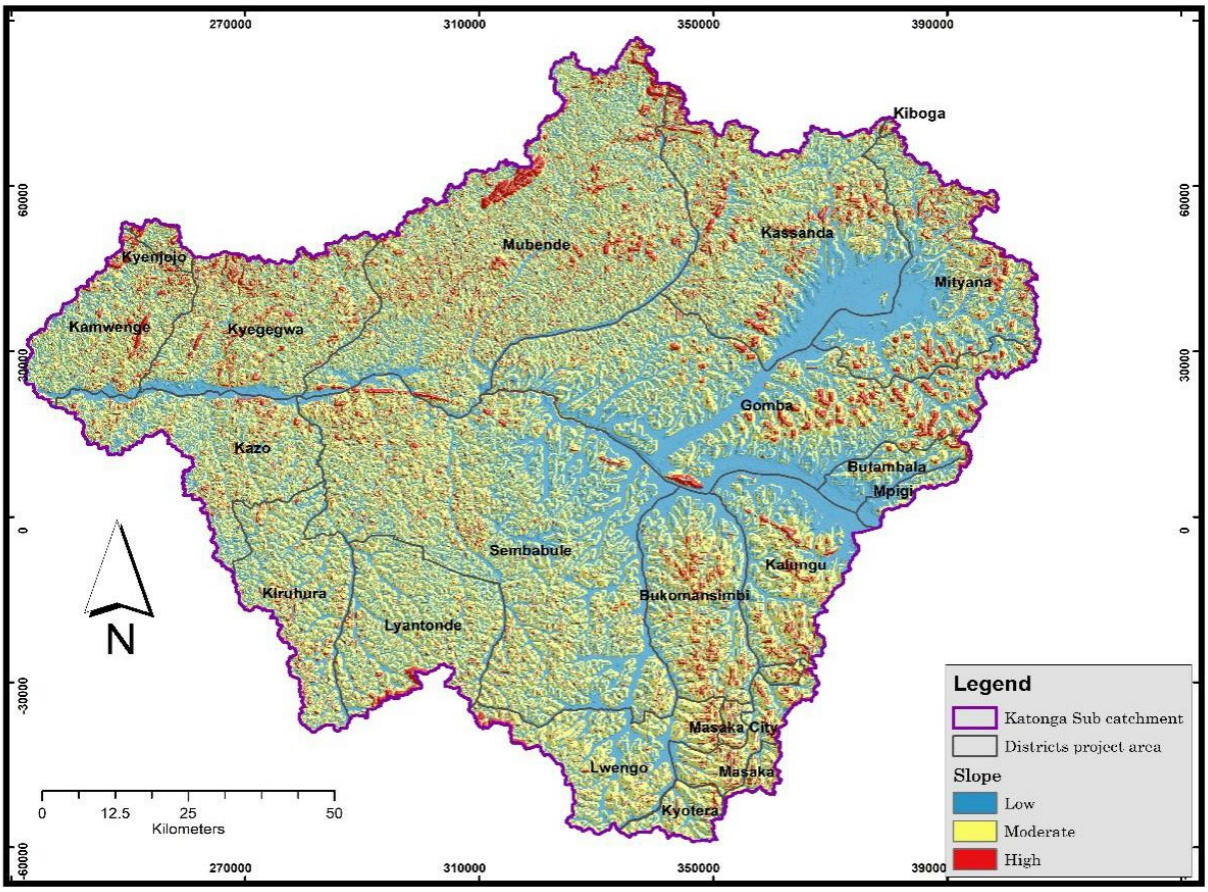

Figure 3. Slope distribution in the Katonga micro-catchment.

2.3. Multiple Criteria Analysis (MCA) for the Evaluation of Soil and Water Conservation

Multi-Criteria Analysis (MCA) has been developed as a decision-making tool when different objectives have to be achieved. Therefore, it is a decision-making technique utilized for choice problems, particularly in scenarios where multiple different alternatives and conflicting criteria are present [12] [29] [40] [42]. As defined by [43] and [44], MCA is a tool developed for tackling complex problems of multi-criteria that encompass both qualitative and quantitative dimensions of a problem in the process of decision-making. According to [45] and [29], MCA is an evaluative approach grounded in the theory of sustainable development economics, which systematically ranks or scores the decision-making options' performance against numerous criteria, ensuring that the outcomes are clearly meaningful in terms of sustainability [42] [46]. Key characteristics of MCA include the presence of multiple objectives, the diversity of these objectives, and the involvement of several decision-makers [47] [48]. The MCA method has specific advantages and disadvantages when it comes to assessing SWC practices [12] [33]. (**Table 2**) and also holds significant potential for overcoming the limitations associated with other SWC assessment methodologies. Thus, a more suitable tool to evaluate SWC practices is the MCA.

Table 2. Advantages and disadvantages of MCA for assessing SWC.

Advantages	Disadvantages
It focuses on several objectives and alternatives	Non-comparability among objectives
It uses both qualitative and quantitative effects	Use of qualitative scales, where quantitative could be used
It considers the intangible effects of SWC	Exposed to the subjectivity problem: subjective weights attached to several criteria
It increases the rationality of the decision process	Difficult to incorporate the time dimension
It can incorporate CBA (cost-benefit analysis) and other financial efficiency criteria	Different methods give different results
It is an interactive method	Different conflicting evaluation criteria are considered
It identifies the knowledge gaps in SWC practices	Gives petite attention to uncertainty and to possible trade-offs among some of the objectives

2.3.1. Steps in Multiple Criteria Analysis (MCA) Methods

To identify the best alternatives on the basis of relevant criteria, MCA uses a number of defining steps [12] [29] [30] [46]. The key steps in MCA are:

1) **Step One:** The objectives are determined.

2) **Step Two:** The various alternatives or options that aid in reaching the objectives are identified.

3) **Step Three:** The criteria for evaluating the performance of the proposed alternatives are established.

4) **Step Four:** Based on the defined measurable criteria, the impacts of the alternatives are identified and assessed, whether qualitatively or quantitatively.

5) Step Five: Eliminates the effect of different dimensions in scoring of alternatives by making the unit of scores comparable on a scale between 0 and 1.

6) Step Six: Stakeholders, including farmers, policymakers, or others, assign weights to the criteria to reflect their relative significance for the respective groups.

7) Step Seven: The methods of Additive Weighting and Sequential Elimination are employed, which involve aggregating the weighted scores for each alternative, highlighting the most critical aggregation techniques.

2.3.2. Data Analysis

In addition to the Multi-Criteria Analysis (MCA) methods, survey questionnaires were coded and entered into SPSS software version 18 for analysis. Tables, graphs, and regression models were obtained using descriptive statistics, cross-tabulation, and linear regression analysis. The data analysis involved ranking the most important SWC alternatives and standardization of their effects. The average weightings were utilized to accommodate the different views of farmers on the relative importance of each criterion. Farmers evaluated SWC measures by giving scores to each criterion on a scale of 1 for the worst to 5 for the best in all six (6) sub-counties. Frequencies/percentages were used to aggregate rankings of individual farmers. Scoring of alternatives was calculated by averaging the scales to cross-check the results. The SPSS software was used to obtain a complete ranking/scoring and further detailed information on the relative importance between alternatives and criteria, as well as on the relative importance of the alternatives in achieving the criteria objectives. Chi-square analysis was done on the frequencies and percentages obtained from SPSS results to establish whether differences were statistically significant or not. Linear regression analysis was conducted to determine the household characteristics that significantly influence the use, the preference level, and the ranking of SWC practices. Conclusions were made at $p < 0.01$ and $p < 0.05$. These two conclusions were used to differentiate the effects that were "highly significant" from the effects that were "significant" in the regression analysis results.

3. Results

3.1. Soil and Water Conservation Alternatives and Their Effectiveness

Soil and Water Conservation (SWC) measures are an integral part of the farming systems observed in the study areas. A significant majority of farmers (84%) recognized issues related to soil erosion and acknowledged the profitability of implementing SWC measures. In response to these erosion challenges, both governmental and non-governmental organizations have introduced various SWC strategies within the Katonga Micro-catchment. The major SWC practices implemented widely by farmers in this region include trenches/ditches, mulching/cover cropping, grass bunds/hedgerows, and agroforestry/tree planting ($p < 0.01$). Therefore, the evaluation included the first three SWC measures named trenches, mulches, and grass bunds, along with the "No measure" alternative.

3.2. Major Actors and Their Objectives

Erosion negatively affects the economic, ecological, and social dimensions of farming communities. In their decisions regarding investments in soil and water conservation (SWC), farmers assess these varied impacts. Our surveys revealed that the major objectives of farmers concerning SWC investments include achieving economic advantages (such as increasing production, increasing income, and reducing costs), promoting ecological restoration (including erosion control, improved soil fertility, enhanced water retention, and weed management), and mitigating the socially detrimental effects associated with erosion and SWC practices ($p < 0.01$).

3.3. Evaluation Criteria and Weightings

The farmers defined and employed eleven (11) evaluation criteria to evaluate SWC measures, which were subsequently categorized into economic, ecological, social, and others (Table 3).

Table 3. Evaluation Criteria of Soil and Water Conservation (SWC) Technologies by Farmers.

Criteria	Objectives	Unit of measurement
Economic impacts		
Maximize crop yields	Crop yields	Rank
Maximize grass production	Grass production	Rank
Minimize labor for establishment	Labor requirements for the establishment	Rank
Minimize maintenance costs	Maintenance costs	Rank
Maximize the farmer's income	Farmer's income	Rank
Ecological impacts		
Minimize soil loss	Erosion control	Rank
Minimize nutrient loss	Enhance soil fertility	Rank
Maximize water retention	Water retention	Rank
Minimize weeding	Weed control	Rank
Social and others impacts		
Minimize risk of pest harboring effect	Risk of pest harboring effect	Rank
Minimize disputes with adjacent farmers	Avoid disputes with adjacent farmers	Rank

"Rank" refers to the order of priority or performance assigned to each criterion by farmers during the evaluation of SWC technologies.

3.4. Major Cropping and Livestock Systems in the River Katonga Sub-Catchment

The major crops grown in the Katonga Sub-catchment include coffee, banana, cassava, maize, beans, Irish, ginger, tomato, sweet potatoes, vanilla, peas, trees and fruits, cassava, soya, tea, wheat, yam, green pepper, and Gnuts (Figure 4). Coffee, maize, bananas, and beans are the dominant crops in the area ($p < 0.01$). Coffee is generally intercropped with bananas and maize, with other crops such as beans. Relatively fewer households grow Irish potatoes, tomatoes, vanilla, peas, fruits, soya, tea, and wheat. About 74% of the respondents grew coffee, 66% grew maize, 60% grew Banana, and 34% grew beans in all the planting seasons, and only a few of them grew other crops.

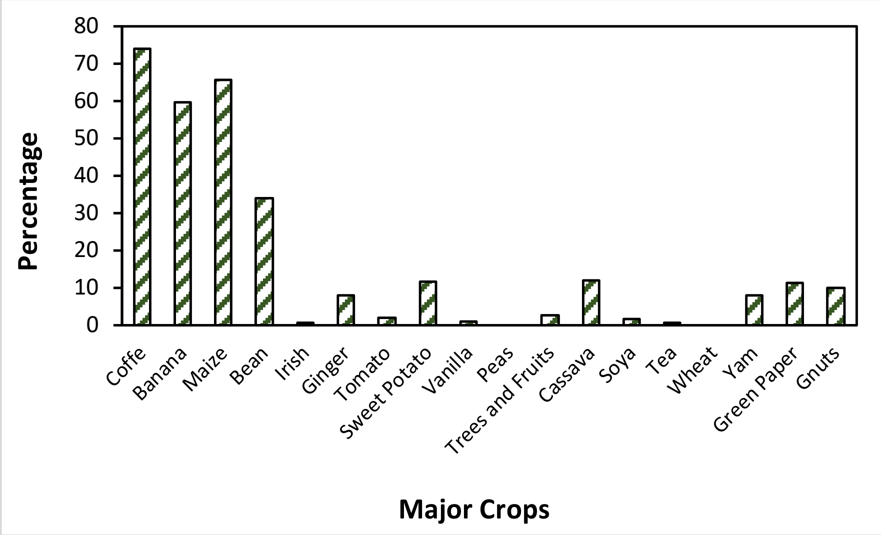

Figure 4. Major crops grown in the River Katonga sub-catchment.

The major livestock kept in the Katonga Sub-catchment include cattle/cow, poultry, goat and sheep, piggery, cats, dogs, and rabbits (**Figure 5**). Goats and Sheep, cattle/cows, piggery, and poultry are the dominant livestock in the area ($p < 0.01$). Goats are generally kept with sheep, and cats with dogs, while the piggery, poultry, and cattle/cows are kept alone. Relatively fewer households keep rabbits, cats, and dogs. About 73% of the respondents kept Goats and Sheep, 67% kept Cattle/Cows, 44% kept pigs, and 37% kept chickens in all seasons, and only a few of them kept rabbits (2%) and Cats and dogs (1%).

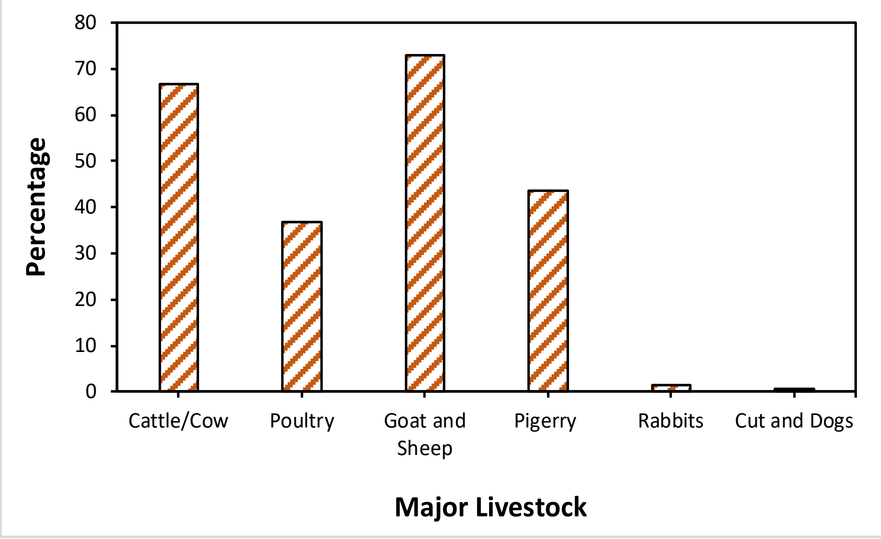

Figure 5. Major livestock of the river Katonga sub-catchment.

3.5. Existing Soil and Water Conservation Practices in the Katonga Micro-Catchment

The commonly used practices in the region include Trenches/ditches, Mulches/cover crops, Grass bunds/Hedgerow, agroforestry, Terraces, contour bunds, surface drainage ways, stone wall, live fence, woodlots, Irrigation, Manure/Fertilizer, ploughing and Digging holes (Figure 6). Mulches/cover crops are mainly used under Banana and coffee plantation while the other practices are used under annual crops. The most used practices ($p < 0.01$) were trenches/ditches, followed by Mulches/cover crops, Agroforestry, and Grass bunds/Hedgerows, while the least used included contour bunds, surface drainage, stone wall, live fence, irrigation, and woodlots.

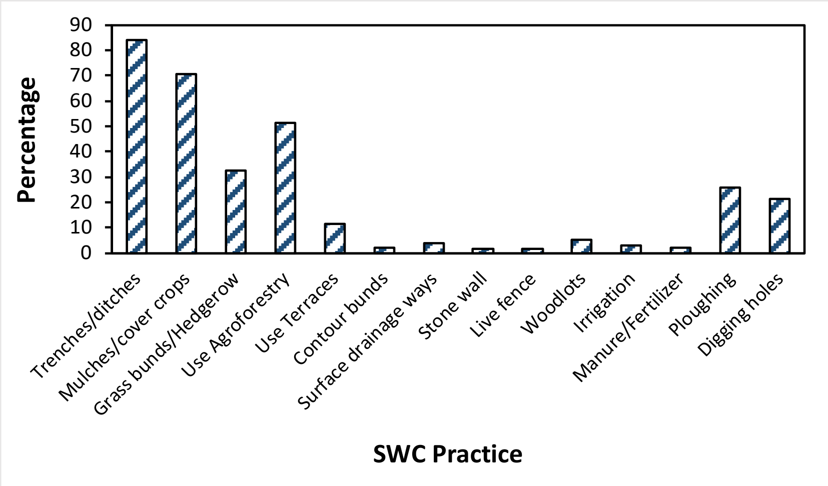

Figure 6. Soil and water conservation practices in the Katonga sub-catchment.

3.6. SWC Practices Evaluation Criteria Commonly Used in the River Katonga

The commonly used Criteria to evaluate the SWC practices in the region include minimizing soil loss, enhance soil fertility, maximize water retention, maximize/increased crop yields, maximize fodder (grass) production, minimize labor requirement for establishment, minimize maintenance costs, minimize Risks of pest effect, minimize dispute with neighbouring farmers, presence of grass on Trenche for livestock, minimize weeding and increased income (Figure 7). The most important criteria ($p < 0.01$) were minimizing soil loss followed by maximize water retention, enhance soil fertility and maximize/increased crop yields while the least important included maximize fodder (grass) production, minimize labor requirement for establishment, minimize maintenance costs, minimize risks of pest effect and presence of grass on Trenches.

3.7. Preference Level and Ranking of Soil and Water Conservation Practices

Figure 8 shows that trenches, mulches, grass bunds, and agroforestry are the most preferred soil and water conservation practices in the region ($p < 0.01$), followed by ploughing and digging holes. The least preferred practices included irrigation, woodlots, live fences, stone walls, surface drainage ways, and contour bunds. "No measure" was not preferred (a). The figure also shows that Trenches, Mulches, Grass bunds, and Agroforestry are the highly ranked soil and water conservation practices in the region ($p < 0.01$), followed by ploughing and digging holes. The least ranked practices included irrigation, woodlots, live fences, stone walls, contour bunds, and surface drainage ways. No measure ranked worst (b).

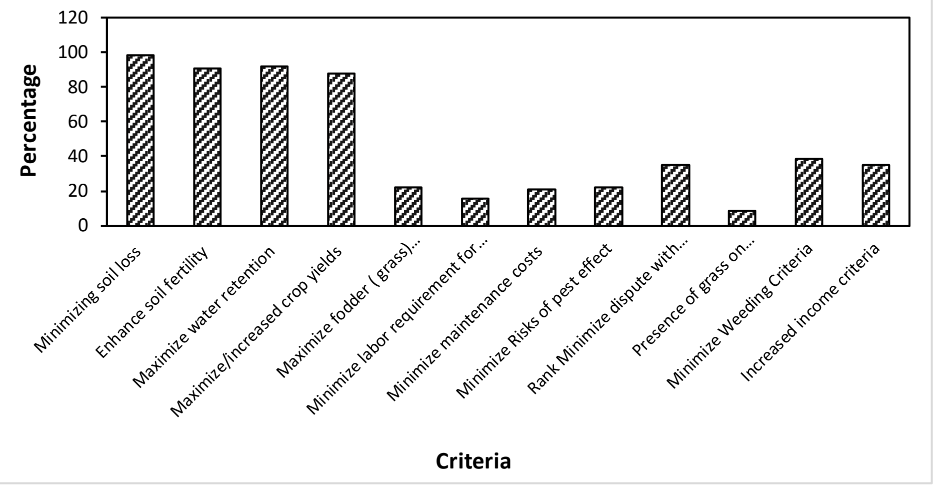

Figure 7. Evaluation criteria for SWC practices in the Katonga sub-catchment.

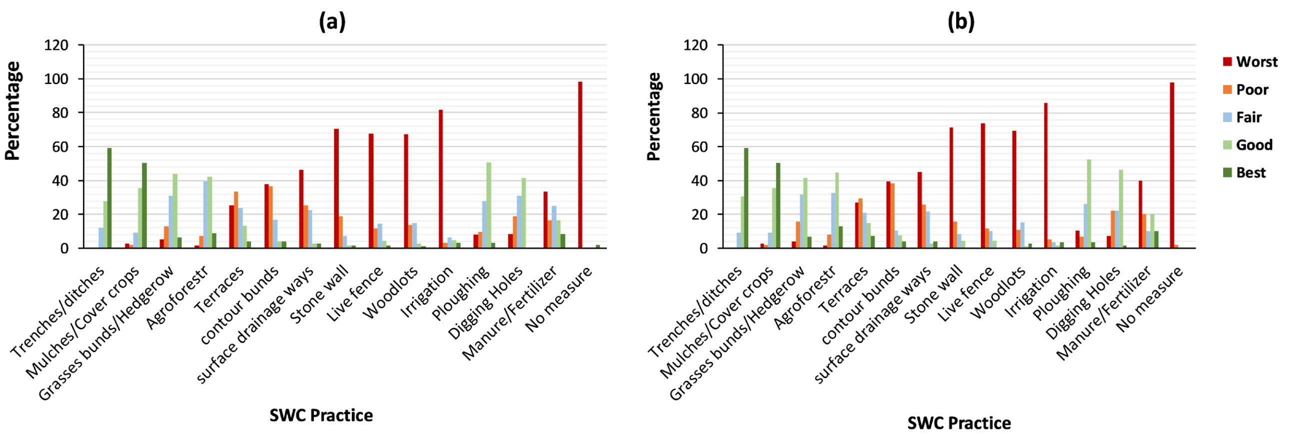

Figure 8. Soil and water conservation practices' preference level (a) and ranking (b) in the Katonga sub-catchment.

3.8. Farmers' Multi-Criteria Ranking of the Alternatives and Criteria Scores of Soil and Water Conservation Practices

Figure 9 shows that minimizing soil erosion, enhance soil fertility, maximizing water retention and increasing crop yield are perceived as very important criteria by most of the farmers in the region, while minimizing weeding and increased income are perceived important ($p < 0.01$). The least important criteria included maximizing fodder (grass) production, minimizing labor requirements for establishment, minimizing maintenance costs, and minimizing the Risks of pest effects and the presence of grass on Trenches.

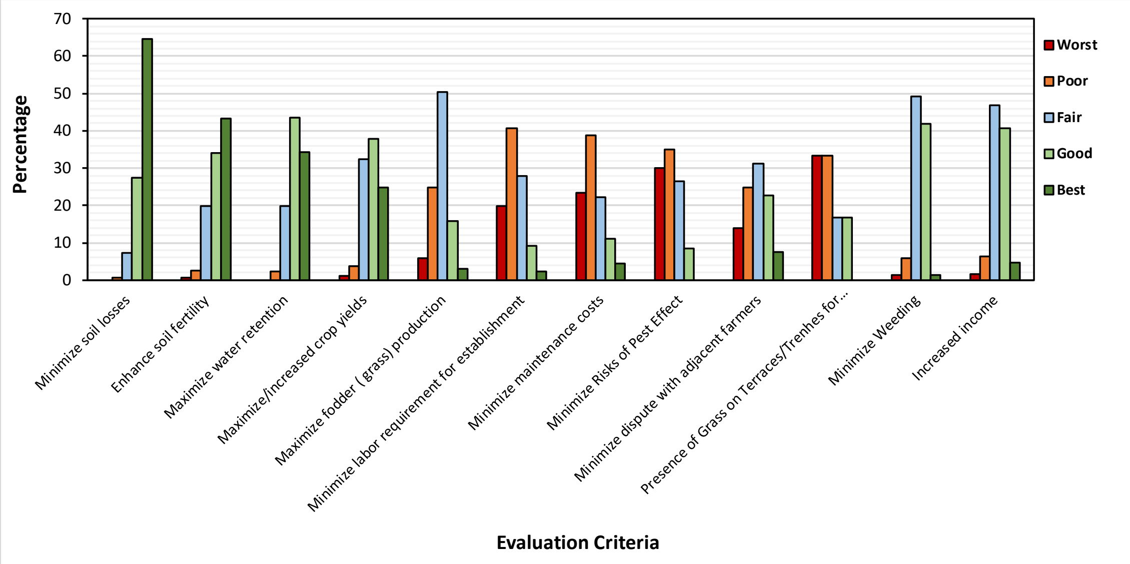

Figure 9. Criteria scores of soil and water conservation practices in the Katonga sub-catchment.

Figure 10 shows that Manure/fertilizer, Trenches, Mulches, Grass bunds, Agroforestry, Ploughing, and Digging holes are perceived to be very effective in maximizing/increasing crop yields ($p < 0.01\%$). Irrigation, woodlots, live fences, stone walls, surface drainage ways, and contour bunds were least effective in maximizing/increasing crop yields on farmers' gardens. "No measure" was perceived to be worse or not important (a). The figure further shows that manure/fertilizer, trenches, mulches, grass bunds, and agroforestry are perceived to be very effective in maximizing fodder (grass) production by most farmers ($p < 0.01\%$). Irrigation, woodlots, live fences, stone walls, surface drainage ways, and contour bunds were least effective in maximizing fodder (grass) production on farmers' gardens. "No measure" was perceived to be worse or not important (b). It also shows that manure/fertilizer was perceived to be very effective in minimizing labor requirements by most of the farmers ($p < 0.01\%$), followed by trenches, mulches, grass bunds, and agroforestry, which are perceived as fairly effective. Irrigation, woodlots, live fences, stone walls, surface drainage ways, and contour bunds were least effective in minimizing labor requirements for establishment on farmers' gardens. "No measure" was perceived to be worse or not important (c). It also shows that manure/fertilizer was perceived to be very effective in minimizing maintenance costs ($p < 0.01\%$), followed by trenches, mulches, grass bunds, and agroforestry, which were perceived as fairly effective. Woodlots, live fences, stone walls, surface drainage ways, and contour bunds were least effective in minimizing maintenance costs on farmers' gardens. "No measure" and Irrigation were perceived to be worse or not important (d). Mulches and ploughing are perceived to be effective in increasing income by most of the farmers ($p < 0.01\%$). Manure/fertilizer, trenches, grass bunds, and agroforestry were fairly effective in minimizing maintenance costs on farmers' gardens. "No measure", irrigation, woodlots, live fences, stone walls, surface drainage ways, and contour bunds were perceived to be worse or not important (e).

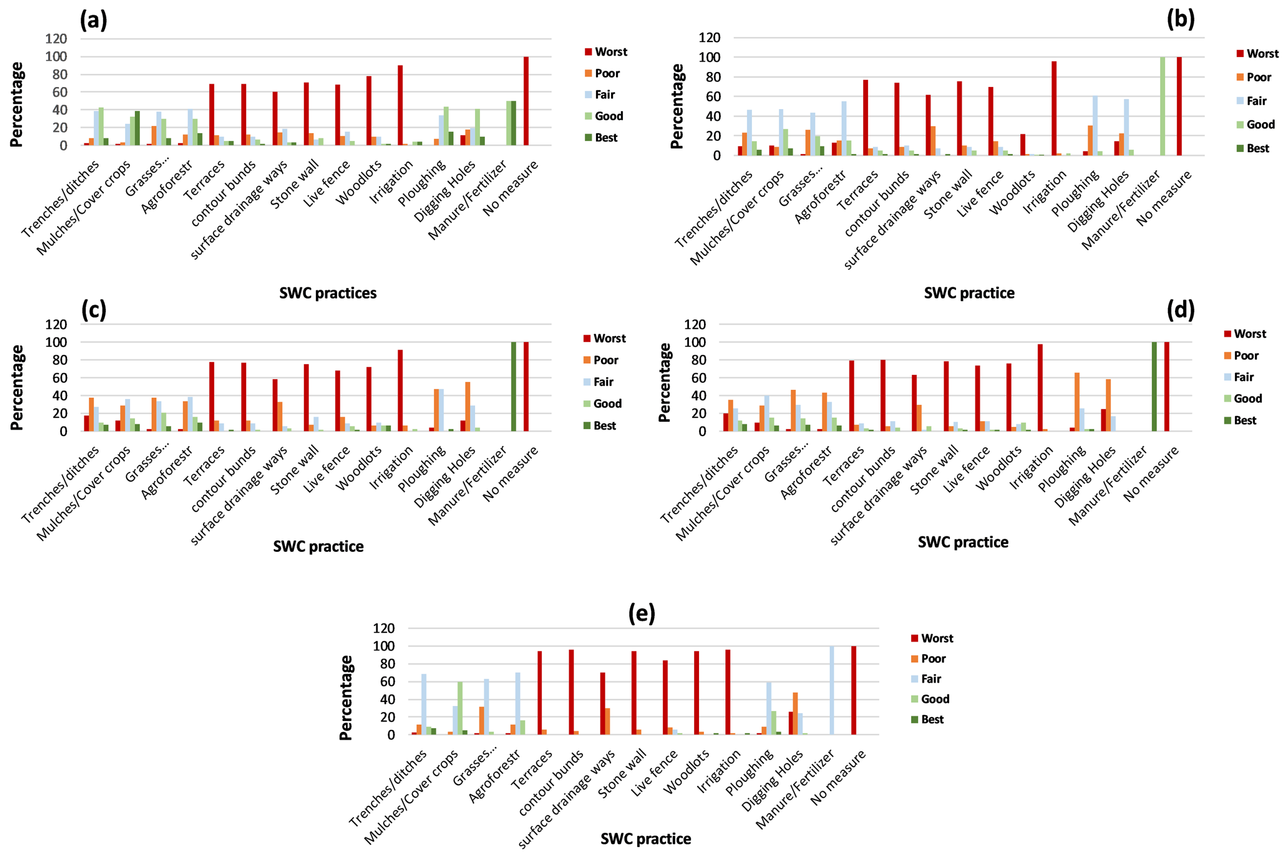

Figure 10. SWC practices and increasing crop yields (a), maximizing fodder production (b), minimizing labor requirements (c), minimizing maintenance costs (d) & increasing income (e) in the Katonga sub-catchment.

Figure 11 shows that Trenches, Mulches, Grass bunds, Agroforestry, and Ploughing are perceived to be very effective in minimizing soil loss or controlling erosion ($p < 0.01\%$). Irrigation, woodlots, live fences, stone walls, surface drainage ways, and contour bunds were least effective in minimizing soil loss on farmers' gardens. "No measure" and Irrigation were perceived to be worse or not important by all farmers (a).

The figure further shows that Manure/fertilizer, Trenches, Mulches, Grass bunds, Agroforestry, and Ploughing are perceived to be very effective in enhancing soil fertility by most of the farmers ($p < 0.01\%$). Irrigation, woodlots, live fences, stone walls, surface drainage ways, and contour bunds were least effective in enhancing soil fertility on farmers' gardens. "No measure" and irrigation were perceived to be worse or not important (b). It also shows that Manure/fertilizer, Trenches, Mulches, Grass bunds, Agroforestry, Ploughing, and digging holes are perceived to be very effective in maximizing water retention by most farmers (p <

0.01%). Woodlots, live fences, stone walls, surface drainage ways, and contour bunds were least effective in maximizing water retention. Also, “No measure” and Irrigation were perceived to be worse or not important (c).

It also shows that mulching and ploughing are perceived to be effective in minimizing weeding ($p < 0.01\%$). Trenches, grass bunds, agroforestry, ploughing, and digging holes were fairly effective on farmers’ gardens. “No measure”, irrigation, woodlots, live fences, stone walls, surface drainage ways, and contour bunds were perceived to be worse or not important by all the farmers (100%), implying that it had no benefits and therefore wasn’t an option to choose on their gardens (d).

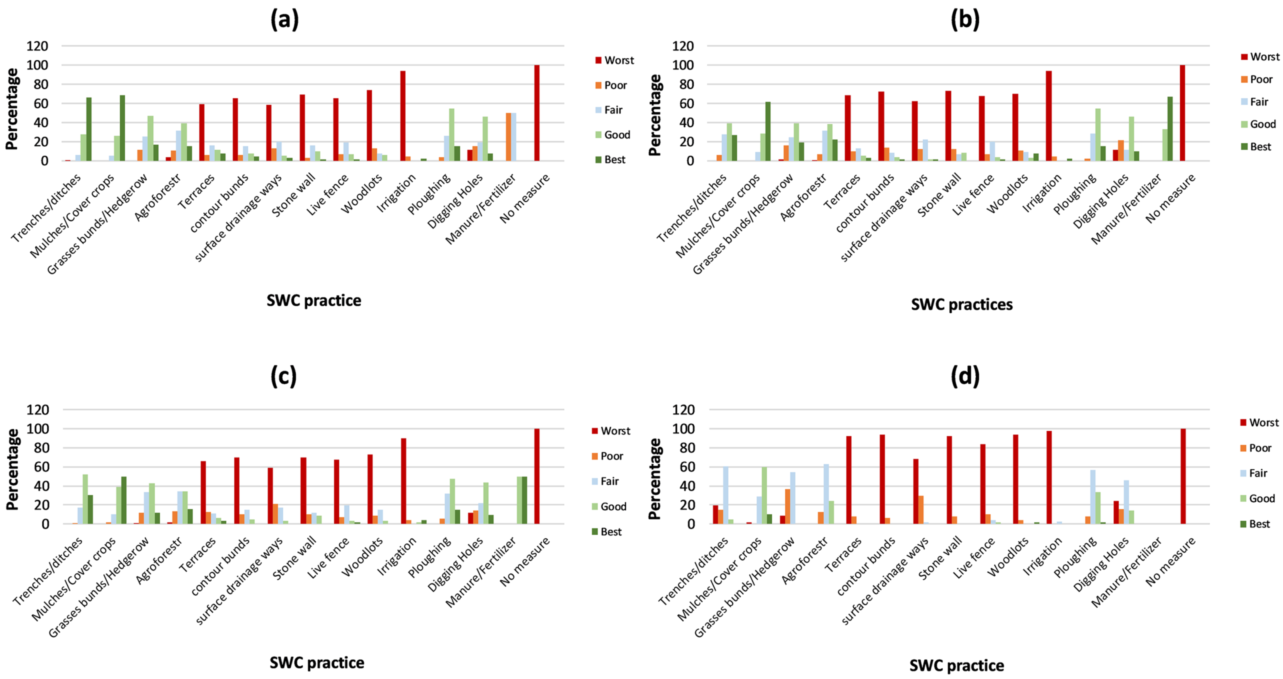

Figure 11. SWC practices and minimizing soil loss (a), enhancing soil fertility (b), maximizing water retention (c) & minimizing weeding (d) in the Katonga sub-catchment.

Figure 12 shows that Trenches, Mulches, Grass bunds, Agroforestry, and Ploughing are perceived to be fairly effective in minimizing Risks of pest effects by most farmers ($p < 0.01\%$). Irrigation, woodlots, live fences, stone walls, surface drainage ways, and contour bunds were least effective in minimizing the risks of pest effects on farmers’ gardens. “No measure” was perceived to be worse or not important by all the farmers (a).

This figure further shows that Manure/fertilizer, Trenches Mulches, Grass bunds, and Agroforestry are perceived to be fairly effective in minimizing disputes with neighbouring farmers ($p < 0.01\%$). Woodlots, live fences, stone walls, surface drainage ways, and contour bunds were least effective in minimizing disputes. “No measure” and irrigation were perceived to be worse or not important by all the farmers (b).

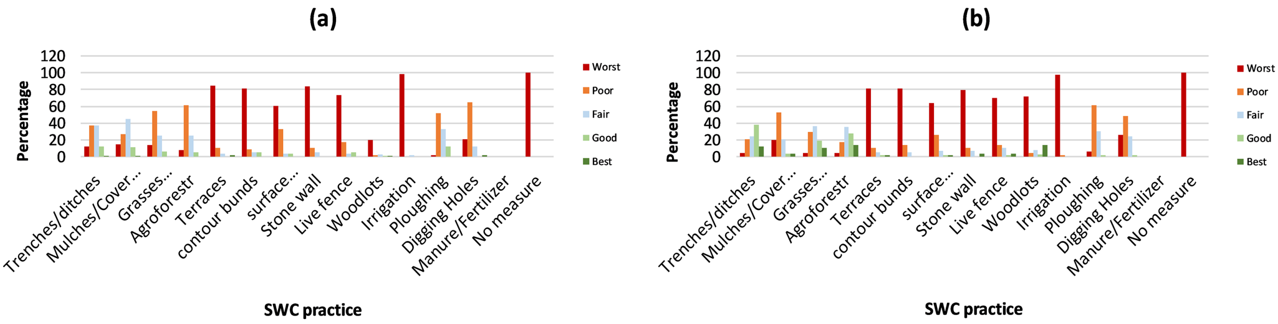

Figure 12. SWC practices and minimizing risks of pest effect (a) & minimizing disputes with neighbouring farmers (b) in the Katonga sub-catchment.

3.9. Factors Influencing the Adoption of Soil and Water Conservation Practices in the Katonga Micro-Catchment

3.9.1. Effect of Household Characteristics on the Use of SWC Practices

Table 4 shows the linear effect of Household characteristics on the use of SWC Practices in the catchment. The linear model was significant ($p \leq 0.01$ and $p \leq 0.05$) for trenches, grass bunds, and digging holes, though it had a low coefficient of determination ($R^2 = 0.05 - 0.16$). All the other practices were not linearly affected by household characteristics. The use of trenches was determined by gender and age. Trenches are more used by women and/or under 20 years old people. The use of grass bunds was determined by gender. Grass bunds are more used by women. The use of digging holes was determined by age. Digging holes was more used by people under 20 years old. These results were the same using regression analysis with both "Enter" and "Stepwise" methods. The use of trenches, grass bunds, agroforestry, stone walls, irrigation, manure, and digging holes was affected by inherent household socio-economic characteristics ($p < 0.01$ and $p < 0.05$). Trenches were significantly affected by gender ($p < 0.01$) and age ($p < 0.05$). Grass bunds, agroforestry, and stone walls were also significantly affected by gender ($p < 0.05$). Irrigation was significantly affected by the level of education ($p < 0.05$). Manure was significantly affected by status ($p < 0.05$). Digging holes was significantly affected by Age ($p < 0.05$). On the other hand, the use of mulches, contour bunds, surface drainage ways, live fences, woodlots, and ploughing was not affected by inherent household socio-economic characteristics.

3.9.2. Effect of Household Characteristics on the Preference Level of SWC Practices

Table 5 shows the linear effect of household characteristics on the preference level of SWC Practices in the catchment. The linear model was significant ($p < 0.05$) for Trenches/ditches, Contour bunds, surface drainage, stone walls, Live fences, Irrigation, and ploughing, but with a very low coefficient of determination ($R^2 = 0.04$). All the other practices were not linearly affected by household characteristics. The linear model for surface drainage, stone walls, and ploughing was statistically significant ($p < 0.05$) using regression analysis with the "enter method" while the linear model for Trenches/ditches, Contour bunds, Live fences and Irrigation was statistically significant ($p < 0.05$) using regression analysis with the "stepwise method". Trenches/ditches preferences were determined by gender. Trenches were more preferred by men. Contour bunds preferences were determined by gender. Contour bunds were more preferred by women. Surface drainage ways preferences were determined by land acres. As acreage increases, the level of preference for Surface drainage ways reduces. The preference for stone walls is determined by gender. Stone walls were more preferred by women. Live fence preferences were determined by gender. Live fences were more preferred by women. Irrigation preferences were determined by land acres. As acreage increases, irrigation preferences also increase. Ploughing preferences were determined by gender and household head status. Ploughing is more preferred by men and/or single people. The preference for trenches, grass bunds, agroforestry, contour bunds, surface drainage ways, stone walls, live fences, irrigation, ploughing, and digging holes was affected by inherent household socio-economic characteristics ($p < 0.01$ and $p < 0.05$). The preference for trenches and live fences was significantly affected by gender ($p < 0.05$), while contour bunds and stone walls were significantly affected by gender ($p < 0.01$). The preference for Grass bunds was significantly affected by the level of education ($p < 0.05$). The preference for agroforestry was significantly affected by age and level of education ($p < 0.05$). The preference for irrigation was significantly affected by land acres ($p < 0.01$), while the preference for surface drainage ways was significantly affected by land acres ($p < 0.05$). The preference for ploughing was significantly affected by status ($p < 0.01$) and gender ($p < 0.05$). The preference for digging holes was significantly affected by age ($p < 0.05$). The preference for mulches, woodlots, manure, and "no measure" was not affected by inherent household socio-economic characteristics.

Table 4. Effect of household characteristics on the use of SWC practices in the Katonga micro catchment.

Model	Trenches/ ditches	Mulches/ cover crops	Grass bunds/ hedgerow	Agroforestry	Contour bunds	Surface drainage ways	Stone wall	Live fence	Woodlots	Irrigation	Manure/ fertilizer	Ploughing	Digging holes
Gender	0.327**	0.094	0.154*	0.141*	−0.106	−0.059	−0.155*	0.081	0.027	0.009	0.052	0.061	
Age	−0.033*	0.056		0.102	−0.114	−0.086	−0.139	−0.002	−0.070	−0.061	0.036	−0.049	−0.145*
Status	−0.122	−0.065		−0.006	0.066	0.005	0.081	−0.011	0.033	0.072	−0.149*	−0.026	
LandAcres	−0.088	0.084		−0.092	−0.004	0.028	0.012	−0.014	−0.001	−0.026	−0.023	0.030	
Level of education	0.047	−0.102		−0.010	0.056	0.012	−0.007	−0.011	0.079	−0.121*	0.075	−0.026	
R2	0.122	0.023	0.024	0.035	0.021	0.010	0.029	0.007	0.013	0.025	0.024	0.009	0.021
Sig.*	**0.000**	0.531	**0.037**	0.262	0.577	0.871	0.376	0.939	0.791	0.483	0.508	0.899	**0.049**

** is the significance level at 0.01, * is the significance level at 0.05. Regression model method: Enter.

Table 5. Effect of Household Characteristics on the Preference Level of SWC Practices.

Model	Trenches/ ditches	Mulches/ cover crops	Grass bunds/ hedgerow	Agroforestry	Contour bunds	Surface drainage ways	Stone wall	Live fence	Woodlots	Irrigation	Manure/ fertilizer	Ploughing	Digging holes	No measure
Gender	−0.173*	−0.075	−0.050	−0.013	0.304**	0.188	0.451**	0.266*	0.116		−0.491	−0.041*	0.078	−0.128
Age		0.010	−0.010	0.153*		0.287	0.264		0.166		−0.036	0.107	0.241*	−0.105
Status		0.078	−0.045	−0.016		0.024	−0.043		−0.077		0.565	−0.400**	−0.105	0.029
LandAcres		0.053	0.240	0.004		−0.520*	−0.265		−0.119	0.331**	0.098	−0.080	0.003	0.206
Level of education		−0.075	−0.261*	−0.145*		0.414	0.140		−0.057		0.500	0.101	0.182	−0.127
R^2	0.029	0.016	0.089	0.045	0.093	0.186	0.195	0.071	0.038	0.109	0.253	0.198	0.091	0.025
Sig.*	**0.027**	0.812	0.146	0.388	**0.010**	**0.018**	**0.017**	**0.028**	0.748	**0.010**	0.830	**0.029**	0.404	0.942

** is the significance level at 0.01, * is the significance level at 0.05. Regression model method: Enter and Stepwise.

3.9.3. Effect of Household Characteristics on the Ranking of SWC Practices

Table 6 shows the linear effect of household characteristics on the Ranking of SWC Practices in the catchment. The linear model was significant ($p \leq 0.05$) for agroforestry, surface drainage, stone walls, Irrigation, ploughing, and digging holes, but had a low coefficient of determination ($R^2 = 0.05 - 0.16$). All the other practices were not linearly affected by household characteristics. The ranking of agroforestry was determined by gender. Agroforestry was highly ranked by women. Surface drainage ways ranking was determined by land acres. As acreage increases, the Surface drainage ways ranking reduced. The Stone walls ranking was determined by gender and land acres. Stone walls were highly ranked by women, and/or as the acreage increased, their ranking reduced. The ranking of Irrigation was determined by land acres and level of education. Irrigation was highly ranked by people with a primary level of education, and/or as the acreage increased, its ranking increased as well. The rankings of ploughing were determined by gender, household head status, and level of education. Ploughing is highly ranked by men, single people, and/or people with a degree level of education. Rankings of digging holes were determined by age, land acres, and level of education. Digging holes was highly ranked by people over 55 years old, with a degree level of education. The ranking of grass bunds, agroforestry, contour bunds, surface drainage ways, stone walls, live fences, irrigation, ploughing, and digging holes was affected by inherent household socio-economic characteristics ($p < 0.01$ and $p < 0.05$). The ranking of Agroforestry, contour bunds, and live fences was significantly affected by gender ($p < 0.05$). The ranking of grass bunds and surface drainage ways was significantly affected by land acres ($p < 0.05$). The ranking of stone walls was significantly affected by gender ($p < 0.01$) and significantly affected by land acres ($p < 0.05$). The ranking of irrigation was significantly affected by land acres and level of education ($p < 0.01$). The ranking of ploughing was significantly affected by status and gender ($p < 0.01$) and level of education ($p < 0.05$). The ranking of digging holes was significantly affected by age and land acres ($p < 0.01$) and level of education ($p < 0.05$). The ranking of "no measure" was significantly affected by age ($p < 0.05$). The ranking of trenches, mulches, woodlots, and manure was not affected by inherent household socio-economic characteristics. The significance of surface drainage and land acres was considered at $p = 0.062$ from the Pearson one-tailed results, and that of No Measure and Age at $p = 0.063$.

Table 6. Effect of household characteristics on the rank of preference of SWC practices.

Model	Trenches/ ditches	Mulches/ cover crops	Grass bunds/ hedgerow	Agroforestry	Contour bunds	Surface drainage ways	Stone wall	Live fence	Woodlots	Irrigation	Manure/ fertilizer	Ploughing	Digging holes	No measure
Gender	−0.075	−0.086	0.040	0.229*	0.256*	0.197	0.418**	0.274*	0.000	0.068	−10.232	−0.251**	0.146	−0.014
Age	0.030	−0.025	−0.013	0.216	0.173	0.203	0.205	0.048	0.211	−0.052	−0.636	0.016	0.320**	0.295*
Status	−0.002	0.086	−0.044	−0.202	−0.249	−0.146	−0.102	−0.081	0.022	−0.194	10.052	−0.299**	−0.178	0.041
LandAcres	0.061	0.055	0.241*	−0.041	−0.157	−0.416*	−0.349*	−0.205	−0.159	0.480**	−0.123	−0.156	0.068**	−0.186
Level of education	−0.012	−0.066	−0.231	−0.097	0.034	0.350	0.254	0.206	−0.032	−0.060**	0.217	0.252*	0.226*	−0.040
R^2	0.012	0.015	0.074	0.092	0.103	0.144	0.183	0.092	0.055	0.215	0.329	0.289	0.195	0.085
Sig.*	0.869	0.839	0.200	**0.046**	0.167	**0.059**	**0.021**	0.287	0.578	**0.027**	0.834	**0.003**	**0.057**	0.518

** is the significance level at 0.01, * is the significance level at 0.05. Regression model method: Enter.

4. Discussion

4.1. Major Cropping Systems in the River Katonga Sub-Catchment

Coffee, Maize, Banana, and Beans are the dominant crops in the Katonga micro-catchment, reflecting similar agricultural trends observed in other agro-ecological zones of East Africa [11]. The dominance of Coffee is associated with Uganda's significant role as a major producer of Robusta and Arabica coffee, reinforced by favorable climatic conditions such as altitude, temperature, and rainfall [49]. Furthermore, governmental and international support, including extension services and export incentives, have increased the production of coffee [50] [51]. Maize is extensively cultivated because of its adaptability to a range of agro-climatic conditions and its essential role in food security, flourishing in regions like Katonga, which have moderate rainfall and fertile soils [52]. This aligns with its importance as a staple food throughout Sub-Saharan Africa [53] [54]. Beans are significant for their high nutritional value, especially as a protein source in regions with limited access to animal products [51]. In addition, beans enhance sustainable farming by improving soil fertility through nitrogen fixation, thereby supporting intercropping systems in Katonga [55].

Bananas (Matoke) serve as both a staple food and a cash crop in Uganda, flourishing because of their adaptability to local climatic conditions and their aptitude to grow in various soil types [56]-[58]. They enhance food security and rural incomes while also supporting agroforestry practices that improve soil conservation and offer shade for other crops [58] [59].

4.2. Major Livestock Systems in the River Katonga Sub-Catchment

Goats, sheep, cattle, pigs, and poultry are the main livestock in the Katonga micro-catchment, underlining the significance of livestock to local economies and food systems, and reflecting broader mixed farming trends across East Africa [59]. Smallholder farmers frequently prefer goats and sheep because of their adaptability to various environments with limited resources [60]-[62], and because they are well-suited to the variable climate of Katonga, requiring fewer inputs and better adapting to fluctuations in rainfall [63]. The broad dietary range of goats makes them less reliant on high-quality pasture compared to cattle [64]. The dominant presence of cattle shows the local reliance on dairy and beef, which are both key to the livestock industry of Uganda [65] [66], and reveals the role of cattle as a symbol of wealth [67]. Piggery is also a major, which is driven by the increasing pork demand and the efficient feed conversion of pigs, making them appealing for resource-limited regions [68]. Poultry, particularly chickens, offers income and an affordable and accessible source of protein, requiring low initial investment and providing quick returns [69]. Additionally, the resilience of poultry farming to disease and environmental stresses makes it particularly suitable for small-scale farmers [70] [71].

4.3. Existing Soil and Water Conservation Practices in the Katonga Micro-Catchment

Trenches/ditches, Mulches/cover crops, Grass bunds/Hedgerows, Agroforestry, Terraces, Contour bunds, Surface drainage ways, Stone walls, Live fences, Woodlots, Irrigation, Manure/Fertilizer application, Ploughing, and Digging holes are the commonly used Soil and Water Conservation practices in the Katonga micro-catchment showing the farmers' reliance on a range of soil and water conservation technologies. The most frequently used soil and water conservation practices in the Katonga micro-catchment are trenches/ditches, followed by mulches/cover crops, agroforestry, and grass bunds/hedgerows. The widespread use of trenches or ditches is attributed to their effectiveness in capturing rainwater, minimizing runoff, and preventing soil erosion in sloped areas [72]. Additionally, trenches are also relatively simple and cheap to build, which enhances their popularity among smallholder farmers having limited resources and access to resources [73]. Similarly, mulching or planting cover crops is crucial for preserving soil moisture and fertility [74] [75]. Mulches offer a protective layer for the soil, decreasing evaporation, inhibiting weed growth, and preventing erosion [76]. Agroforestry provides numerous benefits, which include enhancing soil structure, decreasing erosion, increasing biodiversity, and offering extra income from tree products such as fuelwood, timber, and fruits [77]. Furthermore, agroforestry strengthens resilience to climate variability by enhancing water retention and offering shade for crops [78]. Grass bunds or hedgerows serve as natural barriers that slow down water flow and allow the flowing water to infiltrate the soil, thereby decreasing the risk of surface runoff and erosion [79]. These grass bunds or hedgerows, typically made up of fast-growing trees or shrubs, also fulfill multiple functions, which include offering fodder for livestock, land demarcations, and fuel [80] [81].

4.4. Criteria Scores of Soil and Water Conservation Practices

The evaluation criteria which included minimizing soil loss, enhancing soil fertility, maximizing water retention, increasing crop yields, maximizing fodder production, minimizing labor and maintenance costs, reducing risks of pests, resolving disputes with adjacent farmers, and increasing income, show that the farmers weigh the ecological, economic, and social factors when they are evaluating the suitability of SWC practices. The most important and highly scored criteria for evaluating soil and water conservation (SWC) practices comprise minimizing soil loss, maximizing water retention, enhancing soil fertility, and increasing crop yields, while minimizing weeding and increasing income are scored second as important criteria by the farmers. Minimizing soil loss reveals the major impact of soil erosion on agricultural productivity in the Katonga micro-catchment, as soil erosion removes nutrient-rich topsoil, decreasing land fertility and lessening crop yields [35]. Maximizing water retention ensures the success of agriculture in semi-arid and seasonally dry areas such as Katonga. Farmers prioritize water retention to mitigate the risk of water stress on crops, especially during vital growing stages [82]. Enhancing soil fertility underlines farmers' interest and commitment to maintaining productive and nutrient-rich soils [83], which support high crop yields without relying heavily on chemical fertilizers that are expensive and harmful to the environment. Increasing crop yields is also prioritized and crucial for farmers since it directly affects their income and food security, as agriculture is the main livelihood source for the majority of the population residing in the Katonga micro-catchment [1]. Minimizing weeding helps manage time and labor, but it is secondary to more immediate concerns such as soil health and water retention [84]. Increasing income is seen as an outcome of yield enhancements, showing that farmers perceive economic benefits as a product of using sustainable practices.

4.5. Preference Level of Soil and Water Conservation Practices

The most preferred soil and water conservation (SWC) practices in the micro-catchment included trenches, mulches, grass bunds, and agroforestry. These practices are followed by ploughing and digging holes. This preference reveals local agronomic conditions, available resources, and immediate needs of farmers for effective soil and water management strategies [39] [85]. Trenches are preferred because they are highly effective in mitigating soil erosion and enhancing water retention. They act as physical barriers that intercept runoff, allowing water to penetrate the soil and minimize soil loss [86] [87]. Farmers frequently recognize the immediate impact of trenches on reducing soil erosion and enhancing the availability of moisture for crops. These results align with the findings from former studies showing that farmers tend to give priority to SWC practices that offer them clear and immediate results or benefits [9] [13]. Mulches are also highly preferred because of their multifunctional benefits. These practices aid in preserving soil moisture, inhibit weeds, and improve soil fertility by adding organic matter as they deteriorate [76]. This preference for mulching highlights farmers' broader understanding of the importance of maintaining soil health and lessening the labor burden related to weeding. Grass bunds and agroforestry practices are preferred because of their ability to stabilize soils and enhance ecological health. Grass bunds act as barriers that decrease water runoff and soil erosion, and at the same time offer fodder for livestock [88]. Equally, agroforestry, which incorporates trees and crops, increases biodiversity and enhances soil fertility by fixing nitrogen and adding organic matter [89]. The preference for these methods demonstrates farmers' awareness of the interconnected nature of agricultural systems and the necessity for integrated land management approaches [90]. Ploughing and digging holes are viewed as less effective than the previously mentioned practices. Ploughing is a traditional method that prepares land and manages weeds, but it can intensify soil erosion if not blended with other conservation methods. Digging holes, which involves creating planting pits to conserve moisture, provides benefits such as localized nutrient concentration and water retention [91]. The lack of preference for "no measure" indicates farmers' recognition of the crucial importance of using soil and water conservation methods, as well as their awareness of the challenges caused by soil erosion and water scarcity in agricultural production [92].

4.6. Ranking of Soil and Water Conservation Practices

The most highly ranked soil and water conservation (SWC) methods include Trenches, mulches, grass bunds, and agroforestry. This ranking highlights the adaptability of these practices to local agricultural conditions and their effectiveness in reducing soil erosion and enhancing water retention in a resource-limited context [93] [94]. Trenches are highly valued for their capability to mitigate runoff on sloped lands, a prevailing characteristic in this area, and for their role in enhancing soil moisture retention during dry times, which is critical in semi-arid regions of East Africa [95]. Mulching also ranked highly because of its aptitude to maintain moisture, inhibit weeds, and improve soil structure, making it especially beneficial in areas experiencing irregular rainfall trends [96], and because it is a low-input practice that is accessible and cost-effective for smallholder farmers aiming to enhance soil health and crop resilience [97]. Grass bunds ranked highly as well because they offer natural barriers to erosion and stabilize soil on sloped lands susceptible to soil loss during seasonal rains. Many studies conducted in East African highlands have demonstrated that grass bunds effectively reduce soil erosion and enhance soil structure over time, aligning with sustainable land management practices suitable for smallholder farming systems [98]. The high ranking of agroforestry underlines its diverse benefits for farmers in the Katonga area, which include enhanced soil fertility, improved water retention, and supplementary income from the production of fruits, fodder, and firewood. Agroforestry fits well within the smallholder farming systems since it incorporates trees into the landscape, thereby contributing to biodiversity and soil health [99] [100]. Ploughing and digging holes ranked lower than the previously mentioned SWC measures due to their labor intensity and limited effectiveness in soil erosion prevention when used in isolation. While ploughing assists in soil aeration and water infiltration, it can worsen erosion if not blended with other conservation technologies, which may discourage farmers seeking sustainable erosion control [101]. The poorer ranking of "No measure" underlines the region's growing awareness and proactive approach towards implementing SWC practices in response to visible land degradation and the need to safeguard agricultural productivity [82]. In general, these rankings align with tendencies in East African regions where smallholders prioritize practical, low-cost, and labor-efficient SWC methods to improve soil health, increase crop productivity, and enhance environmental resilience [99] [100].

4.7. Farmers' Multi-Criteria Ranking of the Alternatives

Manure/fertilizer, trenches, mulches, grass bunds, agroforestry, ploughing, and digging holes were perceived as very effective in maximizing crop yields by farmers. These practices enhance crop productivity or yield by directly or indirectly increasing soil fertility, moisture retention, and soil structure. Manure or fertilizer delivers key nutrients such as nitrogen, phosphorus, and potassium essential for crop growth, while manure also contributes organic matter, enhancing soil texture and water retention capacity that boosts crop resilience and yield [102] [103]. Many studies across Sub-Saharan Africa show that organic and chemical fertilizers considerably raise crop yields by restoring nutrients lost during cultivation [104]. Trenches and digging holes are effective SWC methods that aid in the management of water, avoiding soil erosion and permitting water infiltration, which is essential for rain-fed agriculture. These methods enhance soil moisture availability, which is vital for crop growth, mostly during dry periods, by capturing rainwater and permitting it to get absorbed into the soil [105]. This aligns with findings from arid or dry regions, where trenching and pitting are acknowledged to boost yields by enhancing soil moisture [106] [107]. Mulching also contributes significantly to increasing crop yields by decreasing water evaporation, inhibiting weeds, and adding organic matter when it decomposes. This helps maintain soil moisture and safeguards plants from drought stress, a usual challenge in the Katonga area [74]. Grass bunds help stabilize soils, avoid soil loss, retain moisture and nutrients, offer organic material, and improve soil structure, which collectively leads to more fertile soils that support higher yields for crops [88]. Agroforestry increases crop yields by providing multiple ecological benefits such as enhanced nutrient cycling, decreased soil erosion, and shade, which keeps soil temperatures lower and preserves crops from extreme heat [99] [100]. Additionally, nitrogen-fixing trees in agroforestry systems naturally increase the levels of soil nitrogen, making it possible for crops to grow without the use of synthetic fertilizers [108]. Farmers traditionally value ploughing because it breaks compacted soil layers, permitting effective root access to nutrients and water. Conservation tillage techniques that limit soil disruption are mainly effective for soil moisture retention, which contributes to higher crop yields and improved crop resilience [82] [109] [110].

Manure/fertilizer, trenches, mulches, grass bunds, and agroforestry were viewed as highly effective in maximizing fodder production by farmers. Manure or fertilizers are indispensable for restoring soil nutrients such as nitrogen and phosphorus that enhance plant growth and production of biomass. Manure, especially, enhances soil structure by adding organic content, which enhances water retention and stimulates root development for fodder plants such as grasses [106] [111]. Studies confirm that the application of manure boosts fodder crops' yields by enhancing the availability of nutrients, a common result broadly seen in smallholder farming systems across Sub-Saharan Africa [104]. Trenches assist in capturing rainwater, promoting its effective infiltration in the soil, which is valuable for grass production, especially in drier zones like Katonga, by maintaining soil moisture. Additionally, trenches limit runoff and erosion, conserving soil stability and nutrients, essential for reliable fodder growth [105]. Mulching covers the soil, reducing evaporation and increasing moisture retention, stabilizing soil temperature, and limiting weed competition. As mulch deteriorates, it further enriches the soil, creating a supportive environment for grasses to grow well, and it is then beneficial in semi-arid areas known for moisture retention challenges [74] [75]. Grasses help stabilize the soil, prevent erosion, add organic matter, and support a self-sustaining nutrient cycle when trimmed and left to decompose, which enhances continuous and ongoing grass growth [112]. Agroforestry benefits fodder production by improving ecosystem functions like nutrient recycling, shading, and reducing wind erosion. Trees in agroforestry systems, particularly nitrogen-fixing species, enrich the soil for neighboring grasses, and the shaded micro-climate they create helps reduce moisture loss, which is advantageous for the growth of some fodder grasses [99] [100].

Manure/fertilizer was perceived as the most effective in reducing labor requirements by farmers. This can be due to the application process that is simple, where spreading manure on the field involves minimal physical effort. Once applied, manure gradually improves soil fertility and structure, boosting crop growth without frequent reapplication [113]. The preference of farmers for manure as a labor-saving technology aligns with results indicating that organic amendments enhance soil properties with low labor inputs, especially compared to more intensive SWC technologies [104]. On the other hand, trenches, mulches, grass bunds, and agroforestry were seen as fairly effective in minimizing labor requirements for their establishment. Although these methods demand initial labor, they generally require minimal maintenance after establishment, providing long-term benefits that decrease ongoing labor needs. Studies have shown that trenches, for instance, need labor to dig and position along slopes, but once established, they help stabilize the land and control runoff, thereby lessening other labor demands in soil and water conservation tasks, aligning with farmer perceptions in Katonga [105]. Mulching also involves some labor for setup, but it saves labor in the long run by cutting down on weeding, conserving moisture, and enriching soil as it decomposes [74] [114]. Grass bunds, while requiring initial planting labor, reduce future labor related to erosion control, providing a valuable return on the initial labor investment [115]. Agroforestry, though initially labor–intensive, becomes low maintenance after the establishment of trees and as trees mature, offering benefits such as enhanced soil fertility, soil stabilization, and a favorable microclimate for crops, which boosts productivity with minimal additional labor inputs [99] [100]. Agroforestry also offers potential economic gains through marketable products, which can help compensate for initial labor.

Manure/fertilizer was seen by farmers as the most effective practice for minimizing maintenance costs. This is due to the double benefits of manure: it supplies essential nutrients and enhances soil structure and health over time. Manure, if applied properly, not only boosts soil fertility but also reduces dependence on chemical fertilizers, which are often more costly and require more labor for application [106] [116]. By improving soil quality, manure leads to higher crop yields, consequently lowering the need for additional fertilizers and associated costs [104]. On the other hand, Trenches, mulches, grass bunds, and agroforestry were seen as fairly effective in minimizing maintenance costs. While they involve initial labor and investments, these practices tend to lower ongoing expenses over time. Trenches, for example, aid in water retention and erosion control, considerably reducing the maintenance required for soil conservation. Once in place, trenches require limited maintenance, helping stabilize soil and lessen the costs of crop failures caused by erosion or water runoff, and helping farmers allocate resources to other farming aspects or activities [105]. Mulching is valuable for conserving soil moisture and suppressing weeds, which cuts down on labor and inputs needed for irrigation and weeding. Research indicates that mulching considerably reduces the need for herbicides and manual weeding, thus lowering maintenance expenses [74] [117]. Additionally, mulch deteriorates over time, enriching soil fertility and boosting crop resilience without having to incur high maintenance costs. Grass bunds provide soil stability and support nutrient cycling, leading to fewer input costs over time. Once established, they require limited maintenance and enhance the health of nearby crops, thus reducing expenses for pest control and fertilizers [115] [118]. Although agroforestry is labor-intensive initially, it offers long-term benefits that minimize maintenance costs. Trees are vital in enhancing soil health, creating a beneficial microclimate for enhanced crop resilience, and lessening the need for chemical fertilizers [78] [99] [100] [103]. Over time, agroforestry can also generate diverse income sources, reducing overall financial risks and ongoing maintenance costs for farmers.

Mulching and ploughing are viewed as effective methods for increasing income among farmers. Mulches are broadly acknowledged for enhancing soil health, maintaining moisture, and inhibiting weeds, which together contribute to higher yields of crops [74] [119]. By creating an advantageous environment for plants' growth, mulching can considerably increase productivity, permitting farmers to increase their earnings through increased harvests. In addition, mulches lead to long-term soil fertility, which is indispensable for sustainable farming [117] [119] [120]. Ploughing, a fundamental tillage method, prepares the soil for planting and aids in managing weeds, improving crop development [121]. By enhancing the structure and aeration of soil, ploughing can contribute to better germination of seeds and establishment of crops, both essential for maximizing yields. Higher yields, in turn, lead to increased income for farmers, making this practice a valuable method in their agricultural practices. However, it is crucial to balance ploughing with conservation measures to avoid the degradation of soil in the long run [109] [122].

Farmers in the Katonga micro-catchment view trenches, mulches, grass bunds, agroforestry, and ploughing as the most effective practices for reducing soil erosion or minimizing soil losses. These results align with numerous studies that have highlighted the impact of these technologies on moisture retention and soil stability. For example, trenches are well-documented for reducing surface runoff by capturing water and sediments, which helps lower erosion rates [105]. Mulching similarly minimizes soil exposure, preserves soil moisture, and enhances soil organic matter, thus strengthening soil structure and resilience to erosion [74] [123]. Grass bunds are also effective for erosion control by forming a dense root system that stabilizes soil particles and slows down water flow [124] [125]. Agroforestry, which integrates trees with crops, helps protect soil through canopy cover and root systems that retain soil in place while leaf litter and nitrogen fixation enhance soil fertility [99] [100] [106] [107]. Ploughing, frequently utilized for soil aeration improvement and preparation for planting, can reduce erosion when done as contour ploughing, following the land's natural slope to minimize runoff [12] [82] [124].

Manure/fertilizer, trenches, mulches, grass bunds, agroforestry, and ploughing are broadly perceived as highly effective practices for enhancing soil fertility by farmers in the Katonga micro-catchment. This perception is supported by the well-established benefits that these practices offer for improving soil structure, nutrient content enhancement, and erosion prevention. Manure or fertilizer applications are valued and acknowledged for directly enhancing soil fertility by providing essential nutrients like nitrogen, phosphorus, and potassium, which are crucial for plant growth [127]. Manure specifically increases soil organic matter, boosts microbial activity, and improves water retention, thereby providing long-term soil health and productivity [106] [127] [128]. These farmers' reliance on these inputs for fertility improvement aligns with broader findings in Sub-Saharan Africa, where manure and fertilizer are key strategies for addressing nutrient deficiencies in soils [104]. Trenches, mulches, and grass bunds contribute to soil fertility indirectly by reducing erosion and preserving soil moisture, which in turn helps retain organic matter in the soil. Trenches minimize surface runoff and soil loss, which conserves nutrient-rich topsoil [105]. Mulching helps to inhibit weed growth, retain soil moisture, and, as it deteriorates, gradually add organic material to the soil [74] [75] [123]. Grass bunds aid in stabilizing soil structure and contribute organic matter over time through root decomposition and leaf litter [129]. Agroforestry also improves soil fertility through various mechanisms such as tree roots drawing up nutrients from deeper soil layers, while decomposing leaves add organic matter [78] [99] [100]. Certain agroforestry tree species, like nitrogen-fixing legumes, enhance soil nitrogen levels, which increase crop productivity without additional fertilizer inputs [108]. Ploughing, especially conservation tillage, further enhances soil structure, facilitating root access to nutrients and moisture [82] [130].

Farmers also perceive manure/fertilizer, trenches, mulches, grass bunds, agroforestry, ploughing, and digging holes as very effective measures for maximizing water retention. These technologies are known for their ability to enhance soil moisture retention through mechanisms such as runoff control, soil structure improvement, and organic matter enhancement, which collectively help retain water within the soil. Manure or fertilizer not only improves soil fertility but also enhances soil structure by augmenting organic matter, which consequently increases water-holding capacity. Manure is especially beneficial as it improves soil porosity, permitting deeper water infiltration, which is a vital feature during dry times [102] [106] [128]. This aligns with findings from similar regions, where organic amendments are highly valued for both fertility and water retention benefits [131]. Trenches and digging holes are effective as they capture rainwater and slow surface runoff, permitting more water to penetrate the ground rather than run off. Trenches, in particular, are noted in SWC studies for their double role in erosion control and water conservation (maximize infiltration) [105]. Digging holes, frequently blended with mulching or tree planting, form small basins around plants, helping retain water in dry situations [132]. Mulching is another highly valued technology that covers the soil surface to minimize evaporation and maintain cooler soil temperatures, both of which support higher moisture retention. As the mulch decomposes, it also adds organic matter, further enhancing the soil's moisture-holding ability over time [75] [123]. Grass bunds also aid in water retention by stabilizing the soil and forming a vegetative or plant cover that reduces runoff and increases infiltration, especially in regions having heavy rainfall [129] [133]. Agroforestry, by integrating trees with crops, provides shading for crops and improves soil structure. Tree roots lengthen deep into the ground, forming pathways that facilitate water infiltration and storage in deeper soil levels, keeping it accessible and available for crops during dry times [99] [100] [130]. Ploughing, particularly when done with conservation tillage methods, can aid in enhancing soil aeration and form channels that trap water, though excessive tillage might reduce soil moisture if not properly done [82] [126] [134].

Mulches and ploughing are seen as effective in minimizing weeding. Mulches are well known broadly for their ability to inhibit the growth of weeds, maintain soil moisture, and enhance the fertility of soil [74] [117]. By covering the surface of the soil, mulches prevent sunshine, which is necessary for the germination and growth of weeds. Farmers in the Katonga micro-catchment see mulching as a cost-effective strategy to decrease weeding labor, making crop management more efficient. In addition, organic mulches decompose over time, enriching the soil and boosting plant resilience and growth [117] [119] [120]. Ploughing also has a double purpose, such as aeration of the soil and inhibition of weeds. By overturning the soil, ploughing disrupts the growth of weeds and exposes the seeds of weeds to natural predators and environmental constraints that reduce their viability [121]. Farmers find regular ploughing to be effective in controlling the population of weeds, especially in annual cropping systems where weeds are highly competitive. However, it is important to point out that while ploughing can be advantageous, excessive tillage can degrade soil quality if not done sustainably [122] [122].

Trenches, mulches, grass bunds, agroforestry, and ploughing are seen as fairly effective in minimizing pest risks. Trenches help control water flow and limit soil erosion, creating conditions that inhibit certain pests. By diverting excess water away from crops, trenches maintain optimal soil moisture, reducing waterlogged conditions that can encourage pest growth [105] (Raj *et al*., 2024). Mulching is known for its double benefits of retaining moisture and inhibiting weeds, which can indirectly aid in pest management. Mulches also offer habitats for advantageous insects that prey on pests, naturally lowering the population of pests [74] (El-Beltagi *et al*., 2022). Furthermore, mulches can act as a physical barrier that prevents certain pests from reaching crops. Grass bunds can function as a trap crop or offer habitation for natural pest predators, contributing to natural pest control and thus reducing pest outbreaks [135]. Agroforestry systems increase farms' biodiversity, which is essential for pest control, as the variety of plant species disrupts pest life cycles and stimulates natural enemies' populations [99] [100]. Agroforestry also offers shade and wind protection, creating an advantageous microclimate that helps crops better resist pest pressures. Ploughing disrupts pest habitats and can decrease soil-borne pests and diseases [115] [136]. This tillage method also increases soil aeration and structure, promoting healthier crop growth that is less vulnerable to pest invasion.

Manure/fertilizer, trenches, mulches, grass bunds, and agroforestry are seen as fairly effective in minimizing disputes among farmers. Manure can enhance soil fertility and increase crop yields. When farmers effectively use manure, their competition for soil nutrients is lessened, leading to decreased disagreements over land productivity [121]. Additionally, sharing manure between neighboring farms can foster cooperation and reinforce community bonds. Trenches aid in controlling water runoff and preventing erosion of soil. Effective erosion control practices can lessen conflicts arising caused by land degradation, as adjacent farmers may feel safer in their land's ability to uphold agricultural undertakings [105]. Mulching inhibits weeds and maintains soil moisture, leading to improved crops and bigger yields. As more farmers adopt mulching, the overall productivity of the micro-catchment may increase, lowering competition and disputes over land and resources [137] [138]. Integrating grass bunds into agricultural systems offers various benefits such as enhanced soil structure, controlled erosion, and can work as cover crops to increase soil fertility and decrease differences over degraded land [9] [88] [129]. The incorporation of Agroforestry into agricultural systems offers additional resources, including timber and fodder, while increasing biodiversity that aids in buffering against failures of crops, thus lessening arguments over the availability of resources [139].

4.8. Factors Influencing the Adoption of Soil and Water Conservation Practices in the Katonga Micro-Catchment

Trench and grass bund technologies are mostly used by women in the Katonga micro-catchment. This aligns with wider literature underlining women's critical role in agricultural activities and resource management within rural communities [140] [141]. Women are frequently involved in activities that directly influence the production of crops and the conservation of soil, demonstrating their traditional responsibilities in the security of food and the management of the households. This use of trenches by women highlights an acknowledgment of their effectiveness in controlling soil erosion and increasing moisture retention [105]. Women's participation in the construction of trenches can also be influenced by women's roles in crop production and their need to keep sustainable agricultural practices to support their families. The use of grass bunds by women further underlines their role in the local management of farming ecosystems. The grass bunds not only aid in erosion control but also enhance soil fertility by accumulating organic materials [74] [129]. Women's involvement in these technologies may reveal women's understanding of the long-term advantages of such methods, which are crucial for retaining the health of soils and the productivity of crops. On the other hand, the use of digging holes and trenches is more prevailing among younger individuals, particularly those under twenty (20) years old of age. Younger people may favor the use of these methods due to their physical demands, which they might find easier to carry out than older farmers [142]. This trend is also possibly related to specific cultural or educational perspectives where younger family members are encouraged to participate in agricultural practices. These findings align with the results of [143], who highlighted that engaging youth in farming promotes the early development of skills and raises their awareness of sustainable methods.

The preference for Trenches/Ditches by men highlights a possible linkage with traditional gender roles in agricultural activities. Men are frequently more engaged in the initial construction and maintenance of physical structures such as trenches, which are essential for the conservation of soil and water [140]. This may reveal not only expectations around physical labor but also the decision-making authority regarding land management methods. The higher preference for Contour Bunds by women underlines their engagement in practices that may directly impact the production of crops and the management of land. Women's involvement with contour bunds may also reveal their roles in handling the household food supply and ensuring sustainable farming practices [74]. This result aligns with findings showing that women frequently implement methods that increase soil fertility and control erosion, which are crucial for food security [144]. The preference for stone walls and live fences by women further underlines their role in maintaining farming infrastructure. These methods may serve various purposes, such as guarding crops from animals and enhancing farm aesthetics [145]. The preference for live fences by women may also be related to their role in managing farm borders and increasing the overall land productivity. The inverse relationship between the preference for Surface Drainage Ways and land acreage highlights that farmers with larger plots might depend on other water management strategies, probably because of the complexity of implementing drainage methods across larger areas. These farmers with wider land may prioritize methods that permit for efficient resource management over those that call for intensive, smaller area management [146]. This tendency can enlighten extension services to fine-tune recommendations based on the size of the land and agricultural practices. The positive relationship between irrigation preferences and land acreage points out that larger farms are more likely to implement irrigation systems to maximize water use and increase productivity, responding to the need for augmented efficiency in larger land area management and maximizing the yields of crops [105]. The preference for ploughing being more predominant among men and single people points out the importance of household dynamics in farming practices. Single people, possibly missing shared labor, may prefer ploughing as a more convenient practice, while married people might share duties or take on different methods based on their family structure [140].

The high ranking of agroforestry by women reveals their dynamic role in sustainable land management practices. Women frequently engage in agroforestry because of its diverse benefits, such as increasing food security, enhancing soil health, and offering supplementary income sources [140]. This preference for agroforestry may also be due to their traditional roles in the management of resources, making them the main stakeholders in promoting such methods. The high ranking of stone walls by women, together with the effect of land acreage on its ranking, points out that women may give priority to methods that improve farming productivity and the management of resources on their farms. Stone walls aid in demarcating property borders and protect crops, revealing women's double roles in farming production and in ensuring household security [145]. As land size augments, the decreased ranking may indicate a shift in focus towards technologies that maximize larger areas, possibly showing that stone walls' management becomes less practical on bigger farms. The ranking of surface drainage ways reduces as land acreage increases, underlining the complexity and challenges of managing resources on larger farms. Farmers with wide land might embrace different water management strategies, probably choosing more scalable solutions instead of localized drainage methods. This result aligns with [147], who found that bigger farms frequently call for integrated water management methods that can manage greater variability in land use and the availability of water. The high ranking of irrigation by people with a level of primary education and the increases in its ranking with land acreage indicate a significant relationship between the level of education and resource management. Those with a primary education level might have a more practical understanding of the benefits of irrigation, especially for increasing the yields of crops on smaller farms or plots [105]. The higher ranking of irrigation by larger landholders highlights an acknowledgment of its indispensable role in maximizing productivity in large-scale farming systems. The high ranking of ploughing by men, single people, and those with a degree level shows that this practice is preferred by particular demographics. Men's prevalence in ploughing can be related to traditional gender roles in farming labor, where men frequently carry out demanding tasks physically [74]. The association of ploughing with single people and degree level holders indicates that these groups may give priority to more intensive farming practices that require higher technical knowledge and skill that might not be as accessible to people with less education or to married couples who share duties [140]. The high ranking of digging holes by people over 55 years of age shows a possible generational preference or learned methods that might be tied to traditional agricultural methods. Older farmers might have a profound understanding of the digging holes ecological benefits for water retention and soil fertility, often embedded in their long-term agricultural experiences [82]. In addition, the relationship between the level of education and land acreage indicates that as older farmers gain or purchase more land, they also adopt more sustainable practices that reflect their accumulated knowledge.

The findings of this study provide valuable insights into the agricultural dynamics of the Katonga micro-catchment and underscore the potential to empower smallholder farmers to adopt sustainable agricultural practices that improve productivity, enhance food security, and strengthen resilience to environmental challenges. The integration of diverse cropping systems and livestock, alongside the implementation of effective soil and water conservation strategies, offers a promising pathway toward sustainable development in the region, ultimately benefiting both farmers and their wider communities.

5. Conclusion

Several SWC practices in the Katonga micro-catchment of South-Central Uganda were evaluated using qualitative criteria by diverse stakeholders to assess their economic, ecological, and social impacts. The study revealed that the most commonly used SWC practices in the Katonga micro-catchment included trenches/ditches, followed by Mulches/cover crops, Agroforestry, and Grass bunds/Hedgerows, while the least used included contour bunds, surface drainage, stone walls, live fence, irrigation, and woodlots. Farmers in the Katonga micro-catchment have a range of criteria to evaluate the performance of SWC measures; minimizing soil erosion, enhancing soil fertility, maximizing water retention, and increasing crop yield are very important criteria. The most preferred and highly ranked soil and water conservation practices in the region include trenches, mulches, grass bunds, and agroforestry. Trenches, mulches, grass bunds, and agroforestry are very effective in minimizing soil losses or controlling erosion, maximizing or enhancing soil fertility, maximizing water retention, maximizing or increasing crop yields, and maximizing fodder (grass) production. The findings of this study contribute to the existing literature on participatory evaluation of SWC technologies by validating farmer-driven criteria as essential elements in assessing the effectiveness of these technologies. Policymakers and practitioners are urged to give attention to farmers' preferences, experiences, and local conditions when developing SWC strategies and programmes. Further research is needed to determine soil, runoff, and nutrient losses from these SWC practices to enhance their effectiveness and inform sustainable land management strategies.

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Authors' Contributions

Wivine Matabaro Adidja: Conception and design; methodology; fieldwork and data collection; data cleaning, coding, and entry into the software for analysis; data analysis, interpretation, and discussion; drafting the full paper; and revising the paper critically for intellectual content. Joseph Sekkandi: Supervision of the PhD study. Akalu Teshome and Wivine Matabaro Adidja: Design and development of research tools such as questionnaires, checklists, and interview guides. All authors consent to publish.

Conflicts of Interest

The authors report that there are no competing interests to declare.

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