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Research article

Constraints on Adopting Land Conservation Technologies Among Cassava Farmers in Volcanic Hillslope Prone to Landslide, Indonesia

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Abstract

The adoption of land conservation technologies (LCTs) in smallholder farming systems often remains limited due to diverse, context-specific constraints, highlighting the need for localized analyses. This study examines the barriers to LCTs adoption among cassava farmers residing on landslide-prone volcanic slopes in Magelang Regency, Indonesia. A qualitative approach was employed, involving semi-structured interviews with eight low-income farmers. The analysis identifies two key determinants of non-adoption: perceived benefits and socio-cultural dynamics. Findings indicate that LCTs are perceived as having low applicability because farmers limited investment capacity, and encounter difficulties in altering traditional cultivation practices. These results expose the shortcomings of previous intervention programs and underscore the need to foster long-term conservation practices through institutional support. Government involvement in establishing village-level environmental regulations is essential to enable the allocation of village funds for farmer investments in LCTs. The study calls for more context-sensitive strategies and policy frameworks that address the underlying causes of limited adoption among smallholder farmers in disaster-prone landscapes.

Keywords: Cassava Farming; Adoption Constraints; Land Conservation Technologies; Landslide-Prone Areas.

1. Introduction

Land Conservation Technologies (LCTs) are not only beneficial but essential for sustainable farming in landslide-prone areas. Numerous studies have shown that techniques such as drainage and terrace management are effective in reducing runoff and soil erosion, which are key triggers of landslides (Chen & Chui, 2025; Luo *et al.,* 2023). Agroforestry and vegetative cover have also been proven not only to improve farmers' livelihoods by providing diversified and stable income sources (Mukhlis *et al.,* 2022) but also simultaneously enhancing soil health and slope stability (Do *et al.,* 2025; Lan *et al.,* 2020). Without appropriate conservation measures, agricultural activities in hilly, landslide-prone areas can lead to land degradation, increase disaster risk, and eventually threaten long-term food security.

Agricultural practices on sloped terrain without proper LCTs have also become a serious environmental concern in Magelang Regency, Indonesia. Effendy *et al.*, (2019) reported that cassava cultivation on volcanic slopes exceeding 25% is the largest contributor to severe erosion in the area. Farmers' reluctance to use vegetation cover during the early growth stages of cassava is also believed to accelerate erosion, especially during the rainy season (Jin *et al.,* 2021; Prasetyo *et al.,* 2021). Erosion concentrated in steep areas often leads to the formation of deep gullies and compromises slope stability, thereby increasing the risk of landslides (Batumalai *et al.,* 2023) and land degradation (Kastridis *et al.,* 2024). These conditions underline the urgent need to implement appropriate LCTs to protect the environment, reduce disaster risk, and sustain agricultural productivity in vulnerable hilly areas. In 2020, the LCT model was implemented in a hilly area prone to erosion and landslides. This model integrates the construction of small agricultural reservoirs with a relay cropping system and organic fertilizer as a comprehensive approach to control surface runoff, reduce soil erosion, and improve land productivity. However, once the project ended, most farmers discontinued the conservation methods and returned to monoculture cassava farming and chemical fertilizers. Furthermore, not all farmers were willing to collect and redistribute the soil accumulated in the mini pits back to their farmland. These challenges underline the importance of understanding the factors behind cassava farmers' reluctance to adopt land conservation practices on a long-term basis. Research on farmers' adoption of LCTs is often interpreted through theoretical frameworks that highlight different dimensions of decision-making. The Technology Acceptance Model (TAM) emphasizes perceived usefulness and ease of use, showing that adoption depends on whether practices are seen as beneficial and manageable (Venkatesh & Davis, 2000). The Sustainable Livelihood Framework (SLF) situates these decisions within farmers' financial, social, and human capital, which can limit their ability to adopt or sustain conservation practices (Scoones, 2021). The Diffusion of Innovations (DOI) theory further explains why adoption rarely spreads evenly, underscoring the importance of relative advantage, compatibility with local traditions, and observability of results (Rogers, 1983). Together, these frameworks suggest that adoption or non-adoption emerges from the interaction of perceptions, livelihood assets, and social diffusion processes.

Empirical studies support these insights by showing that adoption is primarily motivated by farmers' perceptions of benefits across economic, ecological, and emotional dimensions. Economic incentives such as higher yields and reduced input costs remain the strongest motivators (Tufa *et al.,* 2023; McCollum *et al.,* 2022), while perceived ecological gains, including soil health, reduced pollution, and long-term sustainability, also encourage uptake (Liu & Liu, 2024). Emotional drivers, such as pride in stewardship and trust in new practices, further enhance receptiveness to conservation even without immediate financial returns (Swart *et al.,* 2023). At the same time, sociocultural factors such as traditional knowledge, peer influence, and participation in farmer groups significantly shape adoption by fostering collective learning and building trust in new technologies (Guo *et al.,* 2025; Njenga *et al.,* 2021). These findings underscore that a complex interplay of individual, social, and institutional factors shapes adoption decisions.

Many studies have explored factors influencing the adoption of LCTs in both developed (Rizzo *et al.,* 2024) and developing countries (Bhujel & Joshi, 2024). In the Indonesian context, similar studies have been conducted, but most have focused on rice-based systems (Purnomo *et al.,* 2021) or livestock farming (Kurniati *et al.,* 2021; Widarni *et al.,* 2020), with limited attention given to cassava cultivation in dryland, hilly areas. In this case, local-scale research becomes essential because various aspects, including the type of conservation technologies can influence farmers' willingness to adopt LCTs (Knowler & Bradshaw, 2007), and ecological settings (Lu *et al.,* 2022). Moreover, the majority of these studies employ quantitative approaches aimed at identifying statistically significant results, yet they often fall short in capturing the underlying reasons behind farmers' decisions from their own perspectives.

In response to these gaps, this study seeks to provide context-specific insights into the constraints that hinder long-term adoption of land conservation technologies (LCTs) among cassava farmers in landslide-prone hilly areas. Using a qualitative approach, the research explores these constraints through the lived experiences and perspectives of farmers who have previously participated in LCTs programs. To provide context for the study, the following section provides a description of the qualitative research methods used. The article then presents the findings and discussion, ends with conclusions that include key insights and recommendations for more sustainable land conservation strategies.

2. Research Methods

2.1. Study Area

The research was conducted on the southern slopes of Sumbing Volcano, with a case study focus in Wonogiri Village, Magelang, Central Java. The southern slope of Sumbing volcano has a varied topography ranging from gentle to steep slopes (Figure 1a) that affect land use patterns and agricultural practices in this area. The thick volcanic soil, which has a high level of fertility, coupled with sufficient annual rainfall averaging 2,761 mm, strongly supports agricultural land use. The combination of these factors makes land use in this area dominated by food crops, horticultural crops and horticultural agriculture. Cassava is the main dryland commodity in Wonogiri Village, Magelang (Figure 1b). This commodity is very important for the local economy as most of the local people depend on agricultural activities as their main livelihood. Monoculture is a common cropping pattern applied by the community. This monoculture cropping pattern contributes to the high erosion rate in cassava farmland in the study area, which reaches 441 tons/ha/year (Effendy *et al.,* 2019).

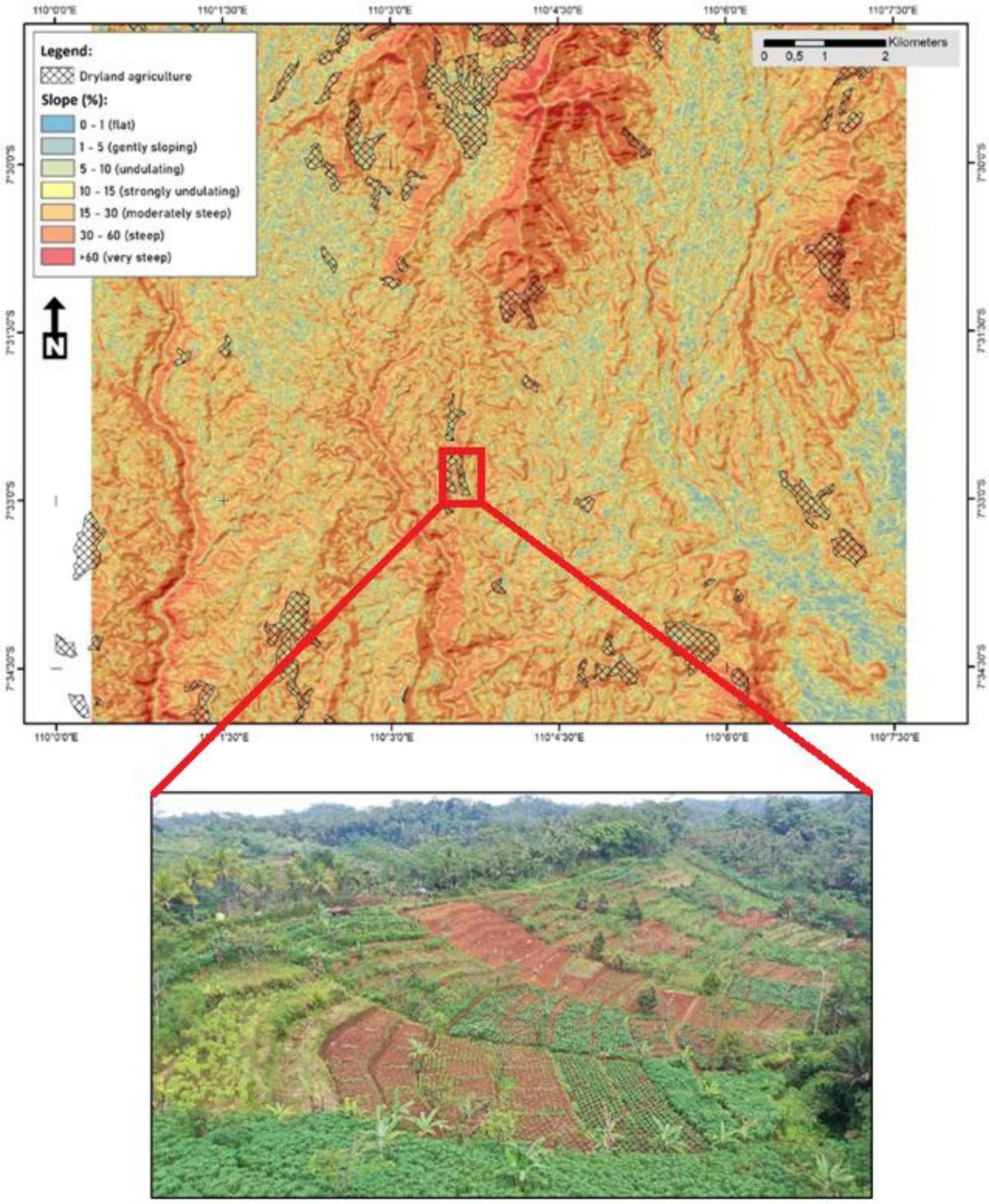

Figure 1. Research Area. (a) Distribution of Dryland Farming Over the Slope Variation at the Foot of the Slope of Sumbing Volcano. (b) Dryland Cassava Farming in Wonogiri Village.

2.2. Farmer's Demographic Characteristics

The study participants were eight cassava farmers who had previously participated in an LCTs program. All of the participants were male, with ages ranging from 44 to 67 years. In addition to cassava cultivation, several farmers engaged in other forms of livelihood, such as coconut sap farming, construction labor, and traditional woodcutting, reflecting the diversified strategies often employed to sustain household income. Each farmer lived in relatively small households, with family sizes ranging between two and four members. These characteristics highlight the profile of resource-limited, middle-aged to elderly male farmers whose livelihood options are shaped by both agricultural and non-agricultural activities in the study area.

2.3. Data Collection and Analysis Techniques

This study employed a qualitative approach, using semi-structured interviews, to explore the factors that hindered farmers' adoption of LCTs. The interviews were conducted face to face with participants. Prior to each interview, informed consent was obtained from all participants. To support data collection, the researchers used questionnaires and field notes to document both verbal responses and relevant contextual information. Drawing on previous literature that identifies a variety of potential barriers to LCTs adoption, this study focused specifically on two key areas:

farmers' perceived benefits and their socio-economic conditions (Table 1). Perceived benefits were categorized into three dimensions: environmental, economic, and emotional. Socio-economic factors were examined through the lenses of traditional beliefs, human capital, and financial constraints. This framework guided the formulation of interview questions and the interpretation of participant responses.

Each interview included six core questions, each comprising two parts. The first part involved a closed ended statement measured using a 5 point Likert scale to assess the participant's level of agreement with specific aspects of the LCTs program. The second part consisted of an open-ended question asking participants to explain the reasoning behind their Likert scale responses. In this research, the Likert items were not subjected to statistical analysis due to the small sample size. Instead, they served as an entry point for identifying the variation and degree of consistency in opinions among respondents, while the open-ended questions were used to explore in greater depth the reasons underlying their attitudes.

The main analytical focus was placed on the responses to the open-ended questions. Narrative data were analyzed thematically using an inductive approach that allowed themes to emerge organically from the interview transcripts. The analysis process involved repeated reading of the data, open coding of participant responses, and the clustering of similar codes into overarching themes representing barriers to LCTs adoption. To support the interpretation of these themes, selected direct quotes from participants were incorporated into the findings. The analysis was conducted with careful attention to consistency between the Likert scale responses and the accompanying narratives.

Table 1. List of Interview Questions.

Dimension	Sub-dimension	Questions	Type of data
Perceived benefits	Environmental benefits	To what extent do you agree that using land conservation techniques helps protect the environment?	Likert scale
		Why do you give that scale?	Narrative
	Economic benefits	To what extent do you agree that using land conservation technologies provides economic benefits for your farming activities?	Likert scale
		Why do you give that scale?	Narrative
	Emotional benefits	To what extent do you agree that using land conservation techniques gives you a sense of pride, security, or personal satisfaction in your farming activities?	Likert scale
		Why do you give that scale?	Narrative
Socio-economic factors	Traditional belief constrains	How much do you trust modern agricultural technologies compared to traditional farming methods?	Likert scale
		Why do you give that scale?	Narrative
	Human capital constrains	How difficult do you find it to implement the LCTs program without expert guidance?	Likert scale
		Why do you give that scale?	Narrative
	Financial constrains	How costly do you find the implementation of the LCTs program compared to traditional farming methods?	Likert scale
		Why do you give that scale?	Narrative

3. Results

3.1. LCTs Project Summary

As part of a participatory approach to sustainable land management, the researchers have introduced LCTs in collaboration with local farming communities. The two LCTs introduced were small reservoirs (referred to locally as *rorak*), a relay cropping system, and organic fertilizer. The researchers engaged eight local farmers, all of whom expressed their willingness to participate by signing informed consent forms. These farmers were users of communally managed village land and implemented the LCTs directly on their own agricultural plots. In this program, all the financial costs of the LCTs program were covered by researchers, including seeds, fertilizer, and the cost of making a small reservoir.

The small reservoirs, each measuring approximately 1m × 2m × 1m, were designed to intercept and retain both surface runoff and sediment resulting from soil erosion. A total of five reservoirs were constructed with impermeable bases and strategically placed along the existing rill erosion channels to optimize their effectiveness in reducing erosion that can accelerate landslides at the foot of the slope (Figure 2). Three reservoirs were installed on the erosional slope (referred to as erosional reservoirs) to reduce runoff, while two reservoirs were installed on the depositional slope (referred to as depositional reservoirs) to trap erosion-derived sediment. Empirical evidence has demonstrated that such reservoirs significantly reduce erosion rates (Islami *et al.,* 2024) and improve water productivity (Senzanje *et al.,* 2008). Furthermore, participating farmers were advised to periodically excavate and reuse the deposited sediment, which is known to contain valuable mineral and nutrient-rich materials transported by overland flow. This practice not only aims to support soil conservation but also facilitates the recycling of nutrients within the farming system.

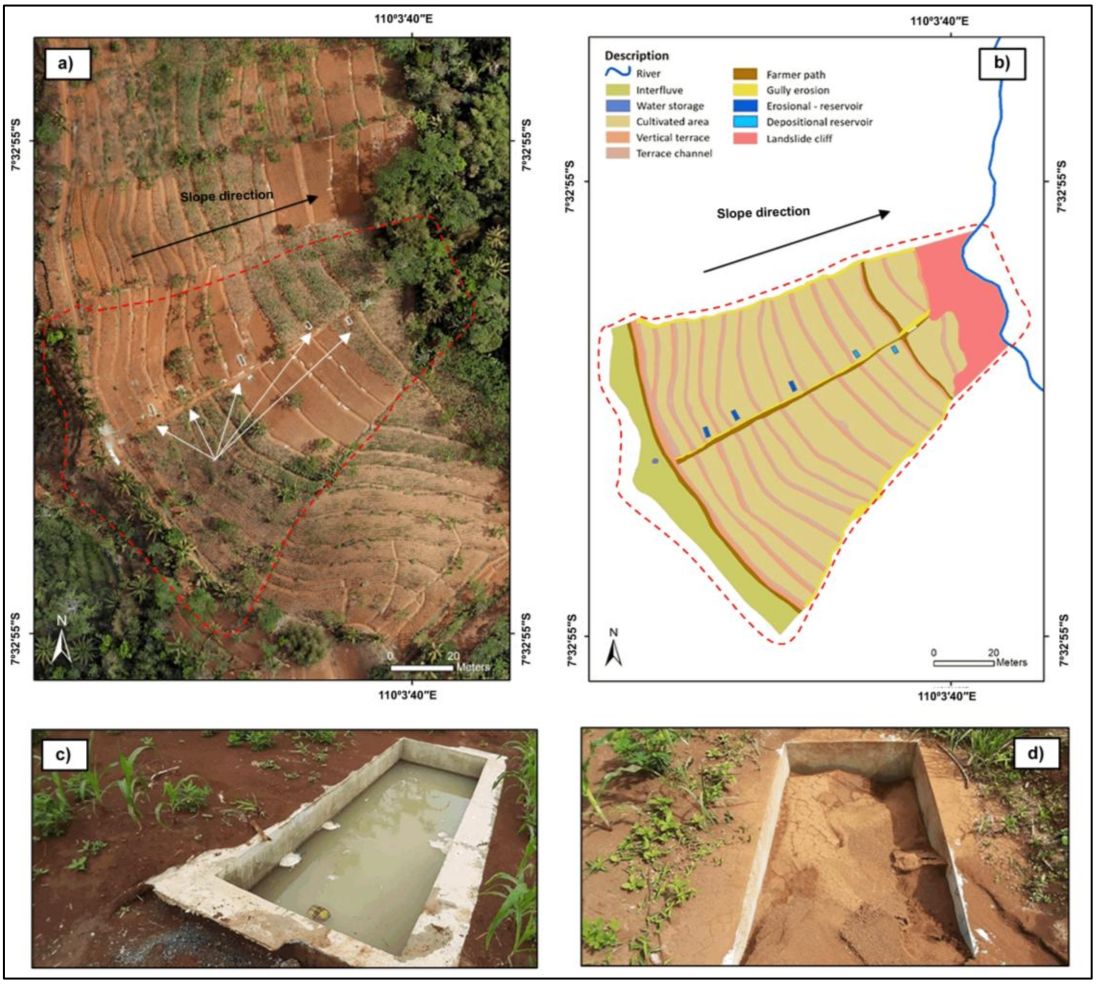

Figure 2. Small Reservoirs Installation Within the Study Area (Red Dashed Outline). (a) Locations of the Reservoirs as Seen in UAV-Based Aerial Photography. (b) Map of Reservoirs Within Terraced Landforms Identified From the Aerial Imagery. Types of Reservoirs Installed at the Study Area: (c) Erosional Reservoir and (d) Depositional Reservoir.

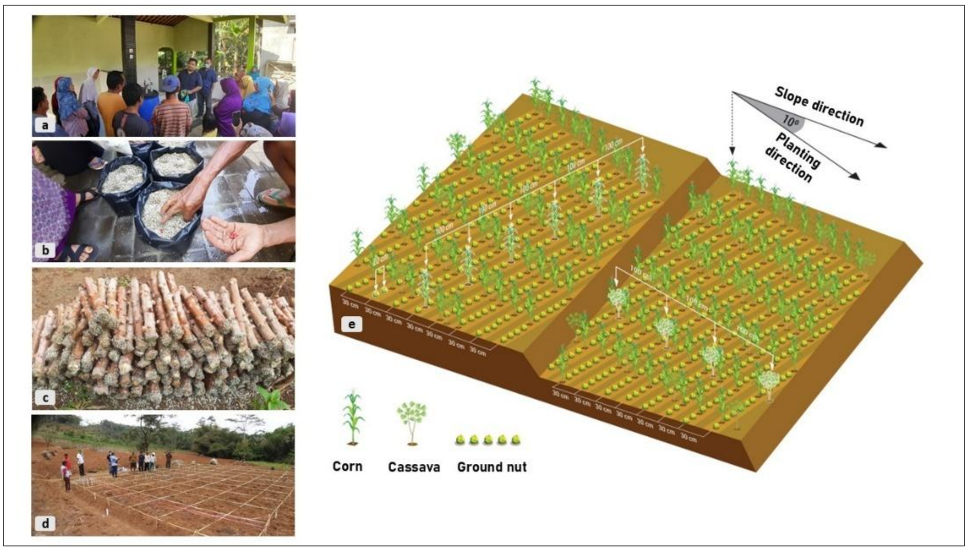

Figure 3. Land Conservation Technologies Activities in the Study Area. (a) Training in the Production of Organic Bacillus-Based Fertilizer. (b)(c) Preparation and Application of Mycorrhizae. (d) Row Spacing. (e) The Design of Relay Cropping Systems Adapted to Slope Orientation and Sunlight Exposure.

In addition to this physical infrastructure, the relay cropping system (referred to locally as tumpang gilir) and organic fertilizer involve planting several types of crops at different time intervals (Figure 3). Farmers are trained in mycorrhizae. In addition to being environmentally sustainable, Bacillus enhances soil fertility, supports plant growth, and protects soils against pathogenic diseases (Wu *et al.,* 2025). Mycorrhiza contributes to improved water and nutrient uptake and, more importantly, strengthens soil structure (Huey *et al.,* 2020). The synergistic application of Bacillus and mycorrhizal fungi is expected to significantly increase crop productivity.

Ground nuts and corn are planted simultaneously at the beginning of the growing season, followed by cassava in the second month after the nuts harvest. Those crops were planted in one garden plot with a predetermined distance. The initial planting of ground nuts and corn aim to increase soil nutrients, particularly nitrogen and phosphorus, while also protecting the soil from erosion during the early stages of cassava growth. This combination of ground nuts, corn, and cassava within a single plot was expected to enhance agricultural productivity, with yields reaching up to 26.3 tons per hectare for cassava, 2.8 tons per hectare for ground nuts, and 6.9 tons per hectare for corn. Under favourable growing conditions, the LCT program aims to increase farmers' income by as much as 140% compared to monocropping systems.

At the end of the LCTs program, the researchers intentionally allowed the participating farmers to decide independently whether to continue using the introduced conservation techniques or revert to their traditional cassava farming practices. This approach was adopted to respect the farmers' autonomy and to observe the long-term voluntary adoption of the interventions. Eight months after the program's completion, follow-up field observations were conducted to assess the continuity of LCTs application. The results revealed that seven out of eight farmers had returned to traditional farming methods, opting not to maintain the use of the small reservoirs and relay cropping systems.

3.2. Constraining Factors for LCTs Adoption Derived From Interviews

The pattern of Likert scale responses suggests that although many expressed uncertainty and negative views toward the LCTs, all participants (referred to as R1, R2, R3, R4, R5, R6, R7, and R8) acknowledged emotional benefits from participating in the project (Figure 4). Several participants (R1, R2, R7, R8) reported a sense of personal growth and fulfilment, describing the program as a valuable opportunity to gain knowledge, adopt new techniques, and stay motivated in their farming practices. As one farmer (R8) expressed, "Even though I'm old, I still feel enthusiastic to learn something new," reflecting the ongoing motivation sparked by learning. Additionally, the project helped strengthen social bonds, both among local farmers (R3, R4, R5, R6) and with university experts, fostering a sense of collaboration and mutual support. As noted by R6, "This program has strengthened the spirit of cooperation between farmers and university experts." These emotional outcomes suggest that, beyond technical or economic considerations, the program contributed to meaningful psychological and social value.

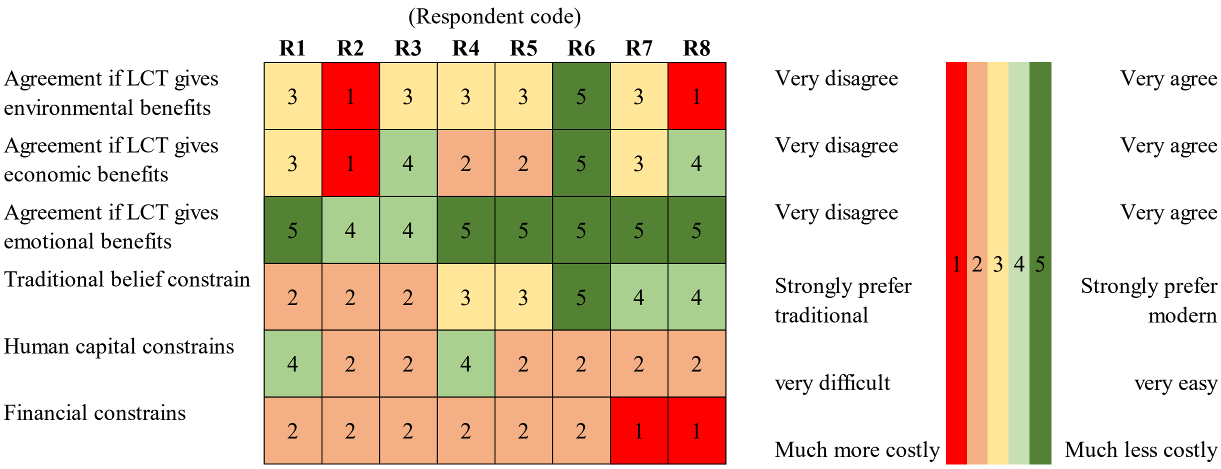

Figure 4. Farmers' Likert-Scale Responses Show That All Participants Agreed or Strongly Agreed That the LCT Provided Emotional Benefits but Was More Costly, While Their Views on Other Aspects Varied Considerably.

Nevertheless, despite the emotional benefits experienced during the program, farmers expressed scepticism and negative perceptions regarding several other factors that appeared to hinder the continued adoption of LCTs after the project ended. These included low perceived environmental and economic benefits, strong attachment to traditional farming practices, the perception that

LCTs are difficult to implement, and concerns about high implementation costs. Thematic analysis revealed how these perceptions function as barriers to long-term adoption. These findings are explored in detail in the following subsections.

3.2.1. Low Perceived Environmental Benefits

Farmers' low perceived environmental benefits of LCTs were primarily shaped by two factors: the limited perceived impact of erosion on their land and doubts about the effectiveness and utility of specific LCTs components (Table 2). Although farmers acknowledged that LCTs such as reservoirs and relay cropping could contribute to environmental protection, they often viewed the impact as minimal. For instance, while they recognized that small reservoirs helped trap eroded sediment, the volume of soil loss was considered too minor to warrant concern. As a result, erosion was not perceived as an urgent or serious issue requiring management. In addition, some farmers questioned the broader functionality of LCTs, expressing the expectation that reservoirs should also store water for irrigation or serve as mixing tanks for fertilizers and pesticides. When these expectations were not met, the perceived environmental value of the technologies declined further.

Table 2. Thematic Analysis of Farmers' Low Perceived Environmental Benefits.

Main theme	Sub-theme	Representative quotes (Farmer code)
Limited perceived environmental impact	Lack of visible outcomes	"I would say it's fairly average, with no noticeable impact. Perhaps the bean plants underneath help reduce soil erosion to some extent "(R1) "I haven't yet seen its impact on my surroundings or my own field." (R3) "The small reservoir helps reduce erosion, but only slightly." (R5)
	Lack of urgency or concern about erosion	"Erosion hasn't really affected soil quality that much." (R7)
Perceived ineffectiveness of LCT components	Doubt about functionality	"I think it's because the reservoir isn't working." (R2) "To be honest, I haven't really felt that this program has helped reduce erosion." (R8)
	Limited utility	"The reservoir is effective in trapping sediment, but beyond that, it's mostly used just for washing hands. So, I think it's not being used to its full potential. It should ideally be used for irrigation or spraying" (R4)

3.2.2. Low Perceived Economic Benefits

Farmers' low perceived economic benefits of LCTs were largely influenced by two interconnected themes: the low profitability of the intercropping system and the low market value of intercrops (Table 3). First, farmers expressed concerns about the limited economic gains from intercropping, citing both low returns and inconsistent yields. While some farmers reported favourable outcomes from certain intercrops, others experienced crop failure or poor harvests, particularly with ground nuts and corn. This variability led to the perception that intercropping does not offer a reliable improvement in farm income. Second, even when intercrops such as groundnuts grew well, their low market value diminished overall profitability. Farmers noted that despite good crop growth, the economic returns remained marginal, which reduced their motivation to continue the practice. These findings suggest that without consistent yields and stronger market support for intercrops, farmers are unlikely to view intercropping based LCTs as financially viable in the long term.

Table 3. Thematic Analysis of Farmers' Low Perceived Economic Benefits.

Main theme	Sub-theme	Representative quotes (Farmer code)
Low profitability of the intercropping system	Low returns from intercrops	"The cassava produced yesterday produced a larger tuber, so it could be more profitable. However, on my land, planting ground nuts and corn hasn't been very successful, so I do not get profit from it" (R1) "The Cassava actually has the potential to produce a higher yield because the tubers are larger. However, when corn is planted in between, it limits the space available for cassava. Moreover, my last corn harvest was poor, and some of the crops failed" (R5)
	Mixed yield outcomes from intercrops	"The corn yielded good results, but the ground nuts yielded poor results. So, the profit margins were not significantly different." (R2)
Low market value of intercrops	Limited return despite good growth	"Although ground nuts grow well, their market price is low. They're not very profitable because I only sell a small amount of them." (R4) "Actually, Intercropping is quite promising, but the returns can be modest when the harvested quantities are small. I would be willing to try it again if other farmers also adopt the practice, so that collectively we can produce larger volumes and achieve better profits." (R7)

3.2.3. Preference for Traditional Practices

Farmers' continued preference for traditional farming practices over LCTs was shaped by three primary themes: perceived simplicity and familiarity of conventional methods, concerns about the risks associated with LCTs, and the labour demands involved in implementing them (Table 4). First, many farmers favoured traditional techniques because of their long-standing use and perceived reliability. Having experienced consistent results in the past, they expressed confidence in these methods and appreciated their minimal maintenance requirements. Second, several farmers expressed concern about the potential risks of adopting LCTs, particularly the risk of crop failure and yield uncertainty associated with intercropping. These anxieties made them hesitant to shift away from practices they viewed as more predictable. Third, farmers highlighted the increased labour and time required by LCTs. The need for more frequent field visits and close attention to intercrops was seen as burdensome, especially for those who relied on off-farm work or lacked sufficient time. These factors collectively explain why traditional practices remain the preferred choice for many farmers, despite the introduction of more sustainable alternatives.

Table 4. Thematic Analysis of Farmers' Preference for Traditional Practices.

Main theme	Sub-theme	Representative quotes (Farmer code)
Perceived simplicity and familiarity of traditional methods	Confidence from past success.	"I've been managing my farm independently, and the results have been quite good so far." (R1) "I'm used to farming the way I always have, and I haven't encountered any major issues." (R2)
	Minimal maintenance required	"I still follow the farming methods passed down from my father. His technique is easier. Once the cassava is planted, I don't need to check on it often, which gives me time to do other work." (R5)
Concerns about the risks of LCTs	Fear of crop failure	"Honestly, I'm afraid of crop failure, especially with corn." (R3) "Corn is more vulnerable to disease. Additionally, planting crops at high densities tends to reduce yields." (R1) "Intercropping in this hilly area is quite risky, as I'll likely need more fertilizer and water, while we can only rely on rainwater for irrigation" (R4)
	Yield uncertainty in intercropping	"I'm also concerned that intercropping may reduce overall yield quality, and that instead of gaining, we might actually experience losses." (R2)
Labor intensity and time constraints	More field visits required	"Relay cropping would require me to go back and forth more often to tend to the plants." (R5)
	Lack of attention to intercrops	"Many farmers are not consistent or diligent in managing the intercropped plants." (R1)

3.2.4. Dependence on External Support

Farmers' perceptions that LCTs are difficult to implement independently were shaped by three main themes: the need for continuous technical guidance, the need for motivation and consultation, and reliance on external input and institutional support (Table 5).

Table 5. Thematic Analysis of Farmers' Dependence on External Support.

Theme	Sub-theme	Representative quotes (Farmer code)
Need for continuous technical guidance	To solve specific technical problems	"It would be much easier if we had continuous expert support, so we could ask questions whenever we encountered problems, such as how to prevent crop failure in intercropping systems" (R1) "I think expert guidance is essential, because it will be quite difficult to determine where the exact location of the reservoir is." (R7)
	Uncertainty about new techniques	"It would be better if we had expert support. That way, we wouldn't hesitate to try new practices, particularly those related to proper planting methods" (R3) "We still need expert guidance to help us find farming methods that are both environmentally sustainable and economically viable." (R5)
Need for motivation and consultation	To boost motivation	"Expert guidance is still necessary, especially to keep us motivated." (R2)
	Place for consultation	"It gives us someone to consult about farming." (R3) "I still need support and consultation if I encounter any problems." (R6)
Reliance on external input and institutional support	Dependence on fertilizer and seed distribution	"We need support in the provision of organic fertilizer and monitoring to ensure equitable distribution." (R2) "I also hope to still receive free fertilizer." (R6) "We really need support from experts. We've been greatly helped by the high-quality seeds and fertilizer." (R8)

First, farmers emphasized the importance of ongoing technical assistance to address specific field challenges and reduce uncertainty about unfamiliar practices. They expressed hesitation in applying LCTs without expert input, especially when facing issues such as crop failure or poor growth in intercropping systems. Second, beyond technical matters, farmers indicated the value of motivational support and having a space for consultation. Expert presence was seen not only as a source of encouragement but also as an accessible point of contact for advice and troubleshooting. Lastly, farmers' reliance on external support, particularly in the provision of fertilizers, high quality seeds, and infrastructure like reservoirs, reflected their limited capacity to sustain LCTs without institutional assistance. This dependency highlights the challenges of scaling up or maintaining conservation practices in the absence of ongoing external support.

3.2.5. Perceived High Financial Demands

Farmers' perceptions of the higher financial demands of implementing LCTs were influenced by three main themes: increased input costs, the high cost of infrastructure, and increased labor or time burdens (Table 6).

Table 6. Thematic analysis of farmers perceived high financial demands.

Theme	Sub-theme	Representative Quotes (Farmer Code)
Increased input costs	Fertilizer supply is insufficient	"The fertilizer provided by experts isn't sufficient. I still have to supplement it." (R3) "Fertilizer needs are greater."(R5)
	Need to buy additional chemical fertilizers	"The organic fertilizer recommended by the experts isn't enough, so I have to buy chemical fertilizer as well." (R4) I have to purchase additional fertilizer myself." (R2)
High cost of infrastructure	Financially burdensome	"If I were asked to build a reservoir on my own, that would be quite overwhelming." (R1) "Constructing a permanent reservoir using cement would definitely be expensive."(R2) "The cost of building a reservoir is definitely high, and it also reduces available land for planting."(R8)
	Hope for external support	"I hope the expense for reservoir construction is not borne by the farmers but can be supported by the government."(R5) "It might be feasible if it's a collective effort or if financial support is provided by the village funds." (R1)
Increased labor/time burden	Requires more field visits	"The intercropping system requires more attention. I have to visit the fields more frequently, and because of that, I often have to turn down labor opportunities elsewhere" (R7)

First, many farmers reported that the fertilizer support provided during the program was insufficient, prompting them to purchase additional chemical fertilizers to meet crop needs. This added expense reduced the perceived affordability of LCTs implementation. Second, the infrastructure required to support LCTs, particularly the construction of small reservoirs, was considered financially burdensome. Several farmers expressed concerns about the cost of materials and construction, noting that such efforts would not be feasible without financial assistance from external institutions or village-level support. Third, the application of relay intercropping systems was perceived as more labour-intensive compared to traditional farming methods. Farmers reported the need for more frequent field visits and increased time spent on maintenance, which was viewed as a constraint given their other livelihood responsibilities. Together, these factors contributed to the perception that LCTs require significantly more financial and labor investment than conventional practices.

4. Discussion

4.1. Barriers to Adoption: Empirical Findings and Theoretical Reflections

This study has explored the underlying reasons behind cassava farmers' reluctance to adopt LCTs in Volcanic hillslopes, prone to landslides. Using thematic analysis of semi-structured interviews with eight cassava farmers, the research revealed a complex interplay of environmental, economic, socio-cultural, and institutional factors.

This study shows that emotional benefits, such as the opportunity to learn, personal growth, and collaboration, did not lead cassava farmers to meaningfully adopt LCTs. These findings are consistent with earlier research by Meijer *et al.,* (2015), which emphasized that affective factors such as confidence or personal satisfaction do not necessarily lead to behavioral change in technology adoption. Similarly, Gerli *et al.,* (2022) highlighted that although farmers may demonstrate a high willingness to learn or receive information, this alone is not sufficient to influence the adoption of modern technologies. These findings reinforce the idea that emotional benefits alone are insufficient to drive behavioral change, particularly among smallholder farmers in developing countries, who often face multiple constraints, including limited education and economic resources.

In this case, farmers' motivation to adopt LCTs also appears to be limited by the lack of visible or immediate environmental benefits. Similar findings have been reported in other developing country contexts. Tesfahunegn *et al.,* (2021), studying farmers in Ghana, found that erosion was seen as a problem only when it visibly affected the farmers' own plots, while broader environmental impacts were often overlooked. Research in Ethiopia also showed that conservation practices were considered unnecessary unless there was direct and visible harm to the land (Goba *et al.,* 2022). In volcanic hillslope areas, where soils are deep and naturally fertile, erosion is often perceived as a minor issue. Many farmers assume that since crop production continues and land remains cultivable, erosion is not an urgent problem. This perception is further reinforced by a limited understanding of the long-term ecological consequences. Farmers in this study area, for instance, did not associate soil loss with increased downstream sedimentation or the potential to trigger landslides. Another key factor contributing to farmers' reluctance to adopt LCTs is their low perceived economic benefits. In this study, such perceptions stemmed from the belief that the recommended intercrops, although beneficial for reducing erosion, were not profitable and had low market value. For smallholder cassava farmers with limited financial resources, economic viability is a central consideration. This finding supports previous studies, which consistently emphasize that perceived profitability is a primary driver of farmers' decisions to adopt conservation or sustainable farming practices (McCollum *et al.*, 2022; Barnes *et al.,* 2019). Therefore, to improve the uptake of LCTs, especially in low-income farming communities, it is important to ensure that conservation strategies also align with farmers' economic goals.

The transition from traditional planting methods to modern land conservation techniques also poses a considerable challenge for cassava farmers. One of the primary reasons for this reluctance is their strong familiarity with conventional practices, which are perceived as more reliable and less likely to result in crop failure. Within this context, the introduction of various intercrop species alongside cassava is often viewed as increasing the likelihood of complications and harvest failure. This high level of risk aversion has been frequently identified in the literature as a significant barrier to the adoption of land conservation technologies (Jack *et al.,* 2022; Bakker *et al.,* 2021). In addition, implementing such techniques, including intercropping and using sedimented soil from small reservoirs, requires greater physical effort and more frequent field visits. Consequently, farmers may lose the opportunity to engage in secondary income-generating activities outside farming, which they previously relied on to supplement household income. Adjustments in daily work routines like this may also serve as a barrier to the implementation of land conservation technologies by farmers (Bonke & Musshoff, 2020).

Farmers often perceive LCTs as difficult to implement without external assistance, particularly during the early stages of adoption. This perception stems from limited technical knowledge, unfamiliarity with the required practices, and a lack of confidence in managing potential risks. As a result, the presence of experts or extension agents is viewed as critical to supporting the initial implementation process. Previous studies have shown that access to expert advice and ongoing support can significantly enhance farmers' willingness to adopt new practices, as it reduces uncertainty and builds trust in the effectiveness of the technology (Verburg *et al.,* 2022). Farmers not only expect experts to offer practical solutions when challenges arise but also rely on them for motivational support when they experience setbacks or doubt their ability to continue. In addition to technical challenges, farmers' perceptions of high implementation costs represent a significant barrier to the long-term sustainability of LCTs adoption. Many farmers believe that adopting LCTs requires substantial initial investment, including labor, equipment, and materials, which they may not be able to afford without external support. This perception of high cost often creates a sense of dependency on government programs, non-governmental organizations, or academic institutions for financial assistance. Even studies conducted in developed agricultural systems have also identified high start-up costs as a deterrent to the adoption of conservation practices (Gütschow *et al.,* 2021; Bechini *et al.,* 2020). Among smallholder cassava farmers, who typically operate with limited financial resources, the absence of subsidies or access to capital further discourages adoption.

4.2. Implications for Practice and Policy

The findings of this study underline that the adoption of LCTs cannot be sustained through isolated or short-term interventions. Instead, it requires long-term, economically viable, and institutional supports that simultaneously address technical, social, and financial dimensions. Several key implications for practice and policy can be drawn.

First, long-term demonstration projects are crucial because the ecological, social, and financial benefits of LCTs often take considerable time to materialize. Short project cycles rarely capture gradual improvements in soil stability, crop productivity, and erosion control, nor do they allow sufficient time to build trust and shift entrenched farming behaviors. Evidence from a multi-season study shows that conservation agriculture systems consistently outperform conventional methods only after several years, highlighting the necessity of sustained implementation and mentoring (Thierfelder *et al.,* 2015). Long-term projects, therefore, provide a more reliable foundation for embedding conservation into everyday farming practices.

Second, the role of community-based monitoring is critical. Farmers' decisions are shaped more by immediate, observable outcomes than by distant or abstract risks. When farmers are actively engaged in observing and documenting the performance of LCTs, such as reductions in erosion or improvements in productivity, they develop stronger ownership and trust in conservation practices. This participatory approach, similar to citizen science, has been shown to strengthen both data quality and community engagement in agricultural landscapes (van Noordwijk *et al.,* 2021; van Etten *et al.,* 2019). In this way, community-based monitoring not only empowers farmers but also ensures that conservation interventions are perceived as directly relevant and beneficial.

Third, it is essential to frame LCTs within the concept of productive conservation, which emphasizes that conservation should not be seen as a cost but as a strategy that enhances livelihoods (Sartohadi *et al.,* 2024; Purwaningsih *et al.,* 2020). For instance, integrating high-value crops into intercropping systems can simultaneously protect soil and generate additional income, thereby strengthening farmers' motivation to adopt LCTs (Bechini *et al.,* 2020). Meta-analytic evidence further confirms that agricultural diversification contributes not only to ecological sustainability but also to substantial gains in profitability and resilience over the long term (Tamburini *et al.,* 2020). Positioning LCTs as both ecologically and economically beneficial can therefore be an effective strategy to increase their attractiveness to smallholder farmers.

Fourth, strengthening farmers' economic capacity is fundamental to overcoming adoption barriers. The high upfront costs of LCTs implementation often discourage resource-poor farmers from investing in conservation. Value-chain interventions, such as cassava processing into modified cassava flour or other higher-value products, provide pathways for increasing household income and reducing dependency on volatile raw commodity markets. Empirical studies show that cassava farmers engaged in value addition experience significantly higher incomes and greater financial stability compared to those without value addition (Bosompem *et al.,* 2024; Nwankwo & Chiekezie, 2024). By improving farmers' economic resilience and linking them with stable market opportunities, policy and academic actors may enhance their willingness and ability to invest in LCTs.

Finally, the applicability of land conservation technologies depends on sustained institutional support. Government involvement is crucial in developing village-level environmental regulations that allow the strategic use of village funds to finance farmers' investments in LCTs. Such regulatory and financial mechanisms would complement the technical and financial assistance provided by academic institutions, ensuring that conservation efforts remain both sustainable and locally grounded. Previous studies on agricultural extension have shown that consistent technical guidance and institutional facilitation in accessing credit significantly enhance the adoption of soil and water conservation technologies (Belayneh, 2023; Girma, 2022). This dual role of technical mentorship and financial brokerage is indispensable for overcoming barriers to the long-term sustainability of LCTs.

Taken together, these five implications emphasize that effective practice and policy must extend beyond short-term, top-down interventions. Instead, they should promote long-term demonstration projects, participatory monitoring, productive conservation, economic empowerment, and continuous institutional support. Only through such integrative strategies can the widespread and sustained adoption of LCTs be achieved, ensuring that conservation practices contribute simultaneously to environmental sustainability and the improvement of smallholder farmer livelihoods. Importantly, these approaches also contribute to global development agendas by advancing the Sustainable Development Goals (SDGs): reducing poverty (SDG 1), promoting sustainable agriculture and food security (SDG 2), strengthening resilience to climate risks (SDG 13), and conserving terrestrial ecosystems (SDG 15).

5. Conclusion

This study has uncovered the underlying reasons behind the limited applicability of Land Conservation Technologies (LCTs) among cassava farmers living on landslide-prone hillslopes, most of whom belong to economically disadvantaged groups. Although based on qualitative interviews with a relatively small number of participants, the research has provided valuable insights into both the types of barriers farmers encounter and the deeper socio-economic and perceptual factors that give rise to these obstacles.

By foregrounding farmers' perspectives, this study reveals that the adoption of LCTs can only be achieved when conservation is embedded not merely as a technical solution but as an economically viable and socially inclusive pathway for resilient farming livelihoods. The findings therefore offer a critical foundation for the development of more effective strategies and policies aimed at overcoming barriers to LCTs adoption and preventing the recurrence of project failures. While the limited sample size restricts the generalizability of the results, this exploratory study provides a critical foundation for future larger-scale or mixed-methods research. This research also contributes to the Sustainable Development Goals by linking farmer-centered insights with poverty reduction, sustainable agriculture, climate resilience, and land conservation

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Author Contributions

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Conflict of interest

All authors declare that they have no conflicts of interest

Data availability

Data is available upon Request

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References

Bakker, L., Sok, J., van der Werf, W., & Bianchi, F. J. J. A. (2021). Kicking the Habit: What Makes and Breaks Farmers' Intentions to Reduce Pesticide Use? *Ecological Economics*, 180, 106868. doi: 10.1016/j.ecolecon.2020.106868

Barnes, A. P., Soto, I., Eory, V., Beck, B., Balafoutis, A., Sánchez, B., Vangeyte, J., Fountas, S., van der Wal, T., & Gómez-Barbero, M. (2019). Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmers. *Land Use Policy*, 80, 163–174. doi: 10.1016/j.landusepol.2018.10.004

Batumalai, P., Nazer, N. S. M., Simon, N., Sulaiman, N., Umor, M. R., & Ghazali, M. A. (2023). Soil Detachment Rate of a Rainfall-Induced Landslide Soil. *Water (Switzerland)*, 15(12) 2149. doi: 10.3390/w15122149

Bechini, L., Costamagna, C., Zavattaro, L., Grignani, C., Bijttebier, J., & Ruysschaert, G. (2020). Drivers and barriers to adopt best management practices. Survey among Italian dairy farmers. *Journal of Cleaner Production*, 245, 118825. doi: 10.1016/j.jclepro.2019.118825

Belayneh, M. (2023). Factors affecting the adoption and effectiveness of soil and water conservation measures among small-holder rural farmers: The case of Gumara watershed. *Resources, Conservation and Recycling Advances*, 18, 200159. doi: 10.1016/j.rcradv.2023.200159

Bhujel, R. R., & Joshi, H. G. (2024). *Factors influencing the adoption of sustainable agricultural practices in rural*. 8, 81–89.

Bonke, V., & Musshoff, O. (2020). *Understanding German farmer ' s intention to adopt mixed cropping using the theory of planned behavior*. 6(40), 48.

Bosompem, M., Arhin, P., Nunoo, J., & Amoah, K. K. (2024). Smallholder farmers' participation in Cassava value addition practices: What drivers matter in Ghana? *Journal of Agriculture and Food Research*, 16, 101120. doi: 10.1016/j.jafr.2024.101120

Chen, B., & Chui, T. F. M. (2025). Exploring the effectiveness, risks and strategies for implementing sustainable drainage systems in a landslide-prone catchment. *Journal of Hydrology*, 652, 132645. doi: 10.1016/j.jhydrol.2024.132645

Do, V. H., La, N., Bergkvist, G., Dahlin, A. S., Mulia, R., & Öborn, I. (2025). Spatial and temporal variation in crop productivity and relation with soil fertility within upland agroforestry. *Field Crops Research*, 320, 109675. doi: 10.1016/j.fcr.2024.109675

Effendy, Z., Setiawan, M. A., & Mardiatno, D. (2019). Geospatial-Interface Water Erosion Prediction Project (GeoWEPP) application for the planning of Bompon Watershed conservation-prioritized area, Magelang, Central Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 256(1) 012017. doi: 10.1088/1755-1315/256/1/012017

Gerli, P., Clement, J., Esposito, G., Mora, L., & Crutzen, N. (2022). The hidden power of emotions: How psychological factors influence skill development in smart technology adoption. *Technological Forecasting and Social Change*, 180, 121721. doi: 10.1016/j.techfore.2022.121721

Girma, Y. (2022). Credit access and agricultural technology adoption nexus in Ethiopia: A systematic review and meta-analysis. *Journal of Agriculture and Food Research*, 10, 100362. doi: 10.1016/j.jafr.2022.100362

Goba, W. B., Muluneh, A., & Wolka, K. (2022). Evaluating farmers' perception on soil erosion and management of physical soil and water conservation measures in southwest Ethiopia. *Journal of Forestry and Natural Resources*, 1(2), 39–53.

Guo, F., Jin, J., Liu, D., Yang, J., & Zou, Z. (2025). Factors Influencing Farmers' Behavior of Adopting Conservation Tillage Technology in China: A Meta-analysis. *Journal of Resources and Ecology*, 16(1), 49–61. doi: 10.5814/j.issn.1674-764x.2025.01.005

Gütschow, M., Bartkowski, B., & Felipe-Lucia, M. R. (2021). Farmers' action space to adopt sustainable practices: a study of arable farming in Saxony. *Regional Environmental Change*, 21(4). doi: 10.1007/s10113-021-01848-1

Huey, C. J., Gopinath, S. C. B., Uda, M. N. A., Zulhaimi, H. I., Jaafar, M. N., Kasim, F. H., & Yaakub, A. R. W. (2020). Mycorrhiza: a natural resource assists plant growth under varied soil conditions. *3 Biotech*, 10(5), 1–9. doi: 10.1007/s13205-020-02188-3

Islami, J. D., Pulungan, N. A. H. J., & Sartohadi, J. (2024). Arrangement of Agricultural Reservoir Along Rill Erosion: Case Study in the Sumbing Volcanic Landscape, Java, Indonesia. *Air, Soil and Water Research*, 17, 1-13. doi: 10.1177/11786221241261158

Jack, C., Hotchkiss, E., Sargison, N. D., Toma, L., Milne, C., & Bartley, D. J. (2022). Determining the influence of socio-psychological factors on the adoption of individual 'best practice' parasite control behaviours from Scottish sheep farmers. *Preventive Veterinary Medicine*, 200, 105594. doi: 10.1016/j.prevetmed.2022.105594

Jin, F., Yang, W., Fu, J., & Li, Z. (2021). Effects of vegetation and climate on the changes of soil erosion in the Loess Plateau of China. *Science of the Total Environment*, 773, 145514. doi: 10.1016/j.scitotenv.2021.145514

Kastridis, A., Margiorou, S., & Sapountzis, M. (2024). Post-fire soil erosion: Two years of monitoring − First time detected implications between extremely intense consecutive rainfall events and erosion rates. *Catena*, 243, 108194. doi: 10.1016/j.catena.2024.108194

Knowler, D., & Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy*, 32(1), 25–48. doi: 10.1016/j.foodpol.2006.01.003

Kurniati, N., Sukiyono, K., Purmini, P., & Sativa, M. O. (2021). Adoption level of integrated farming system based on Rice-Cattle and its determinants related to sustainable agriculture. *E3S Web of Conferences*, 226, 1–9. doi: 10.1051/e3sconf/202122600034

Lan, H., Wang, D., He, S., Fang, Y., Chen, W., Zhao, P., & Qi, Y. (2020). Experimental study on the effects of tree planting on slope stability. *Landslides*, 17(4), 1021–1035. doi: 10.1007/s10346-020-01348-z

Liu, M., & Liu, H. (2024). Farmers' adoption of agriculture green production technologies: perceived value or policy-driven? *Heliyon*, 10(1), e23925. doi: 10.1016/j.heliyon.2023.e23925

Lu, J., Ranjan, P., Floress, K., Arbuckle, J. G., Church, S. P., Eanes, F. R., Gao, Y., Gramig, B. M., Singh, A. S., & Prokopy, L. S. (2022). A meta-analysis of agricultural conservation intentions, behaviors, and practices: Insights from 35 years of quantitative literature in the United States. *Journal of Environmental Management*, 323, 116240. doi: 10.1016/j.jenvman.2022.116240

Luo, S., Huang, D., Peng, J., Aierken, A., Li, Z., Kuang, X., & Tomás, R. (2023). Performance and application of a novel drainage anti-slide pile on accumulation landslide with a chair-like deposit-bedrock interface in the Three Gorges Reservoir area, China. *Computers and Geotechnics*, 155, 105199. doi: 10.1016/j.compgeo.2022.105199

McCollum, C., Bergtold, J. S., Williams, J., Al-Sudani, A., & Canales, E. (2022). Perceived Benefit and Cost Perception Gaps between Adopters and Non-Adopters of In-Field Conservation Practices of Agricultural Producers. *Sustainability (Switzerland)*, 14(19), 11803. doi: 10.3390/su141911803

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability*, 13(1), 40–54. doi: 10.1080/14735903.2014.912493

Mukhlis, I., Rizaludin, M. S., & Hidayah, I. (2022). Understanding Socio-Economic and Environmental Impacts of Agroforestry on Rural Communities. *Forests*, 13(4), 1–13. doi: 10.3390/f13040556

Njenga, M. W., Mugwe, J. N., Mogaka, H., Nyabuga, G., Kiboi, M., Ngetich, F., Mucheru-Muna, M., Sijali, I., & Mugendi, D. (2021). Communication Factors Influencing Adoption Of Soil And Water Conservation Technologies In The Dry Zones Of Tharaka-Nithi County, Kenya. *Heliyon*, 7(10), e08236. doi: 10.1016/j.heliyon.2021.e08236

Nwankwo, E. C., & Chiekezie, N. R. (2024). Agricultural Productivity and Postharvest Loss Among Cassava Farmers, In Anambra State, Nigeria. *Global Journal of Agricultural Research*, 12(1), 37–50. doi: 10.37745/gjar.2013/vol12n13750

Prasetyo, A., Setyawan, C., Ngadisih, & Tirtalistyani, R. (2021). Vegetation cover modelling for soil erosion control in agricultural watershed. *IOP Conference Series: Earth and Environmental Science*, 653(1), 012033. doi: 10.1088/1755-1315/653/1/012033

Purnomo, S. H., Sari, A. I., Emawati, S., & Rahayu, E. T. (2021). Factors influencing the adoption of integrated crop-livestock to support land conservation of organic agriculture in Mojosongo area, Karanganyar, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 724(1), 012049. doi: 10.1088/1755-1315/724/1/012049

Purwaningsih, R., Sartohadi, J., & Anggri, M. (2020). Trees and crops arrangement in the agroforestry system based on slope units to control landslide reactivation on volcanic foot slopes in Java, Indonesia. *Land*, 9(9), 327. doi: 10.3390/LAND9090327

Rizzo, G., Migliore, G., Schifani, G., & Vecchio, R. (2024). Key factors influencing farmers' adoption of sustainable innovations: a systematic literature review and research agenda. *Organic Agriculture*, 14(1), 57–84. doi: 10.1007/s13165-023-00440-7

Rogers, E. M. (1983). *Diffusion of innovations. In Encyclopedia of Sport Management, Second Edition. Collier Macmillan.* Retrieved from https://doi.org/10.4337/9781035317189.ch157

Sartohadi, J., Rahma, A. D., & Nugraha, S. S. (2024). Productive conservation at the landslide prone area under the threat of rapid land cover changes. *Open Geosciences*, 16(1). doi: 10.1515/geo-2022-0700

Scoones, I. (2021). *Sustainable Livelihoods and Agrarian Change & Peasant Studies*.

Senzanje, A., Boelee, E., & Rusere, S. (2008). Multiple use of water and water productivity of communal small dams in the Limpopo Basin, Zimbabwe. *Irrigation and Drainage Systems*, 22(3–4), 225–237. doi: 10.1007/s10795-008-9053-7

Swart, R., Levers, C., Davis, J. T. M., & Verburg, P. H. (2023). Meta-analyses reveal the importance of socio-psychological factors for farmers' adoption of sustainable agricultural practices. *One Earth*, 6(12), 1771–1783. doi: 10.1016/j.oneear.2023.10.028

Tamburini, G., Bommarco, R., Wanger, T. C., Kremen, C., van der Heijden, M. G. A., Liebman, M., & Hallin, S. (2020). Agricultural diversification promotes multiple ecosystem services without compromising yield. *Science Advances*, 6(45). doi: 10.1126/SCIADV.ABA1715

Tesfahunegn, G. B., Ayuk, E. T., & Adiku, S. G. K. (2021). Farmers' perception on soil erosion in Ghana: Implication for developing sustainable soil management strategy. *PLoS ONE*, 16, 1–26. doi: 10.1371/journal.pone.0242444

Thierfelder, C., Bunderson, W. T., & Mupangwa, W. (2015). Evidence and lessons learned from long-term on-farm research on conservation agriculture systems in communities in Malawi and Zimbabwe. *Environments - MDPI*, 2(3), 317–337. doi: 10.3390/environments2030317

Tufa, A. H., Kanyamuka, J. S., Alene, A., Ngoma, H., Marenya, P. P., Thierfelder, C., Banda, H., & Chikoye, D. (2023). Analysis of adoption of conservation agriculture practices in southern Africa: mixed-methods approach. *Frontiers in Sustainable Food Systems*, 7. doi: 10.3389/fsufs.2023.1151876

van Etten, J., de Sousa, K., Aguilar, A., Barrios, M., Coto, A., Dell'Acqua, M., Fadda, C., Gebrehawaryat, Y., van de Gevel, J., Gupta, A., Kiros, A. Y., Madriz, B., Mathur, P., Mengistu, D. K., Mercado, L., Mohammed, J. N., Paliwal, A., Pè, M. E., Quirós, C. F., … Steinke, J. (2019). Crop variety management for climate adaptation supported by citizen science. *Proceedings of the National Academy of Sciences of the United States of America*, 116(10), 4194–4199. doi: 10.1073/pnas.1813720116

van Noordwijk, T., Bishop, I., Staunton-Lamb, S., Oldfield, A., Loiselle, S., & Geoghegan, H. (2021). Creating positive environmental impact through citizen science. In K. Vohland, A. Land-Zandstra, L. Ceccaroni, R. Lemmens, J. Perello, M. Ponti, R. Samson, & K. Wagenknecht (Eds.), *The Science of Citizen Science,* 1–529. doi: 10.1007/978-3-030-58278-4

Venkatesh, V., & Davis, F. D. (2000). A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. *Management Science*, 46(2), 186–204.

Verburg, R. W., Verberne, E., & Negro, S. O. (2022). Accelerating the transition towards sustainable agriculture: The case of organic dairy farming in the Netherlands. *Agricultural Systems*, 198. doi: 10.1016/j.agsy.2022.103368

Widarni, N. A. A., Kusumastuti, T. A., & Putra, A. R. S. (2020). A study on farmers' choice in integrating paddy and cattle farming as farm management practices. *Journal of the Indonesian Tropical Animal Agriculture*, 45(4), 356–364. doi: 10.14710/jitaa.45.4.356-364

Wu, X., Liu, Y., Jia, B., Tao, L., Li, H., Wang, J., Yuan, Z., Sun, X., & Yao, Y. (2025). Four Decades of Bacillus Biofertilizers: Advances and Future Prospects in Agriculture. *Microorganisms*, 13(1), 1–21. doi: 10.3390/microorganisms13010187