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Governance challenges of smallholder agricultural carbon projects and the potential of digital tools: Insights from Kenya

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Abstract

The development of agricultural carbon projects is part of global efforts to address climate change and improve food security, particularly for smallholder farmers. Due to their complexity and the involvement of many actors with different interests, needs and power, the implementation of carbon projects poses governance challenges. Meanwhile, despite numerous studies that have demonstrated the potential of digital tools to address challenges in agriculture, there has not yet been an exploration of this potential in agricultural carbon projects. This study uses a qualitative case study of two carbon projects in Kenya and a participatory and visual mapping tool (Process Net-Map) with stakeholders to identify the governance challenges of agricultural carbon projects and the potential role of digital tools in addressing these challenges. The findings reveal a diverse set of governance challenges at different stages of implementation that impact the adoption of sustainable agricultural practices and the accuracy and efficiency of carbon monitoring. Furthermore, non-participatory project design leads to shortcomings in the inclusiveness of such projects. The study identified some strategies, including local capacity building, integration of e-extension, and development of carbon revenue sharing mechanisms at the group level, for efficient establishment of smallholder agricultural carbon projects. The findings also show that digital tools play a key role in data collection and reporting, but other relevant tools have not yet been explored. The authors recommend developing local capacity to use digital tools for data collection and analysis to increase the efficiency of carbon projects and benefits for smallholders.

Key Words

Carbon certificates; Governance challenges; Process Net-Map; East Africa; Voluntary carbon market; Sustainable Agricultural Land Management (SALM)

1. Introduction

The development of agricultural carbon projects is part of a wider effort to promote sustainable agriculture, address climate change and meet global greenhouse gas (GHG) emissions reduction targets. Agricultural carbon projects offer a unique opportunity for smallholder farmers to benefit from the adoption of sustainable agriculture. These practices not only reduce GHG emissions, but also enhance farm productivity by improving soil fertility and increasing farmer resilience and adaptation to climate change (Vågen et al., 2005; Montagnini & Nair, 2004). Smallholder Agricultural Carbon Projects (SACPs[1]) have the unique potential to connect farmers to international voluntary carbon markets to receive payments in exchange for carbon sequestered on their farms (Paul et al., 2023; Foster & Neufeldt, 2014). Sustainable practices promoted by SACPs include Verra's Sustainable Agricultural Land Management (SALM [2]), which includes minimum tillage, residue management, cover crops, intercropping, composting, agroforestry, and dairy management practices. SACPs mimic Payment for Ecosystem Services (PES) schemes, in which farmers receive payments from the sale of carbon credits. However, bringing together thousands of smallholders in complex carbon schemes raises important governance challenges that may affect the success of its implementation.

While there are high expectations for the potential of SACPs to reduce GHG emissions and improve smallholder livelihoods, there is little systematic evidence on the governance challenges affecting their implementation. Previous studies have focused on innovation (Shames et al., 2012), the challenges of engaging smallholders (Lee, 2017; Foster & Neufeldt, 2014), and the role of intermediary organisations (Lee et al., 2016) in SACPs. In their analysis of pro-poor carbon market projects in East Africa, Lee et al. (2016) identified time lags between adoption and carbon revenue distribution, knowledge gaps about voluntary carbon markets, and insignificant carbon payments as major challenges in SACPs. However, it is unclear why these challenges arise and how they relate to different components and stages of implementation. McDermott et al. (2013) and Pascual et al. (2014) emphasize the importance of focusing research on procedures and decision-making, and the overall context in which SACPs occur. Furthermore, despite a large body of literature on digital tools in agriculture (see, for example, Birner et al., 2021; Daum et al.,

[1] SACPs is used in this study to represent smallholder agricultural carbon projects of the AFOLU project categories: (1. Afforestation, Reforestation and Revegetation (ARR); 2. Improved Forest Management (IFM) 3. Reduced Emission from Deforestation and forest Degradation (REDD) 4. Avoided Conversion of Grassland and Shrubland (ACoGS) 5. Agricultural Land Management (ALM) and 6. Wetland Restoration and Conservation (WRC)

[2] Verra's SALM methodology has been inactivated in 2023. Existing projects can still follow the SALM methodology, new projects have to use similar methodologies. Source: Verra, 2023 (https://verra.org/verra-announces-planned-inactivation-of-sustainable-agricultural-land-management-methodology-vm0017/#:~:text=Verra%20will%20inactivate%20VCS%20methodology%20VM0017%20Adoption%20of,the%20VCS%20Methodology%20Development%20and%20Review%20Process%2C%20v4.2).

2019; Khatri-Chhetri et al., 2019; Smith, 2018; Porter & Heppelmann, 2014), there has been little discussion regarding institutional mechanisms and digital tools.

This paper therefore develops a systematic framework for analysing governance challenges in SACPs and applies this framework to identify what digital tools could do to address these challenges. Thus, this study seeks to answer the following research questions:

- What are the governance challenges in the implementation of smallholder agricultural carbon projects?
- What is the role of digital tools in supporting successful (more inclusive) carbon projects?

To answer these questions, a qualitative case study was conducted on two SACPs in Kenya, which differ in scope and implementation mechanisms. To better understand the details of governance challenges in the SACPs, the principal-agent (PA) theory and a participatory mapping tool - the Process Net-Map - were used, following Birner & Sekher (2018). Details on the application of the Process Net-Map are presented in section 3.4. On this basis, a systematic analysis of how digital tools can address these challenges was undertaken. The two case studies are interesting given that the Kenya Agricultural Carbon Project (KACP) was the first SACP to implement SALM, while Livelihood Mt. Elgon added a dairy component and the large number of information and communication technologies start-ups in Kenya (Stroisch, 2018).

2. Governance challenges of agricultural carbon projects: conceptual framework

Fig. 1 shows the generic structure of a SACP, as depicted by Shames et al. (2012). It is a central proposition of this paper that, for analytical purposes, an agricultural carbon project can conceptually be divided into two components referred to here as the "SLM component" and the "carbon credit component". The SLM component is largely equivalent to any conventional development project that aims to encourage farmers to adopt SLM practices. Such projects have been promoted for decades by international development organizations and national governments with the aim of making agricultural production more environmentally sustainable and protecting natural resources, such as soil. Such SLM projects typically involve the actors that are depicted in the center and on the left-hand side of Fig. 1. They include a project developer, which could be a development organization such as the World Bank or a bilateral agency, which engages a field project manager such as a government agency or a non-governmental organization. This organization uses extension agents, referred to as "SLM technical capacity providers" in Fig. 1. They build the capacity of the farmers, who are typically organized in farmer groups (referred to as community-based organizations (CBOs) in Fig.1) to apply SLM practices.

The opportunities and challenges of such SLM projects are well documented in the literature (Pan et al., 2022; Kim et al., 2021; Foster et al., 2017; Lee et al., 2016; Shames et al., 2012). While the environmental benefits are evident, encouraging farmers to adopt SLM practices has proven to be challenging. This is because SLM practices are often labor-intensive, and the benefits are not immediately visible, but rather occur in the long run (Foster et al., 2017; Lee, 2017; Shames et al., 2012). Moreover, like other agricultural development projects, SLM projects are confronted with the typical problems involved in the provision of agricultural advisory services (Aremu & Reynolds, 2024; Namyenya et al., 2023; Anderson & Feder, 2004), which include a lack of incentives for extension staff due to information asymmetry and resulting PA problems (detailed in section 2.1). It is inherently costly for an agency that hires extension agents to supervise them, as their activities are spatially dispersed. Moreover, the results of the extension activities, in this case the adoption of SLM practices, partly depend on factors beyond the control of extension agents (Birner et al., 2009). Extension services often suffer from insufficient financial resources since extension has the characteristics of a public good and a merit good, resulting in a low willingness of farmers to pay for it (Anderson & Feder, 2004).

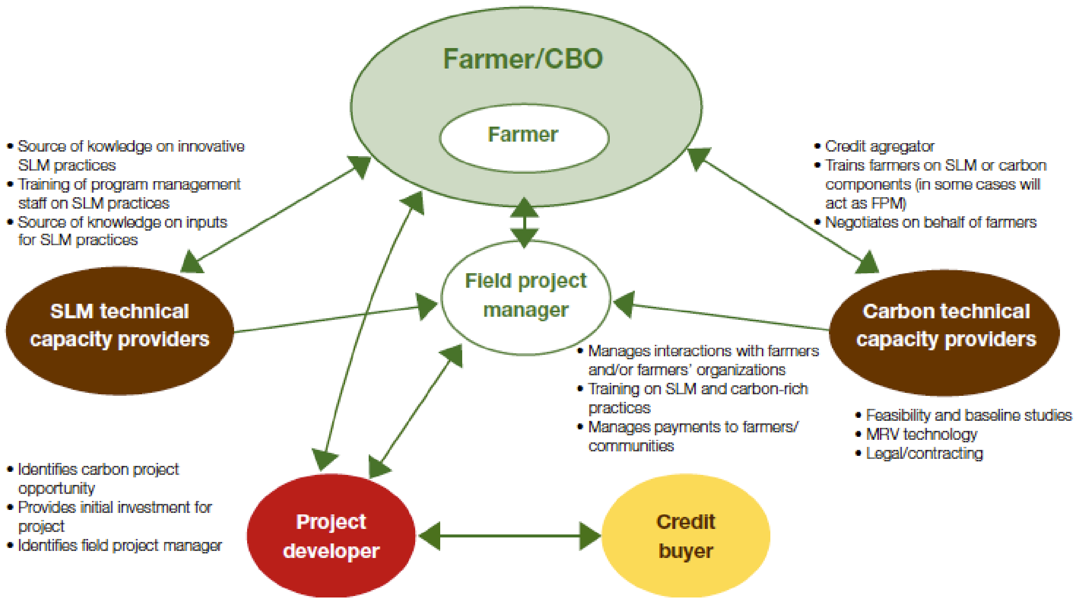

Fig. 1 Key roles and functions in a generic model of smallholder agricultural carbon project (Shames et al., 2012)

SACPs add a "carbon credit component" to such SLM projects. This requires the inclusion of two additional types of organizations, as shown in Fig. 1: "Carbon technical capacity providers” and “carbon buyers.” The promise of SACPs is their potential to resolve some of the long-standing problems of SLM projects by generating financial resources. These resources can be used (1) to better finance the SLM technical capacity provider, and (2) if the carbon revenues are shared with farmers, to create incentives for them to adopt SLM practices. Moreover, the monitoring activities conducted in the carbon component can also improve the monitoring of the SLM component. This is because the carbon credit component requires the project to provide evidence that the SLM technical capacity providers were successful, i.e. that the SLM activities were adopted by the farmers. By adding this evaluation activity, the carbon credit component of an agricultural carbon project can reduce the information asymmetry and the PA problem that exists among the chain of PA relations, as discussed in sections 2.2. Phrased differently, the carbon credit component adds additional accountability to an SLM project.

The inclusion of a carbon credit component into an SLM project, however, presents its own set of challenges. Information asymmetry and a resulting PA problem exist between the carbon technical capacity providers and the field project manager, as well as between the project developer and the carbon buyers. Certification and verification systems, which are implemented by the carbon technical capacity providers, aim to address this challenge.

If one conceptualizes an agricultural carbon project as sketched above, two interesting questions arise from a governance perspective:

- How should SACPs be organized in order to harness the potential synergies between the SLM component and the carbon credit component to reduce the governance challenges arising from information asymmetries in either component of the project?
- How should the financial revenues from the carbon credits be distributed among all relevant organizations in order to create sufficient financial incentives to address typical problems of SLM projects (low adoption rates, insufficient resources for technical capacity development)?

To answer these questions, the literature that has analyzed the governance problems in SLM and agricultural carbon projects is reviewed. To address the first question, this study focusses on papers that have applied an information-asymmetry / principal-agent framework, since - as the above description shows - information asymmetries are a major underlying reason for governance challenges in both the SLM and the carbon components of SACPs. To address the second question, the literature that has addressed questions of benefit sharing in agricultural carbon projects is reviewed. Since the literature on agricultural carbon projects is still limited, papers on other types of carbon projects (such as forestry projects) are also considered in the literature review, if they provide useful information on the two above questions.

2.1. Theoretical considerations

This study uses principal-agent theory from New Institutional Economics to analyze governance challenges in relationships where one party (the principal) is dependent on the actions of another (the agent) (Miller, 1992; Arrow, 1985; Williamson, 2000). A principal-agent relationship exists when an economic actor (the principal) hires another actor (the agent) to carry out an activity and at the same time there is an information asymmetry that gives the agent an informational advantage that allows him or her to act opportunistically (Ross, 1973). The principal relinquishes decision-making but gains control over the agent's actions, while the agent loses autonomy in a particular area but gains decision-making rights for the principal (Braun, 1993). Asymmetric information arises when the principal does not have full knowledge of the agent's actions, leading to possible conflicts such as adverse selection (Arrow, 1985) and moral hazard (Stiglitz, 1987). The problem of adverse selection arises in SACPs when, for example, the project developer has difficulty in selecting an appropriate project manager who will act in its interest, while moral hazard arises because it is difficult to assess whether incentives may encourage undesirable agent behavior (Hotte et al., 2016; Guston, 1996). Both the principal and the agent act in their self-interest, leading to misaligned incentives.

To align goals, joint formulation and public evaluation are recommended, while reducing information asymmetry requires monitoring and reporting, as well as providing incentives for desirable behavior (Schieg, 2008). Adequate incentives to motivate good behavior and monitoring systems to evaluate the efficiency of agents' actions are crucial.

2.2. Principal-Agent problem in smallholder agricultural carbon projects

While the application of principal-agent theory in conventional development projects is well established in the literature (see, for example, Namyenya et al. 2023; Basak and van der Werf, 2019; van Kooten, 2017), it has rarely been applied to SACPs. From the generic model of SACPs (Fig. 1), a chain of principal-agent relationships can be identified (Table 1).

Table 1 Chain of principal-agent relationships among SACP actors

Principal	Agent	Relation/explanation
SLM component		
Project developer	Field project manager	The project developer mandates the field project manager to supervise project implementation and expects adoption of sustainable practices
Field project manager	SLM technical capacity provider	The field project manager requires the SLM technical capacity provider to provide

		extension services and SALM technical support to farmers and expects monitoring report
SLM technical capacity provider	Farmer/community-based organization (CBO)	The SLM technical capacity provider requires farmers/CBO to support in training farmers sustainable practices, data collection and reporting and expects accurate reporting
Carbon credit component		
Project developer	Carbon technical capacity provider	The project developer mandates the carbon capacity provider to train project field managers and SLM technical capacity providers on carbon MRV technologies, quantify emission reduction, and expects accurate estimates and increased carbon credit
Carbon technical capacity provider	Field project manager	The carbon technical capacity provider requires the project field manager to provide monitoring data and expects accuracy
Carbon buyer	Project developer	The carbon buyer seeks certified carbon credit from the project developer and expects accurate representation of the indicated emission reduction

2.2.1. Principal-Agent problem in 'SLM component'

The SLM component of SACPs has three main PA relationships, as shown in Table 1. In the project developer (principal) - project field manager (agent) relationship, the principal provides the financial resources and engages the agent to oversee the overall implementation of the project. Consequently, the agent assumes responsibility for providing extension services to participating farmers through SLM technical capacity providers and for ensuring that all project activities are aligned with the principal's overall objective (i.e. to increase SLM adoption). Given that the implementation of SACPs requires large up-front investments, the self-interested agent may use fewer resources to avoid certain costs in order to maximize its benefits, leading to goal misalignment. For example, Basak and van der Werf (2019) find that project implementers (recipients of funds) may divert resources to their other projects because donors cannot directly observe how their resources are used. Furthermore, project implementers pay little attention to the adequate participation of smallholders in decision making and the development of project activities (Basak and van der Werf, 2019), especially in developing countries. In a forest carbon project in China, project developers decided exclusively on tree species and benefit sharing without including farmers' voices in the negotiation process (Zhou et al., 2017). Such decisions by agents may limit smallholders' understanding and knowledge of SLM and voluntary carbon markets, leading to lower participation in SACPs (Pan et al., 2022; Aggarwal, 2015). It is difficult and costly for the principal to determine the agent's efforts in the project outcome (Laffont and Martimort, 2009). An important control mechanism would be to improve the agent's incentives and align its interests with those of the principal. In the case of SACPs, joint decision-making and strict contractual agreements can be a solution. However, given the complex nature of SACPs, co-ownership and reputation for future contracts will increase the commitment of implementers to make decisions in the interest of the project.

In the relationship between the field manager (principal) and the SLM technical capacity provider (agent), the agent acts as the link between the participating farmers and the principal. The principal delegates responsibility for the provision of extension services to the agent and ensures that the agent's activities are in line with the overall objective of the project. However, capacity problems can lead to inadequate supervision. Capacity problems in the provision of extension services arise due to low salary levels, inefficient financial and human resource management systems, and insufficient operational funds (Daum et al., 2022; Lubungu & Birner, 2018). As a result, field officers may be absent from the field due to low incentives and limited supervision, leading to moral hazard problems. This may affect the adoption of agricultural practices, as the provision of extension services requires more field staff, effort, and time to train farmers and monitor adoption. Surprise visits to randomly selected field extension workers could be used. The principal may not be able to assess the frequency and quality of services received by farmers from field agents due to a lack of resources. In SACPs, carbon sequestration and emission reductions depend on farmers' activities, so misalignment of farmers' activities with those of the projects may jeopardize the sequestration target. While the agent may observe potential changes in the farmers' immediate environment, the principal may have incomplete information because the agent may decide to report fraudulently.

In addition, there may be information asymmetry between the SLM technical capacity provider (principal) and the farmers/CBO (agent). Smallholders have a high time discount rate and may invest in projects that provide short-term economic benefits (Cavanagh et al., 2017). Given that carbon credits can typically only be sold after at least five years (Havemann, 2013), the activities and actions of farmers may be misaligned with the developer's goal of long-term carbon credits. It is therefore difficult for the principal to select farmers who have the potential and desire to implement the promoted sustainable practices, leading to the problem of adverse selection. While the agent may be able to observe the farmer's actions and draw conclusions about potential changes, the principal remains unaware, as the agent may choose to withhold or provide incorrect information to the principal, leading to the problem of moral hazard. The principal may also behave opportunistically by diverting resources intended for farmers and/or providing less training and extension services. This study argues that in the chain of PA relationships in SACPs, the principal assumes the role of an agent at a certain level and behaves opportunistically. In this case, the principal has an information advantage over the agent.

To address these issues, appropriate incentives and monitoring mechanisms are critical. Incentives should aim to motivate the agent to work towards achieving the principal's goals (Namyenya et al., 2023). These incentives could include bonus payments, shared decision making, or rewards and punishments. In addition, the principle of scientific management shows the importance of monitoring employee performance, providing clear instructions and supervision to improve efficiency (Taylor, 2004).

2.2.2. Principal-Agent problem in 'carbon credit component'

The 'carbon credit component' includes accountability measures, such as monitoring, reporting and verification (MRV), to demonstrate the adoption of SLM. However, it has its own challenges arising from the PA relationships between the project developer and the carbon technical capacity provider, the carbon technical capacity provider and the project field manager, and the carbon buyer and the project developer (Table 1). The project developer (principal) hires the carbon technical capacity provider (agent) to provide expertise in estimating carbon credits from project activity data. The carbon technical capacity provider (principal) relies on the project manager (agent) to provide information on SLM implementation and project activities, i.e. MRV for the principal to calculate and claim carbon sequestration and emission reductions. While monitoring is the periodic measurement of changes in carbon stocks, reporting is the process of recording, collecting, and communicating the collected data to project authorities (Pan et al., 2022). The high cost and complexity of monitoring, such as field measurements and modelling, can lead to inaccurate, inconsistent, and fraudulent reporting by the actor. For example, monitoring in carbon projects can account for 42% of total project costs (Pearson et al., 2014), and farmers may not consciously adhere to project activity guidelines (Carton and Andersson, 2017). Additionally, the verification process, which involves identifying potential fraudulent reporting and detecting errors, can also be problematic due to costs. Tennigkeit et al. (2023) argue that high verification costs can lead to frequency challenges, as each verification is costly. Moreover, project managers and verification or validation bodies (VVBs) may provide inconsistent information, hindering effective and accurate third-party validation of the project. Furthermore, agencies responsible for verifying a large number of projects may not thoroughly assess every detail (Pan et al., 2022). Concerns about the reliability of reported carbon offset data have been highlighted in many studies (Haya et al., 2023; Wunder et al., 2020). Approximately 40% of a global sample of PES initiatives did not closely monitor service provider compliance (Wunder et al., 2018). Additionally, approximately 50% of non-compliance cases had never sanctioned a contracting partner (Wunder et al., 2018). The impartial assessment of carbon sequestration initiatives, and therefore the effectiveness of the verification process, can be undermined by potential conflicts of interest.

Promoting data transparency and accessibility is essential to mitigate information asymmetry in the PA relationship. Implementing standardized reporting mechanisms, using advanced technologies for data collection, and fostering open communication channels can increase the reliability of reported data and facilitate the verification and validation processes (Haya et al., 2023; Wunder et al., 2018). Addressing these challenges is critical to ensuring the credibility and effectiveness of agricultural carbon projects in global efforts to combat climate change. One key strategy to address the issue of compliance is to enforce contractual conditionality. For example, compliance with carbon standards can be monitored through remote sensing and/or on-site verification, and sanctions such as partial payment or suspension of payments can be applied (Kerr et al., 2014). However, Ferraro (2017) notes that withholding payments to contracted participants can be costly to the social capital that project developers have built with local people. They may therefore prefer to turn a blind eye to some level of non-compliance (Ezzine-de-Blas et al., 2016).

A PA relationship may also arise between the carbon buyer and the project developer, as voluntary carbon credits are traded between these parties through Emissions Reductions Purchase Agreements (Tennigkeit et al., 2023). Voluntary carbon markets remain unregulated, so the selling price of carbon credits depends on the marketing skills of the project developer and its ability to highlight the attractiveness and match the right type of project with the right buyer (Tennigkeit et al., 2023). The agent may provide only the positive impacts of the project (greenwashing), resulting in incomplete information for the buyer. As voluntary carbon market credits are traded over-the-counter, there is a potential lack of transparency in credit prices (Tennigkeit et al., 2023). Furthermore, buyers of carbon credits are often unaware of or have no incentive to improve the credit generation process (van Kooten, 2017).

2.3. Benefit sharing in agricultural carbon projects

SACPs are not only designed for environmental outcomes, but also aim to generate significant economic and social benefits (Foster et al., 2017; Shames et al., 2016). Benefit sharing is commonly used to describe the flow of these benefits to all stakeholders. It is an essential aspect of voluntary carbon markets and involves the intentional distribution of monetary and/or non-monetary carbon benefits to different stakeholders/beneficiaries for their contributions to GHG emission reductions (World Bank, 2019). However, studies have questioned the effectiveness of project budgets managed by investors and donors, pointing to the need to unpack how costs and carbon revenues are distributed among stakeholders, what proportion of the budget goes to transaction costs, and who determines how much is paid to participating farmers responsible for carbon sequestration (Howard et al., 2016;

Atela, 2012; Fairhead et al., 2012). Evidence suggests that carbon payments to farmers are insignificant and irregular to compensate or motivate participation (Howard et al., 2016; Lee et al., 2016; Shames et al., 2016). Furthermore, the equitable distribution of these benefits may be hindered by the complexity of SACPs (Lee et al., 2016; Shames et al., 2016), lack of trust in project developers (Sipthorpe et al., 2022), limited resources and ensuring the long-term sustainability of SACPs. In this analysis, it is argued that PA problems may arise in benefit sharing due to information asymmetry in the chain of PA relationships (Table 1) and the lack of outlined benefit sharing mechanisms (van Kooten, 2017; Howard et al., 2016).

PA theory is applied to analyze the governance challenges that may arise among the different actors in benefit sharing. The project developer is modelled as the principal, and the farmer/CBO as the agent, but both actors are part of a wider chain (Table 1). These complex relationships between different actors can lead to the problem of information asymmetry, where the agent may hide relevant information from the principal due to self-interest, and the principal may not adequately observe the agent's actions, leading to the problem of moral hazard and adverse selection.

The project developer faces various moral hazard problems with respect to the chain of PA relationships (Table 1). For example, project field managers have different obligations and may use inputs intended for the carbon project for other purposes, which cannot be adequately observed by the project developer. Similarly, the SLM capacity provider may divert inputs to non-participants and provide inadequate training to farmers, which the project manager cannot observe, while CBOs may also act opportunistically by distributing inputs unequally among farmers due to elite capture. In addition, smallholders may not receive the actual monetary benefit from the sale of carbon credits due to possible diversion of funds, lack of information on the actual implementation costs for each actor, leading to inequitable distribution due to power differentials among actors, and misappropriation of funds due to inadequate monitoring (Namyenya et al., 2023), which cannot be directly observed by the project developer. To control the problem of moral hazard, the principal can design benefit-sharing mechanisms, rewards, and sanctions to prevent the agent from breaking the contract.

The principal also faces the problem of adverse selection, which reflects the difficulty in selecting the appropriate agent. For example, the project field manager may struggle to select stakeholders who will contribute to emission reduction and participate in benefit sharing. Similarly, the project developer may find it difficult to select a suitable manager who will distribute benefits fairly among stakeholders. To address adverse selection, the project developer may decide to select organizations with a good track record of implementing SACPs. However, this approach may result in excluding organizations with innovations and possibly selecting organizations with models that may not produce the expected results (Basak and van der Wolfer, 2019). Consequently, it becomes difficult for the project developer to select the appropriate implementing organization. The SLM capacity provider may also find it difficult to select the appropriate farmers whose farming practices contribute to emissions reductions, as the benefits of carbon projects are mainly performance-based. To ensure an equitable distribution of benefits, Lyster (2011) emphasizes the need to include the perspectives, concerns, and interests of local people in the design of carbon project strategies, to build local community capacity, and to foster long-term partnerships with them. In addition, Tennigkeit et al. (2023) recommend aligning the project business case with farmers' objectives for successful SACP development. Participatory decision-making on benefit sharing promotes transparency and accountability and builds trust among stakeholders (Howard et al., 2016). Effective benefit sharing in SACPs is therefore essential to achieve not only environmental integrity but also economic and social sustainability.

2.4. Potential of digital tools in sustainable agricultural carbon projects

While digital tools for agricultural development are increasingly being studied (see, for example, Daum et al., 2022; Birner et al., 2021; Baumüller, 2018), there is little evidence of their application in SACPs. Furthermore, the potential of digital tools is well established in the literature. For example, digital tools can improve the productivity and incomes of millions of smallholder farmers and other actors in agricultural value chains (Birner et al., 2021), facilitate information sharing and learning among farmers and other value chain actors on sustainable agricultural practices and climate change adaptation measures (Hildago et al., 2023), reduce information symmetry and transaction costs (Lerner et al., 2021; Grabs, 2017), and reduce carbon footprints (Daum et al., 2022; Khatri-Chhetri et al., 2019). In their study on mapping soil organic carbon stocks in Brazil, da Silver Junior et al. (2023) showed that remote sensing tools are a fast and inexpensive way to measure soil organic carbon. Shames et al. (2016) also proposed the use of simple handheld tools to measure soil organic carbon by smallholder farmers to reduce transaction costs. However, there is a gap regarding the potential of these tools to address governance challenges in SACPs. This study categorizes the ability of digital tools to address governance challenges based on the two components of SACPs, 'SLM and carbon credit,' and the stages of project implementation.

2.4.1. Capacity of digital tools (SLM component)

1) *Tools for project planning and monitoring:* Project developers and implementers can use connected digital tools, i.e. digital tools that enable information sharing with stakeholders (Daum et al., 2022), to share project schedules with other stakeholders and use virtual communication platforms to discuss project activities. Participating farmers and SLM

capacity providers can use digital tools to collect data to monitor farm yields, such as milk production, or to record the number of trees farmers receive and planting dates for accounting and record keeping purposes. Project implementers can also use digital tools to monitor the field activities of SLM capacity providers. This can improve the quality and extent of extension services received by farmers.

2) *Data collection and analysis tools:* Digital technologies such as mobile applications and GPS can be used by SLM capacity providers and participating farmers to efficiently collect data, while project developers can use big data analytics to identify possible errors and call for immediate corrections or make informed decisions. The socio-economic impact of SACPs, distribution of benefits, and progress towards project goals can inform decisions about project effectiveness. In addition, digital technology can also enable data analysis and modelling of the effectiveness of project activities, identifying key approaches and making informed decisions (Sipthorpe et al., 2022).

3) *Stakeholder engagement tools:* Project developers can develop digital platforms to engage with stakeholders, including local communities and smallholders. These digital platforms can facilitate information sharing and consultation, allowing smallholders to actively participate in decision-making processes and voice their concerns and needs. Stakeholder engagement can promote project information sharing, transparency, and build trust among stakeholders. Farmers can use such digital tools to share information on SALM and dairy practices among themselves to promote peer learning, while technical capacity providers can also use digital tools to provide extension services to farmers. For example, e-extension in Kenya is used by extension officers to provide farmers with information on farm management, including disease control (Daum et al., 2022).

2.4.2. Capacity of digital tools (Carbon component)

1) *Carbon monitoring, reporting, and verification tools:* Digital tools such as satellite imagery and remote sensing can be used to monitor carbon emissions and removals, thereby reducing measurement errors. Carbon measurement involves accurately quantifying carbon emissions and removals, often using scientific methods and standardized protocols. Reporting provides transparent and comprehensive information on measured emissions and removals, including detailed documentation of the methods used, data sources, and calculations (Tennigkeit et al., 2023). Smart contracts could be used to automate the verification process, while blockchain technology could ensure transparency, traceability, and trust in technological solutions such as satellite imagery (Sipthorpe et al., 2022).

2) *Payment/benefit distribution tools:* Project developers can use digital and mobile payment systems to directly transfer payments/funds to smallholder farmers and communities, eliminating intermediaries and ensuring that benefits reach the intended beneficiaries. In addition, seedlings and other planting materials distributed to farmers can be digitally

recorded. This can facilitate the secure distribution of benefits among stakeholders, improve accountability, and reduce potential conflicts among farmer groups.

3. Research design and Methodology

3.1. Overview of the case study

The Livelihoods Mt. Elgon project (hereafter Case 1) and the Kenya Agricultural Carbon Project (KACP) (hereafter Case 2) were implemented in Trans-Nzoia and Bungoma counties in Western Kenya by Vi Agroforestry (project developer), a Swedish NGO. The objective of both projects is to improve the livelihoods of smallholder farmers through improved food production from SALM and dairy management practices, while reducing greenhouse gas emissions. In addition to generating carbon credits, the project developers hope that the adoption of SALM, which includes agroforestry, residue management, cover cropping, reduced or zero tillage, manure management and dairy farming (Lee et al., 2015; Atela, 2012), will improve soil fertility. Table 2 shows the characteristics of these projects.

Table 2 Characteristics of the case studies

Characteristics	Case 1	Case 2
Project implementation period	2016 to 2026	2009 to 2029
Project developers/ implementer	Vi Agroforestry	Vi Agroforestry
Type of funding	Investor fund	Donor fund
Targeted farmers	15,000 smallholders including 70% dairy farmers	60,000 smallholder farmers
Carbon accounting standards	Gold standard: GHG reduction due to increased dairy productivity and Verra: SALM	Verra: only SALM
Expected sequestration during project implementation period	One million tons of CO^2e on 25,000 ha	1.23 million tons of CO^2e on 45,000 ha
Farmer benefit	Extension service provision	Direct cash payment and extension service provision

3.2. Research design

A comparative qualitative case study design was used to gain insights into why and at what stage governance challenges arise in SACPs, and how these challenges can be mitigated. The two cases selected for this study differ in their mode of implementation and sources of funding. In addition, this study considered the two phases of Case 1 to understand the institutional arrangements in transition. Kenya is well suited for such a case study because it was the first developing country to receive funding from the World Bank's Biocarbon Fund to implement the SACP, which used SALM to link smallholders to the voluntary carbon market. The first step in this study involves a review of literature and documents from organisations (project developers, donors, and investors), which not only provided a better understanding of the actors involved in the implementation of the projects, but also helped to triangulate and validate the findings (Adu-Baffour et al., 2021). This review provided the authors with information on the goals, objectives, mitigation practices, carbon accounting methodologies, and certification processes. The first author also attended a training session for field staff on digital tools for data collection, organised by UNIQUE, a carbon technical support provider. Stakeholders were then identified and selected based on their experience, knowledge, and involvement in the two cases with the help of the project managers and snowball sampling. Due to the potential sensitivity of the information and to ensure the anonymity of the respondents from the researchers, the institutional affiliations of the respondents are not reported. Stakeholders were selected from project funders (donors and investors), project developers/implementers, government parastatals, CBOs, dairy cooperatives, farmers, and farmer groups involved in the projects. A total of 85 interviews were conducted, including ten focus group discussions (FGDs), each involving 10-20 members. These discussions were held within ten clusters (groups of farmers), randomly selected from a list of clusters provided by the project developer. These clusters were selected from ten of the fifteen project zones. The FGDs were conducted to gather further information on the participants' perspectives and perceptions of the SACPs.

3.3. Data collection and analysis

Data were collected through farm visits, transect walks, visits to dairy cooperatives and CBOs, participation in field officer training, and FGDs in two counties in Western Kenya between May and September 2022. A participatory and visual mapping tool called Process Net-Map was used. Process Net-Map allows the sequential steps of a process to be mapped (Birner & Sekher, 2018). The tool provides insights into the different stages of SACPs, offering the advantage of visualisation and the identification of actors' power or influence on the outcome (adoption of SALM and dairy practices). Process Net-Map is designed to provide insights into governance challenges in the implementation of complex programs and projects and to elicit implicit knowledge about such projects (Birner et al., 2011; Raabe et al., 2010; Schiffer 2007). The tool was used in this study to assess all stages involved in SACPs and to identify the actors and governance challenges associated with each stage. A total of 85 interviews were conducted, including 48 Process Net-Map sessions (Table 3).

Table 3 Study participants

Stakeholders	Case1	Case 2
Farmer groups (clusters)	10	-
Community facilitators	12	7
Community-based organisations	1	3
Dairy Cooperative executives	5	-
Cooperative Union executives	5	-
Representatives of County Government	2	1
Field officers	15	4
Project officers	3	2
Monitoring and Evaluation officers	1	1
Project Managers	1	1
Staff of UNIQUE	1	1
Staff of Vi Agroforestry	3	2
Staff of Brookside	2	-
Staff of Livelihoods Venture	2	-
Sub-total	**63**	**22**
Total	**85**	

3.4. Description of the Process Net-Map tool

The application of Process Net-Map follows three steps. Firstly, the respondents were asked to describe the entire implementation process of SACP, and at each stage, respondents identified all actors involved. The names of the actors mentioned by the respondent were written on sticky notes (so-called actor cards) by the interviewer and placed on a large flip chart sheet. Arrows were drawn between actors to indicate the steps. Each link (arrow) was numbered and the respective step of implementation corresponding to each number was described in a legend. The links were drawn with different colours to indicate the types of processes identified during the activities.

Secondly, the interviewer asked the respondents to determine how much influence each actor had on the outcome, which was defined as the adoption of SALM and dairy practices. For visualisation, the researcher stacked checker game pieces on top of each actor to build so-called influence towers for each actor on a predetermined scale from 0-8, based on respondents' perceived level of influence. The height of the tower depicts the level of influence assigned to an actor by the interviewees. The influence towers were placed next to the actors, and actors with eight checker pieces were perceived to be the most influential in ensuring the adoption and establishment of SALM and dairy practices. Those actors with no checker pieces were considered not to have any influence on the outcome. Respondents were asked to give reasons for assigning the levels of influence to a particular actor.

In the third step, the researcher used the developed map to ignite a discussion on the governance challenges. The respondents were asked to identify potential challenges and determine at which stage these challenges are likely to occur in the implementation process. This was followed by a discussion on how these challenges were addressed. The facilitator probed for existing digital tools and how their application can help solve some of these challenges.

Given that respondents had in-depth experience and insight in different areas of SACPs, individual maps were first compared and then combined based on discussions with stakeholders who have a broader insight into all stages of SACPs. The individual Process Net-Maps were aggregated into a single simplified map showing consecutive steps, linkages between actors, levels of influence and challenges in implementing the SACPs. The first two authors conducted the mapping and interviews with groups and individual respondents. All sessions and interviews were audio recorded with prior permission from the participants.

Content analysis was used to analyse in-depth interviews, FGDs, and discussions around governance challenges and mitigation strategies. Content analysis is considered a useful tool for exploratory and descriptive studies, particularly in collaborative studies where participating subjects are also stakeholders in a situation in need of change or action (Adu-Baffour et al., 2021; Simms & Erwin, 2021). Participation in field officers' training and visits to farms, dairy cooperatives, and CBOs was used to triangulate interview results.

4. Results

4.1. Systematic description of the implementation of smallholder agricultural carbon projects

The implementation of SACPs follows the generic structure of agricultural carbon projects as shown in the conceptual framework. Fig. 2 shows the general structure of SACPs, indicating the key actors, their roles, and how they are linked, the systematic steps in implementing SACPs, and where governance challenges arise. Details of the roles of the actors and their level of influence on the adoption of sustainable practices are presented in Appendix. As shown in the conceptual framework, SACPs have two main components, namely 'SLM and carbon credits'. The SLM component consists of the actors shown in green on the left side of Fig. 2, while the carbon credit component is shown in blue on the right side of Fig. 2. The systematic steps in the implementation of SACPs in the case studies are presented in Appendix (Table 6).

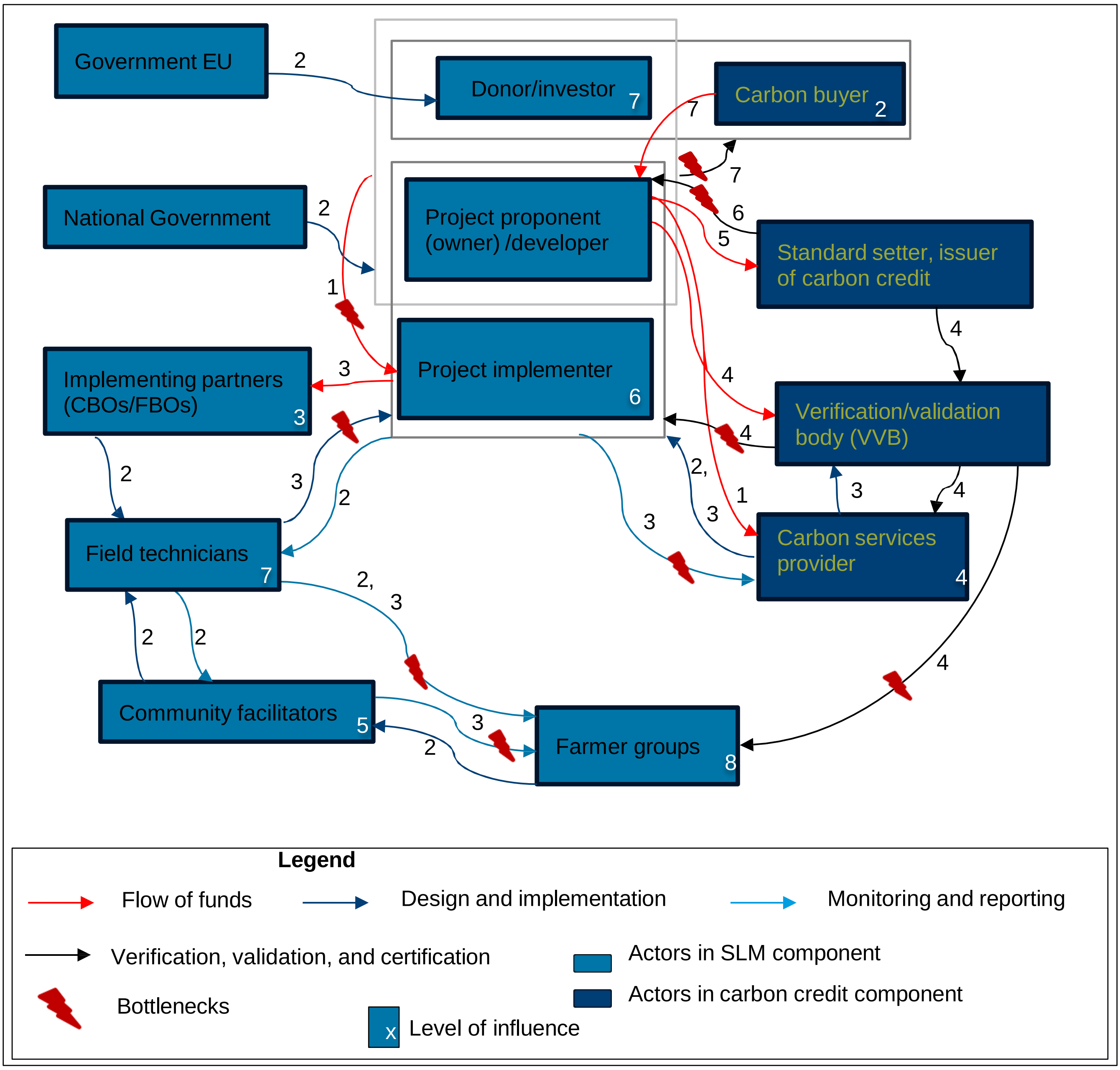

Fig. 2 Key components and functions of a generic model of smallholder agricultural carbon project

4.2. Governance challenges of SACPs and mechanisms employed

This section presents the empirical findings on the governance challenges affecting the two components of the SACPs and the strategies being employed (Table 4), as reported by respondents. In addition, the identified governance challenges are highlighted in the form of lightning bolts in Fig. 2.

4.2.1. SLM component

The SLM component of the SACPs faced several challenges. First, smallholder farmers faced difficulties that hindered their smooth adoption of the promoted SALM and dairy practices, as reported by 51% of respondents (Table 4). The majority (over 70%) of participating farmers in both cases are women, but due to gender and social norms, they lack land ownership and decision-making power. These findings showed that men typically determine the SALM practice to be adopted due to their cultural role as head of the household, which affects the tracking of farmland. These were echoed by a cooperative leader (Case 1) and a community facilitator (Case 2) respectively:

"…so you will find the lady is the one in the project and not the husband; and so, when they [field officers] came in and wanted to measure the land; the husband says no; this is my land; what do you want to do with my land: why do you measure my land; do you want to sell my land".

"Some of my group members couldn't plant the tree seedlings because the Muzee [man] didn't agree. Some husbands also harvested the trees prematurely without the women's consent".

Furthermore, in six out of ten FGDs, respondents reported that culturally, "Ng'ombe ni Baaba" means that men, not women, own cows, although most daily farm activities such as feeding, cleaning the shed, milking and watering are mainly done by women. The morning milk is for the Muzee (man), while the evening milk is for household consumption, with only the surplus going to the woman. Also, only the morning milk is sold to the cooperatives and the account is mainly in the name of the man. This suggests an unequal distribution of non-carbon benefits within the household.

In addition, delays in the delivery of inputs (tree seedlings, fodder grass seeds) by project implementers, the unavailability of some inputs such as Brachiaria, and budget constraints were reported by respondents as barriers to adoption. The results also showed that small plot sizes and the prioritization of food security also hindered the adoption of some SALM practices. For example, agroforestry practices require trees and crops to be planted on the same plots, suggesting competition for space. Understanding the importance of these practices is crucial to increasing farmer adoption. One field officer (Case 1) explained:

"Food security is very important in this project, so adoption of these practices is a gradual process since farmers have small plots and need to also grow food crops to feed their families. Since about 50% to 70% of the farmers are dairy producers, it will take time for the farmer to understand that milk sales are more profitable than the maize that they grow; the point is with time farmers will understand and produce more fodder, get more milk, and use the money to buy food stuffs instead".

To address the issue of gender norms, project implementers used a participatory household approach (Household Road Map) to train households on sharing responsibilities within the household. The FGDs (four out of ten) showed that the training helped men to support their wives in feeding the cows and planting fodder, although some households did not participate.

Secondly, 45% of respondents reported low participation and awareness due to insufficient awareness raising, non-participatory project design and decision-making in the initial project phase, and information asymmetry about the voluntary carbon market. For example, in Case 2, the project was initiated by the top-level actors (project developer, proponent and carbon technical support provider) and project activities were determined without farmers' voices. Similarly, around 16% of respondents indicated that power imbalances between actors and non-participatory decision-making resulted in risks being shifted to weaker actors. For example, in both cases, participating farmers are not supposed to use pesticides and synthetic fertilisers on carbon farms. However, five out of seven community facilitators interviewed in Case 2 reported that some farmers lost a large amount of their crops due to fall armyworm infestation in 2018, compared to other farms that had applied pesticides.

In addition, 42% of respondents cited the lack of accountability of key decision-makers and low local technical capacity as barriers to SACP implementation. It is worth noting that, in both cases, budget constraints resulted in one field officer supervising over 80 dispersed farmer groups. This suggests limited access to training and education for farmers. The findings also show that both projects work with Common Interest Groups (CIGs) primarily composed of women. The group leaders (local elites) who have some training sign contracts and make decisions on behalf of the members but are not held accountable to them. Incomplete contracts and lack of transparency and accountability may also be related to low local technical capacity, as none of the farmers interviewed had a copy of the contract document or the farmer commitment form. This statement by a group leader who is also a community facilitator (Case 2), when asked why farmers do not have a copy of the project contract, reflects this finding:

"We don't know that we can ask for a copy of the contract document and if some people know, we don't have the boldness to ask ViA".

Table 4 Major Governance challenges of SACPs and mitigation strategies

Challenges	%	Underlying reasons	Mitigation strategies
SLM Component			

Adoption of SALM and dairy practices	**51**	– gender roles and local norms – nonparticipation in project design – unavailability of some input, such as fodder grass seed – small land size and prioritization of food security – delay in supply of inputs (tree seedlings, fodders, etc) – budgetary constraints	– participatory project design where participating farmers are consulted regarding project activities – connect input suppliers with farmers at no cost
Participation and awareness	**45**	– lack of transparency – bad expectation management – limited participatory decision-making – gender roles (women participate but no land ownership and decision-making power)	– participatory project design – more efforts from project managers to create awareness and capacity (trainings, information materials, and presentations)
Technical capacity	**42**	– knowledge gap on carbon credit – local elite – low sensitization – inadequate number of field officers	– local capacity development – information sharing platforms – participatory decision-making mechanism – intensive training on voluntary carbon market
Accountability of major decision makers	**42**	– low local capacity – power imbalances – elite capture – little knowledge on voluntary carbon credits – incomplete contracts	– participatory decision-making mechanism – local capacity development – training on how voluntary carbon market works
Risk on weaker actors	**16**	– power imbalances – nonparticipatory project design	– participatory decision – information sharing platforms – mechanisms for expectation management
Carbon credit component			
Transparency (mainly about carbon credit)	**81**	– power imbalances – top-down design – low local technical capacity – limited knowledge regarding carbon credit	– capacity building on voluntary carbon market – participatory decision making – bottom-up decision process

Extension vs data collection	**72**	– low incentives – costs of extension – monitoring demands – power imbalances – complex certification requirements – non-participatory design	– farmer incentives required – local capacity building – use of simple digital tools by farmers and CFs for data collection and analysis

Note: % = percentage of responses

4.2.2. Carbon credit component

The carbon credit component faced two main challenges. Table 4 shows that 81% of respondents reported a lack of transparency regarding carbon credits as a major governance issue of SACPs. The findings identified several factors related to this challenge, including a top-down approach, power imbalances, and a lack of local capacity in voluntary carbon markets. It appears that participating farmers and field officers have asymmetric information about carbon credit estimation, suggesting a lack of project information sharing among all stakeholders. One field officer (Case 1) explained:

"The debate on whether smallholders should know about carbon credits is still open, ... and I will not tell farmers about it if I am not instructed to do so by management".

The above statement illustrates the role of power differentials between different actors.

Another major challenge, reported by 72% of respondents, is the trade-off between intensive data collection and the provision of extension services to participating farmers. The findings showed that the project implementer, ViA, bears the investment risk. Consequently, there is a need for extensive data collection to estimate carbon credits, generate carbon certificates, and demonstrate project impact. The interviews also revealed that the data collection process is cumbersome, coupled with low levels of farmer education. Additionally, there are disincentives for community facilitators to provide full support, inadequate field officers due to high transaction costs (including high annual validation and verification costs), and complex data requirements for carbon certification. These factors lead to a reduced frequency and quality of training received by farmers.

One staff member of the project proponents stated:

"…you know the major aim of this carbon project is to improve livelihoods of smallholder farmers and this is why our carbon is considered as 5-star, but I am worried because now the attention has been shifted to intense data collection".

To address the issue of intensive data collection, the carbon technical capacity provider (UNIQUE) developed a mobile app for digital data collection. The field officers indicated that the tool can potentially improve data accuracy, but it is time demanding (13 out of 15).

4.3. Role of digital tools in SACPs

This study found that digital tools are only being used in the SLM component of SACPs, suggesting untapped potential in the carbon credit component. Details of the findings are presented in Table 5.

Table 5 Role of digital tools

In use	Untapped
Digital data collection and analysis tools: mobile app by field officer, sms by community facilitators and database for data submission and storage, and GPS for tracking of farms	**Payment/benefit distribution tools:** tools that directly transfer money to farmers without intermediaries
Stakeholder engagement tools: Virtual communication platforms for top-level actors	**Carbon monitoring, reporting and verification:** remote sensing, sensors to measure carbon in the soil, hand-held devices
	Project planning and monitoring tools: connected digital tools that enable project information sharing among all stakeholders

4.4. Benefits and beneficiaries in SACPs

This study shows that the identification of beneficiaries and benefits depends on the eligibility criteria for participation, the source of project funding, the type of benefit (monetary or non-monetary), the performance of the group, and the overall objective of the project. Case 1 beneficiaries include farmer groups that receive non-monetary benefits (capacity training on sustainable practices, seedlings and fodder planting material), dairy cooperatives that receive business management training, and international investors that receive carbon credits to offset their emissions. Beneficiaries in Case 2 include farmer groups, who receive both monetary and non-monetary benefits, and the donor organisations, which also act as buyers of carbon credits. It is unclear from our study what proportion of the funds is allocated to each group of actors. Field officers interviewed indicated that the opportunity costs of land use change and the costs incurred by each actor group were not considered in the implementation and benefit sharing processes (13 out of 19). The carbon benefit is derived from the sale of carbon credits generated by smallholders. In both cases, there is an information gap on the benefit sharing mechanism used, as this was determined solely by top-level actors, without the participation of farmers. These results also show that, on the one hand, the power and influence of actors to negotiate their terms of participation played a significant role in benefit sharing, while, on the other hand, the power and influence of actors to adopt sustainable practices did not play a role in benefit sharing. For example, Figure 2 shows that farmer groups are the most powerful actors (influence level 8) in terms of adopting sustainable practices, but their voice was not taken into account in benefit sharing.

The study also identified trade-offs in benefit-sharing arrangements. For example, group benefit sharing can potentially reduce transaction costs but can result in undeserving group members receiving benefits, leading to free-rider problems. Furthermore, performance-based benefit sharing can encourage continued adoption, but it requires robust strategies to monitor group performance, which increases monitoring costs and affects the benefits farmers receive.

5. Discussion and recommendations

From the conceptual considerations presented in Section 2, it is clear that the current study shows that each component of SACPs faces its own governance challenges. However, the design and implementation, as well as the monitoring and reporting phases, are the most challenging. The main challenges of the SLM and carbon credit components, as well as the untapped potential of digital tools, are discussed in this section.

5.1. Key challenges of the 'SLM Component'

5.1.1. Design and implementation

The findings showed that adoption problems arise at the design and implementation stages, and at the monitoring and reporting stages of SACPs (Fig. 2). In both cases, a top-down design approach was used. The lack of farmer participation in project design suggests that farmers' social, economic, and environmental conditions may not have been considered in selecting appropriate project activities, which may negatively affect adoption and yield, thus raising concerns about sustainability and food insecurity.

In terms of gender, the findings show that the socio-cultural context has not been adequately considered. This is in line with other studies on PES or land-based projects, such as Kariuki et al. (2018), who found that land-based conservation schemes mostly benefit men. More than 70% of the participating farmers are women, and the level of farmer influence suggests that the power to adopt or establish SALM and dairy practices rests with women, who have been found to be more efficient and competent than men in implementing practices (Shames et al., 2016). Indeed, Shames et al. (2012) emphasise the need to strengthen the role of women in SACPs in developing countries. Furthermore, women are often resource-poor and have limited decision-making power to adopt SALM practices due to cultural norms, similar to the finding of Lee (2017). The findings further suggest that men perceive common interest groups (CIGs) as a 'women's thing', but both projects work with these CIGs. However, the decision to adopt a particular SALM practice is mainly determined by men due to their cultural roles in the household. These gender issues suggest that the sustainability of SACPs depends largely on the ability of women to continue to adopt most SALM and dairy practices. Strengthening dairy cooperatives can increase their bargaining power and make them competitive in the milk market, while improving men's participation in SACPs as most accounts are in men's names. To address this inequality, capacity building of farmer groups and participatory project design are crucial. Project developers should consider gender and less labour-intensive practices when developing appropriate practices to increase participation. Given the complex nature of project design, which involves different actors who have not previously worked together toward a common goal, it is necessary to build the decision-making capacity of all actors to reduce power-based inequalities.

5.1.2. Monitoring and reporting

The effectiveness of project developers in providing advisory services for smallholders to adopt sustainable practices is affected by budgetary constraints, such as the high cost of implementing and monitoring SACPs. These findings revealed that participating farmers received fewer visits and training due to insufficient field officers. Similarly, budgetary difficulties limited the extent to which farmers could access extension services in four carbon projects in East Africa (Shames et al., 2013). Given that the implementation of SACPs is capital intensive, especially in the early stages of implementation and monitoring, due to the high transaction costs involved in contract negotiation and establishment (Lee et al., 2016; Shames et al., 2016), it emphasizes the importance of securing multiple sources of funding, particularly in cases where the project design is more participatory. Schemes such as Case 2, where farmers receive direct cash payments from carbon revenue in addition to the provision of extension services, are critical to incentivise continued adoption. The upfront investment of carbon revenue supports farmers in purchasing inputs and adopting services that they would not otherwise be able to access due to financial constraints (von Braun et al., 2023; Lal et al., 2018). However, these payments appear to be essentially insignificant due to the large amount of carbon revenue that goes into carbon monitoring and annual verification and validation. These insignificant payments may reduce farmers' motivation to participate in SACPs. Similarly, Jindal et al. (2012) reported that two-thirds of the total carbon revenue from the N'hambita Community Carbon Project in Mozambique went to payments for local transaction costs, commission agents and international brokers. On the contrary, Lee (2017) and Schilling et al. (2023) attributed insignificant carbon payments to low carbon prices and the need for farmers to focus on co-benefits such as productivity. This study also found that limited financial resources affect adequate data collection and reporting, potentially compromising the accuracy of carbon sequestration and emission reduction claims. For example, farmers have low levels of education, and community facilitators who have some education have little incentive to fully engage in monitoring activities. To reduce the high cost of advisory services and annual verification and validation costs, digital platforms, including e-extension and simple handheld tools for soil organic carbon measurement, can be used by field officers and community facilitators (Daum et al., 2022; Shames et al., 2013). Government involvement, in partnership with private investors, is needed for these upfront investments to support resource-poor farmers to participate in SACPs.

5.2. Key governance challenges of the Carbon credit component

The results (Table 4) show that the lack of transparency, particularly in relation to carbon credits, is a governance challenge that may have affected the effectiveness of SACPs. Power imbalances between stakeholders, low technical capacity of some actors and the overall complexity of SACPs are related to this challenge. In particular, smallholders appear to have little knowledge of how voluntary carbon markets work. This lack of transparency can potentially affect trust and credibility among stakeholders, while the accountability of key decision-makers may not be enforced. For example, disputes over carbon payments arise due to a lack of transparency, insignificant payments, and insufficiently well-structured mechanisms for carbon revenue distribution (Shames et al., 2016). Foster et al. (2013) suggest that carbon project implementing organisations should design appropriate mechanisms for sharing carbon payments among farmers to avoid potential disputes. However, the World Bank (2019) finds no standardised carbon benefit sharing mechanisms among standard setters (certifiers).

Mistrust of stakeholders due to a lack of transparency among farmers can also affect adoption and carbon sequestration and deter potential SACPs participants. This suggests that farmers may not fully participate in adoption and monitoring, which can affect data accuracy and reliability of SACPs activities, thus raising doubts about the legitimacy of carbon credits generated and project performance. Oldfield et al. (2022) emphasised the need for trust among stakeholders to avoid a breakdown in the incentive structure of carbon markets. Furthermore, accountability problems can arise if stakeholders have information gaps about how carbon sequestration and emission reductions are quantified and verified, and how carbon revenues are distributed. Information sharing and transparency would incentivise farmers to improve the adoption of SALM to increase environmental integrity and food production for the millions of people who depend on these producers for food. Daum et al. (2022) argue that sharing experiences and data among smallholders can influence learning and best practices.

Another key challenge is the trade-off between the rigorous data collection required for carbon accounting and the need to provide extension services to participating farmers. Rigorous data collection is needed to verify emission reduction practices, which are essential to participate in the voluntary carbon market and earn carbon credits, while also meeting the livelihood objective of the SACP. However, these findings show that resources are limited, resulting in an imbalance. This suggests that resource allocation may be diverted from addressing farmers' extension needs to rigorous data collection and reporting to demonstrate project impact. Meanwhile, sustainable carbon sequestration is achieved through the continued adoption of sustainable practices, which depends on effective extension services (Schilling et al., 2023; Shames et al., 2013), particularly for smallholders. Furthermore, collecting extensive data can be time-consuming and can delay or reduce the frequency of services provided to farmers. This phenomenon can undermine trust among participating farmers and demotivate farmers who may perceive SACPs as prioritising the carbon credit target over their livelihood benefits. As project developers must bear the investment risk, project managers shift their efforts to intensive data collection for carbon estimation. This interest and power of stronger actors may jeopardise the continued adoption of sustainable practices by reducing the provision of adequate extension services and may threaten the achievement of carbon sequestration. Integrated project design is needed at the onset to ensure that livelihood needs, and carbon sequestration are intertwined. Simple digital tools and the development of efficient methods that can streamline the process, while maintaining data quality, are critical. Building local capacity to empower farmers and community facilitators to collect and analyse data is also essential. In addition, food security can be improved through improved soil fertility and higher crop yields or higher milk yields and incomes. On the other hand, it is reduced by reducing the use of mineral fertilizers and pesticides, which can exacerbate pest infestations. Organic farming is promoted without compensation for lower yields. This suggests the need for future research to investigate these factors.

5.3. Untapped potential of digital tools to address governance challenges

The case studies have shown that SACPs rely on the provision of extension services to help farmers adopt sustainable practices. While integrating digital tools into these advisory services can improve their effectiveness and reach (Daum et al., 2022), their potential to address some of the identified governance challenges is underutilised. These findings (section 4.4) show that the use of digital tools in SACPs is rather limited to some aspects of the SLM component, suggesting a digital gap in the carbon credit component. Simple digital tools, such as Smart Cow, iCow, and iShamba in Kenya (Daum et al., 2022), offer opportunities for SACPs to incorporate them into the extension support system for cost-effectiveness and scalability. However, digital tools that provide system-specific information are essential for the adoption of sustainable practices.

In addition, information sharing platforms can provide a digital solution for all stakeholders to access the same project data, thereby increasing trust and transparency. Smart contracts developed on blockchain can automate project transactions and compensation to farmers, potentially ensuring transparent payment processes and reducing potential disputes. In this case, farmer groups can digitally enter group summary data and automatically access payment information. However, data security and privacy concerns (Fraser, 2019; Wolfert et al., 2017) are crucial to protect sensitive information.

Digital tools are essential to further ensure data accuracy, transparency, and efficiency. Remote sensing and satellite imagery can provide real-time data on crop condition and carbon sequestration, improving monitoring and verification. In addition, mobile apps can facilitate data collection and reporting, but should have user-friendly interfaces for field officers and farmers and minimize technical jargon (Daum et al., 2019) for documenting carbon-related activities. A major challenge in the two case studies is the disincentive for farmers to enter data. Daum et al. (2022) suggest that creating an incentive for livestock farmers is essential for digital data entry. Inaccurate data entry is problematic because it affects the measurement of carbon sequestration and emission reductions, and therefore the project's impact. Project developers need to provide incentives and invest in digital literacy training, particularly for farmers, to encourage accurate data entry. However, farmers' engagement in digital data collection is plausible if access to smartphones and the internet continues to develop at the same rate. Large datasets can also be processed by UNIQUE using data analytics and artificial intelligence (AI) to identify trends and anomalies in carbon data in a timely manner. These tools have the potential to reduce administrative and operational costs associated with collecting and monitoring carbon data. However, this suggests that face-to-face contact with farmers would be reduced and could potentially lead to unemployment, as most fieldwork would be done virtually. Face-to-face contact with smallholders is important for the adoption of sustainable practices, as farmers perceive that field officers who visit their fields have a better understanding of their farming practices (Buadi et al., 2013) and can advise them accordingly. This highlights the need to combine digital tools with traditional extension methods, rather than replacing them. Furthermore, these technological solutions will only benefit farmers if issues of power relations are addressed, and participatory decision-making is considered.

Integrating digital tools into SACPs is crucial, even though they may appear insufficient to address gender norms and power issues. Participatory decision-making processes that involve the community and local stakeholders in project design and implementation can address gender and social norms, improving women's access to land resources and promoting equal benefit sharing between men and women. Project developers can also conduct gender analysis to understand the needs, constraints, and opportunities of potential participants, both men and women, and integrate a gender perspective into project design to enhance not only women's but also men's participation.

5.4. Limitations and further research

Carbon projects and schemes are a complex and sensitive topic due to the range of actors involved and the many governance challenges. Therefore, it was essential to build trust with interviewees, conduct longer interviews, and carry out a more in-depth study. A key limitation of this study is the inability to engage with independent carbon standard-setting organizations, such as Verra and Gold Standard. Further research could test some of the digital tools recommended in this study. The challenges identified in this study may also arise in other complex and PES related programs and projects, including in the revised Verra methodologies. Therefore, the strategies used to address the identified governance challenges can guide current and future project managers, project developers, and policymakers in designing appropriate strategies for the implementation of not only SACPs but also other related complex projects involving smallholder farmers, especially in developing countries.

6. Concluding remarks

This paper systematically assesses the governance challenges of SACPs and the potential role of digital tools in addressing some of these issues. Overall, the findings show that the governance challenges of SACPs are linked to the two components (SLM and carbon credit) of agricultural carbon projects and the different stages of project establishment. The findings suggest the need for participatory decision-making in project design and implementation, and for more attention to cultural norms, particularly gender norms. Women are important actors in carbon sequestration and emission reduction in SACPs but have limited decision-making power due to cultural norms. Two-way communication and the integration of digital tools can address data requirements, advisory needs, information asymmetry, and accountability issues in SACPs. This could be achieved by providing feedback on the carbon sequestration and emission reduction performance of groups and involving them more in monitoring. While digital tools are already used for data collection in SACPs, other relevant tools remain unexplored.

7. Appendix

Table 6 Major steps in SACPs implementation

Steps	Description	
	Case 1 (Livelihoods Mt. Elgon)	**Case 2 (Kenya Agricultural Carbon Project)**
1. Release of funds	**Livelihoods fund(investor):** released funds to Unique Forestry (Carbon technical capacity provider) and Vi Agroforestry (project implementors) in addition to a grant from a co-investor (Brookside dairy limited), in accordance with EU and national governments guidelines.	**World Bank (donor):** released fund to Vi Agroforestry (ViA) (the project developer/ implementor) and Unique Forestry (Carbon technical capacity provider).
2. Design and Implementation	**ViA and field technicians:** organized stakeholder engagement, recruited, formed, and registered farmer groups and clusters, conducted baseline survey, trained farmer groups on SALM, dairy management, procured and distributed fodder materials (starter seeds) to farmer groups, and conducted baseline survey, **Farmers groups:** signed farmer commitment forms and elected community facilitators (CFs).	**ViA and field technicians:** mapped actors and project areas, stakeholder engagement to develop working modalities, community entry, and conducted baseline survey. Recruited farmer groups, tracked farms, trained farmers, and rolled out activities with farmers. Procured tree seedlings and distributed to farmers, and formed clusters **Framer groups:** signed farmer commitment forms and rolled out activities, elected CF
3. Monitoring and reporting	**ViA:** contracted implementing partners (CBO) to supervise field technicians, submits monitoring report to UNIQUE, **CFs and Field technicians:** internal verification and submission of group summary data to the database via sms **Farmer groups:** collected self-assessment data on SALM practices, farm output, including	**Farmer groups:** filled annual self-assessment data on number of trees, farm output, SALM practices, **CFs:** submitted self-assessed data (group summary) to a database **ViA and CBOs:** internal verification of data and submission of monitoring report to Unique

	daily milk yield, and number of trees **Carbon technical capacity providers:** developed database, calculates sequestered/ reduced carbon	**UNIQUE:** developed database and calculates sequestered carbon
4. Validation and verification (auditing)	**Project developer:** contracts TÜV NORD (verifier) to conduct validation and verification. **UNIQUE:** submits monitoring report to the verifier **TÜV NORD:** organizes stakeholder engagement and visited sampled farmers and farms for auditing. Provides validation report and certificate to project developer	**Project implementer:** contracted TÜV NORD (verifier) to conduct validation and verification **UNIQUE:** submits monitoring report to the verifier **TÜV NORD:** organizes stakeholder engagement and visited sampled farmers and farms for auditing. Provides validation report and certificate to ViA
5. Registering with standard setters	**Project proponent/developer (Livelihoods):** registered the project at the registry of standard setters (Verra and Gold Standard), provided project documents including validation and verification reports and certificate obtained from verifier	**Project developer/implementer (ViA):** Registered the project at verra registry, provided project documents including validation and verification reports and certificate obtained from Verra
6. Issuance of carbon certificate	**Certifier (Verra and Gold Standard):** issues carbon certificate (carbon credit) to project proponent after successful assessment of project documents	**Standard setters (Verra):** issues carbon certificate (carbon credit) to ViA after successful assessment of project documents
7. Carbon credit marketing	**Project proponent:** distributes carbon credit proportionately to the investors for the project period and ViA will identify buyers, negotiate price, and sells carbon credit afterwards	**ViA: sell first credit to the donor and later i**dentifies credit buyers, negotiates price, and sells carbon credit and distributes carbon revenue to farmer groups based on performance

Note: Steps 3-7 are repeated every 2-5 years of project life

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