Assessment of adoption and impact of management innovations in agriculture carbon project in East Africa

Working Paper No. 334

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

This working paper presents results of an impact assessment of management innovations that were introduced in agricultural carbon projects in East Africa. We evaluated the effect of project design, management, and monitoring transfer of responsibilities to local communities on the performance of agricultural carbon projects. The assessment included the economic, social, and environmental impacts of the projects on the smallholder farmers. The agriculture carbon projects implemented by Vi Agroforestry and Environmental Conservation Trust (ECOTRUST) have received a total of 1,951,437 tCO_2e greenhouse gas (GHG) emissions reduction credits from 2010 to 2019. In Vi Agroforestry, 29,500 farm households in 1,725 farmers groups benefited from the implementation of the projects. They received a total of 624,960 tCO_2e GHG reduction credits in the last 10 years. Similarly, around 9,000 smallholder farmers participated in the agricultural carbon project managed by ECOTRUST and they received 1,326,447 tCO2e worth of verified emissions reduction certificates from 2010 to 2019. The majority of the farmers (~70%) in the agricultural carbon projects were women. This assessment showed that the institutional approach of transferring management authority to local communities, including capacity building activities and social inclusion, can generate multiple benefits (economic, social, and environmental) for the smallholder farmers. Local institutions (i.e., farmer groups) and intermediaries (i.e., non-governmental organizations) played a leading role in the use of management innovations (i.e., training manuals) for effective design, management, and monitoring of the agricultural carbon projects in Kenya and Uganda.

Keywords

Adoption, mitigation options, carbon credit, impact assessment, smallholders, gender

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Contents

Acronyms

AFOLU	Agriculture, forestry, and other land use
AFP	Agroforestry practices
AP	Agronomic practices
CBIs	Community-based intermediaries
CBOs	Community-based organizations
CCAFS	Climate Change, Agriculture, and Food Security
FGM	Farmer group monitoring
ECOTRUST	Environmental Conservation Trust
GEF	Global Environmental Facility
GHG	Greenhouse gas
ILM	Improved livestock management
KACP	Kenya Agriculture Carbon Project
KII	Key informant interviews
NGO	Non-governmental organization
SALM	Sustainable agriculture land management
SHGs	Self-help groups
SNM	Soil nutrient management
SWM	Soil and water management
TGB	Trees for Global Benefits
ToT	Training of trainers
TRM	Tillage and residue management
UNDP	United Nations Development Program
VCS	Verified carbon standard

Introduction

Background on agriculture carbon project

There is a growing interest at the national, regional, and global levels in developing agricultural carbon projects that help reduce greenhouse gas (GHG) emissions from crop and pasture lands and support agricultural growth and development. Agriculture is a relatively young sector in the carbon market, and new approaches are gradually evolving to link smallholder farmers with this new market. With encouraging innovations in voluntary carbon market standards, many carbon credit project developers are experimenting with agriculture projects that promote land-based carbon sequestration. East Africa is one of the regions where international organizations such as the World Bank Group, Global Environmental Facility (GEF), United Nations Development Program (UNDP), the European Union (EU), and others are investing in piloting agricultural carbon projects with smallholder farmers (World Bank 2020; GEF 2020).

The Kenya Agriculture Carbon Project (KACP), supported by the World Bank's Bio-Carbon Fund and its participants—the French Development Agency and the Syngenta Foundation for Sustainable Agriculture—promotes the adoption of sustainable agricultural land management (SALM) practices in crop and grasslands. SALM methodology to quantify and credit the GHG benefits of agricultural land management was approved by verified carbon standard (VCS). The methodology describes how carbon sequestration in soils is measured and engages farmers in the monitoring process (VCS 2011). Since 2009, Vi Agroforestry—a Swedish Development Organization—has been implementing agricultural carbon projects in Kenya. The SALM practices implemented in the agricultural carbon projects include minimum tillage, composting, mulching, residue management, agroforestry, integrated livestock management, applying crop residues on fields, and soil and water conservation, among others (Hughes et al. 2020).

The Environmental Conservation Trust (ECOTRUST) of Uganda—a non-profit environmental conservation organization—manages the carbon projects through its Trees for Global Benefits (TGB) program in Uganda. The TGB is a cooperative community carbon offset initiative that links small scale landowners to the voluntary carbon market. The ECOTRUST assists smallholder farmers to generate carbon credits from on-farm tree planting (agroforestry) and the carbon credits are certified under the Plan Vivo Standard (Shames et al. 2012).

The agriculture carbon projects in Kenya and Uganda have successfully established institutional relationships with the farmers through small farmers' groups and clusters, which enable broad participation, efficient contracting, timely communication, provision of extension services, benefit-sharing, and gender-focused activities (Shames et al. 2012). Projects like these are required to empower local institutions to take on additional project management responsibilities and address challenges of financing from the beginning of the project to carbon offsetting. Table 1 summarizes the key features of the agriculture carbon project in Kenya.

Location	Bungoma, Kisumu and Siaya Counties, Kenya
Project developer	Vi Agroforestry
Other actors	Bio-Carbon Fund of the World Bank, UNIQUE forestry and land use
Objectives	Increase farmers' resilience to climate change Increase food security through increased farm productivity and diversified food sources Increase farm income through farming as a business Reduce greenhouse gas emission Sell carbon credits for the benefit of small-holder farmers
Project activities	Sustainable Agricultural Land Management (SALM) Farm Enterprise Development Village Saving and Loaning
Target group	Small-holder farmer families with an average farm size of < 1 ha
Crediting period	20 years (2009-2030)
Target total emission reduction	1,980,088 t CO_2e (2030)
Outreach model	Farmers organised in groups connected to farmers' organisations
Carbon offset standard	Verified Carbon Standard (VCS)
Monitoring, reporting & verification	The VCS methodology has robust and rigorous measurement system with Farmer-Based Activity Monitoring, validation and verification processes
Benefits distribution & co-benefits	**Direct benefit** from carbon revenues which are shared between farmers (60 %) and to cover costs for the administrative work and advisory services (40%)
	Indirect benefits include higher agricultural productivity, larger monthly savings and more months of food self-sufficiency in a year
	Other benefits include soil conservation, strengthening institutional capacity and gender equality

Table 1. Key features of the agriculture carbon project in Kenya

Source: Vi Agroforestry

Purpose and objectives of the study

The CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS) joined with EcoAgriculture Partners in 2010 to assess the institutional arrangement and management of six agricultural carbon projects in Sub-Saharan Africa. This initiative evaluated projects based on (i) their capacity to sequester and reduce GHG emissions and then verify this process; (ii) effective and efficient management capabilities that can be sustained over time; and adaptability to local and global changes in carbon finance policy and practice; and (iii) capacity to generate adequate financial flows while ensuring sustainable benefits to the farmers. This process drew cross-project lessons that were applied in designing and managing agricultural carbon projects across East Africa. Synthesis of case studies showed that agricultural carbon projects' design and management attributes might significantly influence local communities, households, and farmer behavior (Shames et al. 2012). These case studies include experience gained by the ECOTRUST, ENR Africa Associates, and EcoAgriculture Partners.

CCAFS supported developing trainer manuals for smallholder agricultural carbon projects in Eastern Africa based on lessons learned from the case studies and consultations with key stakeholders in the project countries. The first manual was developed to help build capacities of farmers, farmer groups, extension staff, and project managers who are implementing agricultural carbon projects in Eastern Africa (Masiga et al. 2014). This manual describes steps for implementing the voluntary carbon project based on the Plan Vivo Standard (Plan Vivo 2013). The Plan Vivo Standard certifies the implementation of project activities that enhance ecosystem services and allow communities to formally recognize and quantify carbon sequestration, biodiversity, or watershed protection.

The second trainers' manual was developed to use in the smallholder agricultural carbon project in Western Kenya managed by Vi Agroforestry. This manual provides a training guide for smallholder farmers to implement SALM practices for climate change mitigation and adaptation in agriculture and allied sectors (Recha et al. 2014). Both manuals build on the experience gained from participatory action research focusing on the institutional arrangements of smallholder agricultural carbon projects in Sub-Saharan Africa.

This working paper presents the adoption and impacts of management innovations in the trainers' manuals for developing and scaling-out agricultural carbon projects in Kenya and Uganda. This assessment focuses on the specific type of results defined as changes in behavior and actions of individuals, groups, and organizations with whom the program works directly. The assessment focussed on three objectives: i) assess the use of training manuals for designing and implementing agricultural carbon projects; ii) identify changes in knowledge, attitude, skills, and practices with the use of training manuals; and iii) assess social, economic, and environmental benefits of agricultural carbon credit projects.

Implementation of management innovation

Two trainers' manuals, i) smallholder agriculture carbon project in Eastern Africa-trainers manual (Masiga et al. 2014), and ii) SALM practices for climate change mitigation- a training guide for smallholder farmers (Recha et al. 2014) were used by the Vi Agroforestry and ECOTRUST for (i) building the capacities of community-based intermediaries (CBIs)—individuals who mediate between community organizations and carbon projects—to train on sustainable agricultural land management practices, recruit farmers, and mobilize resources; (ii) building local partnerships to support carbon project management by engaging with local government and partnering with non-governmental actors; (iii) supporting a more active role played by women in the project and increasing benefits to them. Staff from the Vi Agroforestry and ECOTRUST engaged with local government officials, non-government organizations (NGOs), and CBIs to train and recruit farmers in the agriculture carbon projects.

The manuals were piloted in the Mt. Elgon Region of Eastern Uganda to receive inputs from farmers and extension staff and subsequently applied by Vi Agroforestry in SALM training in Bungoma and Kisumu counties in Kenya. The Vi Agroforestry's targeted total emissions reduction from the agriculture carbon project is 1,980,088 t CO_{2e} in a 20 year period (see Table 1) (https://registry.verra.org/app/projectDetail/VCS/1225). The ECOTRUST used the trainer manuals to pilot the TGB project in Budongo Bugoma (Hoima-Masindi), Mt Rwenzori (Kasese), and Bushenyi landscapes within the Albertine Rift in Uganda (https://ecotrust.or.ug/trees-for-global-benefit/). The estimated potential of GHG emissions reduction in the project area is 170,000 t CO_{2e} per year.

Methodology

Assessment of impact pathway

For this assessment, the outcomes and impacts were observed as changes in the next users. The next users include national and sub-national research and education institutions, private sector, extension services, governments, and NGOs (Jost et al. 2014). In impact mapping, such partners are individuals, groups, organizations, or institutions who have the mandate or capacity to deliver impact on the ground. This assessment validated the outcome and impact statement “smallholders have begun to take advantage of a growing pool of investment in climate change mitigation with the expanded role of local actors within the agriculture carbon project”. Evidence validating the outcome and impact statement:

a) The community-based intermediaries can play a leading role in land management trainings; local government involvement is critical to project success; local NGOs and businesses can play a central role in training and providing market incentives to farmers to implement sustainable practices; women’s roles in projects can grow if project benefits are aligned with their needs and trainings are made more accessible (Shames et al. 2016).

b) The agriculture carbon project has proven that effective implementation of SALM practices contributes to the reduction of GHG emissions, increases smallholder farmers' agricultural productivity, and strengthens communities’ capacity to adapt to climate change and earn carbon credit (ECOTRUST 2018; Vi Agroforestry 2017).

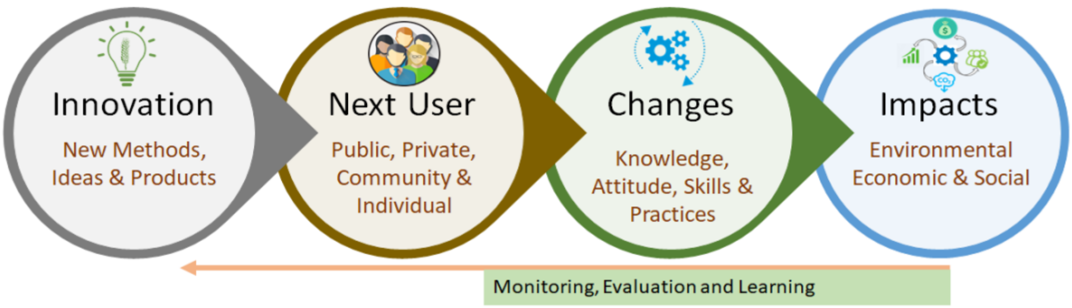

Figure 1. Steps of the impact assessment

Steps of the impact assessment for this study (fig. 1)

1. **Innovation (product):** Trainer manuals were developed to build the capacity of farmers, farmer group leaders, extension staff, and project managers who are involved in designing and implementing agricultural carbon projects.

2. **Use of innovation by the next users:** Vi Agroforestry and ECOTRUST engaged with local government officials, NGOs, and CBIs to recruit and train farmers for the agriculture carbon projects. This assessment identifies key reasons for using the training manuals by the next users in agriculture carbon projects.

3. **Changes in knowledge, attitude, skills, and practices:** This step focused on observable and verifiable changes that can be seen in the individual, group, community, organization, or institution.

    a. *Organizational/Institutional Level:* use of the manual for training, designing, and implementing agriculture carbon projects.

    b. *Community and Group Level:* participatory implementing and monitoring of the projects.

    c. *Individual Farmers:* implementation of practices (both old and new) with new knowledge, attitude, and skill.

4. **Social, economic, and environmental benefits:** This assessment identified project benefits that have directly and indirectly contributed to the social, economic, and environmental aspects. Types of benefits:

    a. *Social benefits*: inclusion of smallholders and women in the agriculture carbon projects, and institutions' buildings.

    b. *Economic benefits*: farm productivity and income from production and carbon credits.

    c. *Environmental benefits*: GHG emissions reduction.

Data collection and sources

This assessment used various sources of data that included secondary information provided by Vi agroforestry and ECOTRUST and available in the Plan Vivo's carbon credit registry, institutional interviews with key informants, and household surveys using different data collection approaches.

Collection of secondary information

Secondary information was gathered from reports, working papers, and other forms of publications available from CCAFS, Vi Agroforestry, and ECOTRUST. The secondary information details key knowledge and skills that the manuals can provide to the users, such as resources required to implement carbon projects, participatory carbon monitoring, and benefit-sharing models. In addition, relevant publications, grey literature, and project reports were reviewed to understand the challenges, opportunities, and lessons learned from the implementation of agricultural carbon projects in Eastern Africa.

Vi Agroforestry provided information on farmers' groups including the number of farmers in the groups, total credit generation, and group payment for the carbon credit. Altogether, 1,725 farmer groups with 29,497 farmers are actively involved in the agriculture carbon projects in Kenya. Information on the TGB project (locations, number of farmers, area, GHG emissions reduction) were collected from the ECOTRUST website. Plan Vivo's carbon credit registry provides the amount of carbon credit verified in the agricultural carbon projects.

Institutional survey

Key informant interviews (KII) included people involved in the training, designing, and implementing agricultural carbon projects and climate-smart village programs in East Africa. The KII collected information on key reasons for using the training manuals, type of participants in the trainings, factors affecting the implementation of the SALM practices, adoption barriers, incentives to adopt SALM practices, and the role of institutions to implement agriculture carbon projects. The interviews were conducted with the national and country or sub-national level institutions (i.e., government, NGOs, CBOs, and other relevant partners).

Individual farmers survey

Farm household surveys were conducted to assess the adoption of SALM practices and their impacts at the farm level. These surveys collected information from 407 farmers in Bungoma County (Kenya), where Vi Agroforestry has been implementing agricultural carbon projects since 2010. The surveys provided supplementary information to secondary data and reports to assess the impact pathway of the agricultural carbon projects in East Africa. Farmers' survey questionnaires were administered through mobile data collection software KoBoCollect for speed, accuracy, and ease of data monitoring. Farmers were randomly selected from the farmer groups, whose membership ranged from 15 to 30 farmers.

Data analysis

This study analyzed three sets of information: data and reports on agricultural carbon projects available from Vi Agroforestry, ECOTRUST, and Plan Vivo's carbon credit registry; an institutional survey with key informants; and data gathered from the farmer surveys. Information on verified carbon credit was received from Vi Agroforestry, ECOTRUST, and Plan Vivo's carbon credit registry. Verified carbon credits were compared with estimated carbon reduction from the agricultural carbon projects over time.

Qualitative and frequency analyses were conducted for information collected from the key informants' survey. These analyses include key reasons for using training manuals, type of participants in the trainings, farmers' priorities to implement the SALM practices, key factors affecting the implementation of the SALM practices, barriers to adoptions, and key incentives to motivate farmers to implement the SALM practices. This analysis also includes an institutional plan to scale out SALM practices and carbon credit projects.

This assessment applied an ordered multivariate probit model to assess the factors affecting the adoption of different levels of SALM practices in the crop and grasslands. All SALM practices were categorized into six groups: i) soil nutrient management (SNM), ii) tillage and residue management (TRM), iii) agronomic practices (AP), iv) agroforestry practices (AFP), v) soil and water management (SWM), and vi) improved livestock management (ILM). These six SALM categories cover 37 different practices (see Appendix A).

Adoption intensity is often assessed based on relative area, but the exact area under each SALM practice was difficult to assess. Following Teklewold et al. (2013) and Kassie et al. (2013), we measured the adoption intensity by the number of SALM practices adopted in an individual farm as the dependent variable. The adoption intensity was different for each SALM category based on the number of SALM practices. For instance, in the SNM category, the level of adoption of SALM practices ranges from 0 to 5. In the AFP, the level of adoption of SALM practices ranges from 0 to 15. In this case, the dependent variable takes integer values ranging from 0 to higher levelS and, thus, an ordered probit model was used. The ordered probit model is represented as:

$$y^* = x'\beta + \varepsilon \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 1$$

Where y^* is unobserved and is given by:

$$\begin{aligned} y &= 0 \; if \; y^* \leq 0 \\ &= 1 \; if \; y^* \leq \alpha_1 \\ &= 2 \; if \; y^* \leq \alpha_2 \\ &\;.\quad.\quad. \\ &= J \; if \; \alpha_{J-1} \leq y^* \end{aligned}$$

Where values of y are observed and α are unknown parameters to be estimated. We assume that ε follows a normal distribution with zero mean and unit variance. In the ordered probit, the probabilities of each outcome can be expressed as:

$$\begin{aligned} &Pr(y = 0|x) = \phi\,(-x'\beta) \\ &Pr(y = 1|x) = \phi\,(\alpha_1 - x'\beta) - \phi\,(-x'\beta) \\ &Pr(y = 2|x) = \phi\,(\alpha_2 - x'\beta) - \phi\,(\alpha_1 - x'\beta) \\ &.\quad.\quad. \\ &Pr(y = J|x) = 1 - \phi\,(\alpha_{J-1} - x'\beta). \end{aligned}$$

Results

Use of innovation

The training manuals were used by various community facilitators – CBIs, NGOs, and government officials. Vi Agroforestry, which is the primary user of the innovation, initially trained seven private organizations and 29 farmers (participants being 10 women and 26 men) as community facilitators of SALM training; six private organizations and 30 farmers (10 women and 26 men) as community facilitators of climate change training; four private organizations and 27 farmers (10 women and 21 men) as community facilitators of resource mobilization training; 10 CBIs and 10 private organizations (6 women and 14 men) as facilitators of SALM training; and 14 government officials and 9 private organizations (6 women and 17 men) for influencing SALM policies.

Table 2. Key reasons for using the training manual and participants

Use of Innovation	Percent of Response
Key reasons for using the training manual	
A comprehensive and systematic training manual to guide field staff and other key stakeholders	5%
Manual includes new models and approach of project design and implementation	50%
Manual focus on the participatory approach and it is easy to communicate to the stakeholders	90%
Participants in the trainings	
Government extension staffs	15%
Staff from community-based organizations (CBOs)	5%
Staff from non-government organizations (NGOs)	5%
Farmers	100%
Representatives from the farmers' group	30%

This study surveyed 20 key informants in the farmers' community-based organizations (CBOs), self-help groups (SHGs), youth groups, government agriculture officials, and staff in the Vi Agroforestry. Respondents were asked about key reasons for using the training manuals and participation in the training events. Most of the key informants (90%) mentioned that manuals focus on participatory approaches and they are easy to communicate to the stakeholders (Table 2). About 50% of key informants revealed that the manuals include new models and approaches for agriculture carbon project design, implementation, and monitoring.

The agricultural carbon project implements a farmer group monitoring system (Appendix B), where farmers are responsible for monitoring on-farm implementation and SALM practices performance. Thus, capacity building training mainly includes farmers and their group representatives. The proportion of participants from the government, community-based organizations, and NGOs was relatively low. The participants from these organizations are mainly responsible for guiding farmers and their group leaders to implement agricultural carbon projects. Vi agroforestry has conducted 401 trainings to design and implement agricultural carbon projects using the training manuals in Kenya.

Trainers also used the manuals as part of the TGB project in Uganda. ECOTRUST managed this project to build capacity among the ECOTRUST staff and other professionals to train farmers, extension staff, and project developers on how to implement an afforestation/reforestation voluntary carbon project. The TGB combines community-led activities recommended in the training manuals to increase carbon sequestration with performance-based payments to the farmers (https://ecotrust.or.ug/trees-for-global-benefit/).

Adoption of SALM practices

SALM includes practices that sequester carbon in above and below-ground biomass by increasing soil organic matter (e.g., minimum tillage, leaving crop residues on fields, livestock enclosures, and manure and compost application on fields), woody perennials (e.g., tree intercropping and planting of woodlots), and nitrogen-fixing plants. The SALM practices also help to reduce GHG emissions by limiting biomass burning and NO2 emissions from inorganic fertilizers. In addition to these practices, farmers are also implementing water harvesting structures, crop rotations, integrated pest and disease management, and the use of improved seeds and livestock breeds.

The agricultural carbon project has reached 29,497 farmers through 1,730 farmer groups and covers approximately 21,966 ha of crop and grasslands in Western Kenya (Vi agroforestry). Further, 211 new groups (114 men groups and 87 women groups) had been recruited, and 61 new training sites were created to provide training to the new groups. Farmers who were enrolled in the carbon credit project are mostly using traditional practices either in cropland or grassland that have depleted soils and low crop yields. The key informant surveys in Kenya indicated that the number of farmers enrolled in the carbon credit project has increased from 15 to 75% and the area under SALM practices has also increased from 10 to 85% in the last 10 years (Fig 2). Currently, the Vi Agroforestry is working with over 100,000 smallholder farmers and around 50 farmers' organizations across Kenya, Rwanda, Tanzania, and Uganda. The training manuals are also used across all of Vi Agroforestry's projects to promote SALM practices.

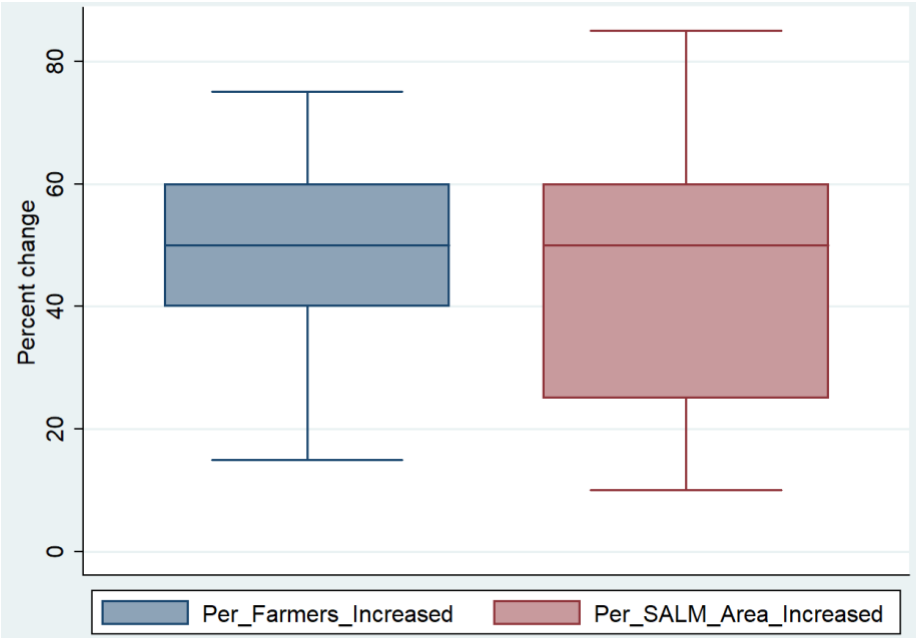

Figure 2. Percent change in number of farmers and area under SALM practices in the agriculture carbon project locations (2010-2019).

Currently, about 9,000 farmers are participating in generating the carbon credits from implementing SALM practices in the TGB project in Uganda (Plan Vivo). Afforestation and reforestation, agroforestry, assisted natural regeneration, and improved land management are farmers' key interventions implemented to generate the carbon credits in the TGB project.

Results from a random survey of farmers in the agriculture carbon project areas in Kenya show that farmers are adopting a combination of SALM practices in their crop and grasslands (Fig 3). Many farmers are implementing crop rotation, composting, trees on boundaries and homesteads, and minimum tillage practices in their farmlands. A significant number of farmers are also implementing alley cropping, mulching, residue incorporation, and cover crops. Use of zero tillage, green manuring, trees in rangeland and grazing lands, improved fallow and shifting cultivation practices are implemented by the farmers in the project areas.

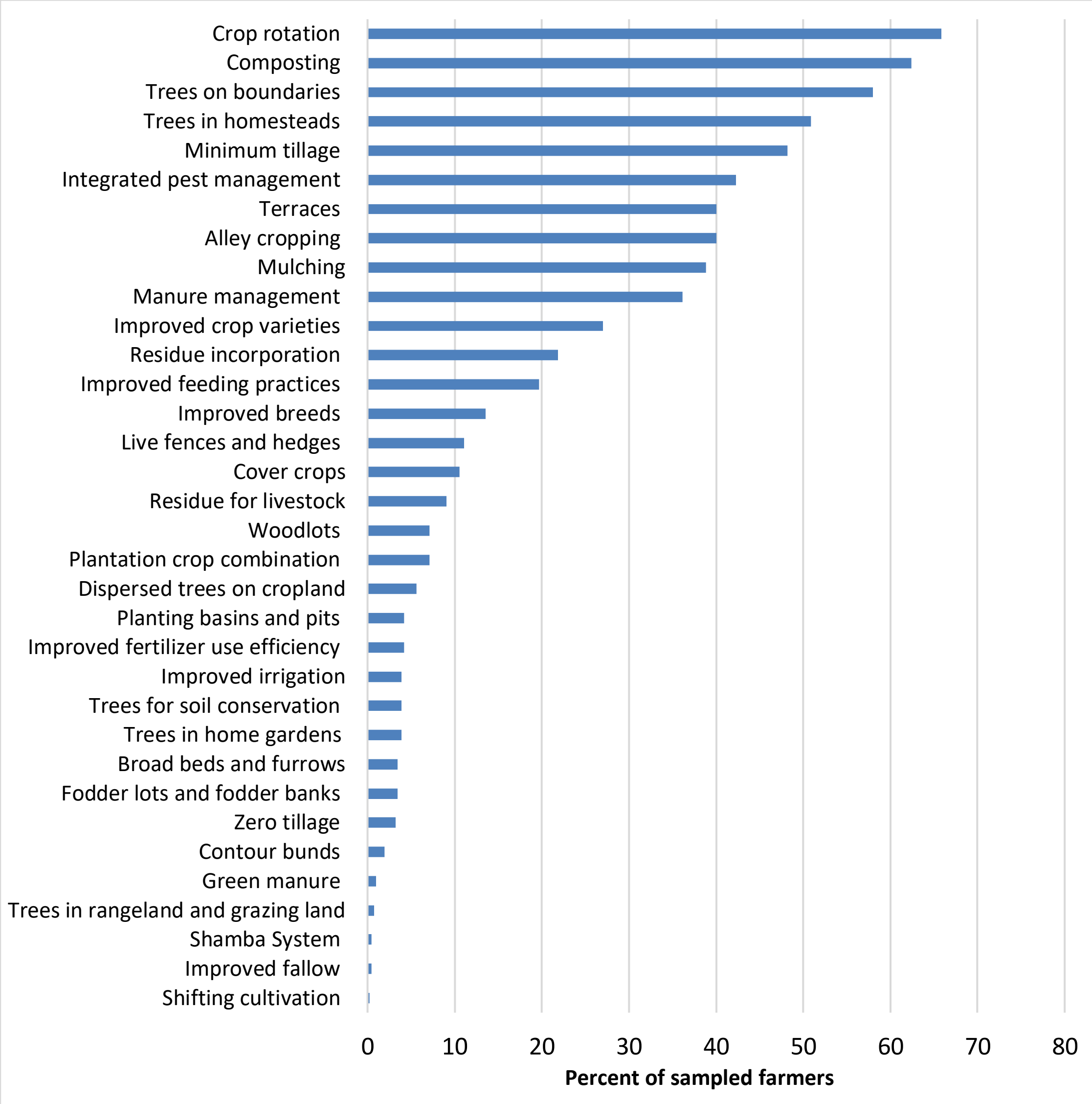

Figure 3. Percent of farmers adopting SALM practices in the project areas

The quantification of GHG emissions reduction and removals considers adoption of single or combination of SALM practices in the crop or grasslands and changes from the baseline activities. The adoption of SALM practices is measured through repeated surveys during the life of the project. Many of the farmers in the project areas are implementing a combination of 4-6 SALM practices (Fig 4). Only 5% of farmers are implementing a combination of more than 10 SALM practices.

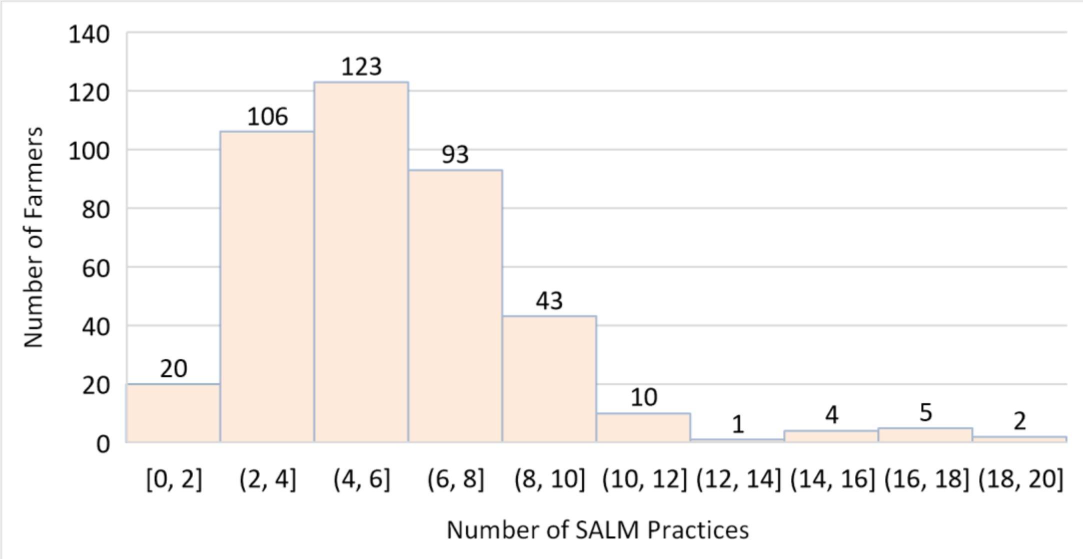

Figure 4. Number of farmers adopting a combination of SALM practices

The area under SALM practices is highly influenced by three indicators: farm productivity, tree biomass, and carbon credit. A regression analysis using secondary data from 1,725 farmers groups showed that the increase in farm productivity can significantly decrease the area under SALM practices (Table 3). This indicates that farmers allocate degraded and low productive lands to implement SALM practices. On the other hand, an increase in tree biomass and carbon credits significantly increase the area under SALM practices. Thus, the carbon credits for SALM practices can motivate farmers to allocate more degraded and marginal lands to implement the SALM practices.

Table 3. Factors affecting area under SALM practices

Dependent Variable = Area under SALM practices						
Independent variable	**Coefficient**	**Standard Error**	**t-value**	**P> |t|**	**95% Confidence Interval**	
Productivity	-0.127	0.053	-2.39	0.017	-0.231	-0.022
Tree_Biomass	1.660	0.325	5.10	0.000	1.022	2.029
Carbon_Credit	0.016	0.001	12.54	0.000	0.014	0.019
Constant	2.200	0.089	24.45	0.000	2.023	2.376
Number of observations = 1725						
F (3, 1721) =83.57						
Prob > F = 0.000						
R-squared = 0.127						
Adj R-squared =0.125						

Farmers in the agriculture carbon credit project were asked whether they are willing to continue or discontinue SALM practices in their crop and grasslands. More than 80% of farmers who implement improved feeding practices, improved breeds, residue incorporation, integrated pest management, terraces, and trees for soil conservation are willing to continue these practices (Fig. 5). A large proportion of sampled farmers (70-80%) are ready to continue composting, minimum tillage, residue and manure management, and some other SALM practices. None of the respondents are keen to continue some SALM practices such as trees in range and grasslands, shifting cultivation, shamba system, and buffer zone agroforestry. One of the reasons to discontinue these practices could be low productivity and income with their implementation in the farmlands. Surveys also showed that these practices have low impacts on on-farm productivity and income changes.

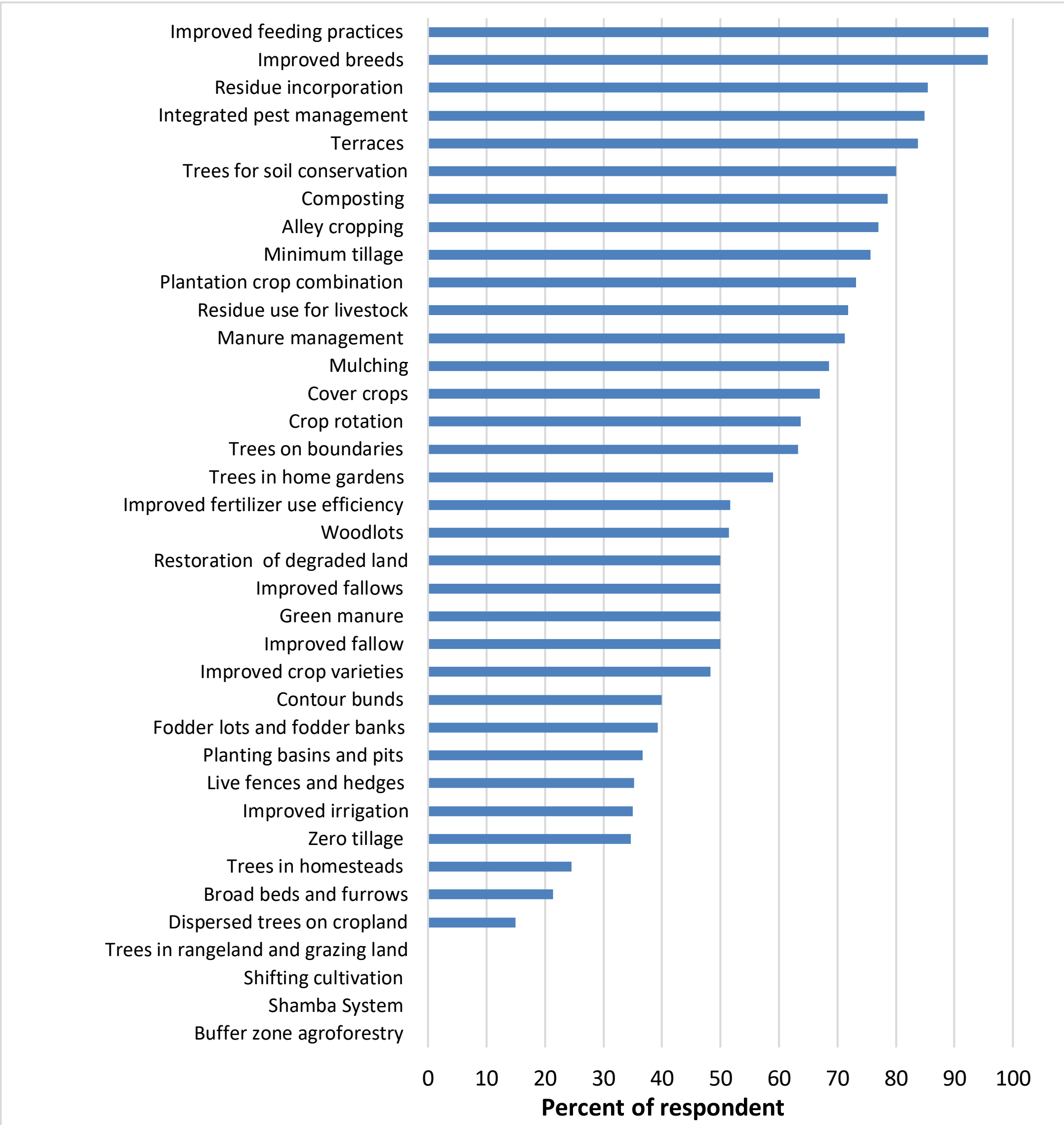

Figure 5. Percent of respondent willing to continue the implementation of SALM practices

Impact of agriculture carbon project

Carbon credit generation

The KACP started in 2009 with estimated GHG emissions for 20 years crediting period. The average estimated annual net GHG emissions reductions or removals was 99,004 tCO_2e, translating to an estimated gross total GHG benefit of 1,980,088 tCO_2e over the project life (20 years). This project also estimated a reversal risk rating of 8.25% and cumulative risk buffer contribution of 163,357 tCO_2e (based on VCS Validation Protocol). The estimated carbon credit from the project was 1,816,731 tCO_2e over the project's lifetime with annual contributions to the cumulative risk buffer of 8,168 tCO_2e.

Figure 6 presents the estimated and verified GHG emissions reduction from the agricultural carbon project in Kenya. The project has received a total of 624,960 tCO_2e GHG reduction credits in the last 10 years (2010-2019). The average verified GHG emissions reduction was 62,496 tCO_2e per year. The amount of GHG reduction is expected to increase with the recruitment of more farmers in the agriculture carbon projects and increase the area under SALM practices.

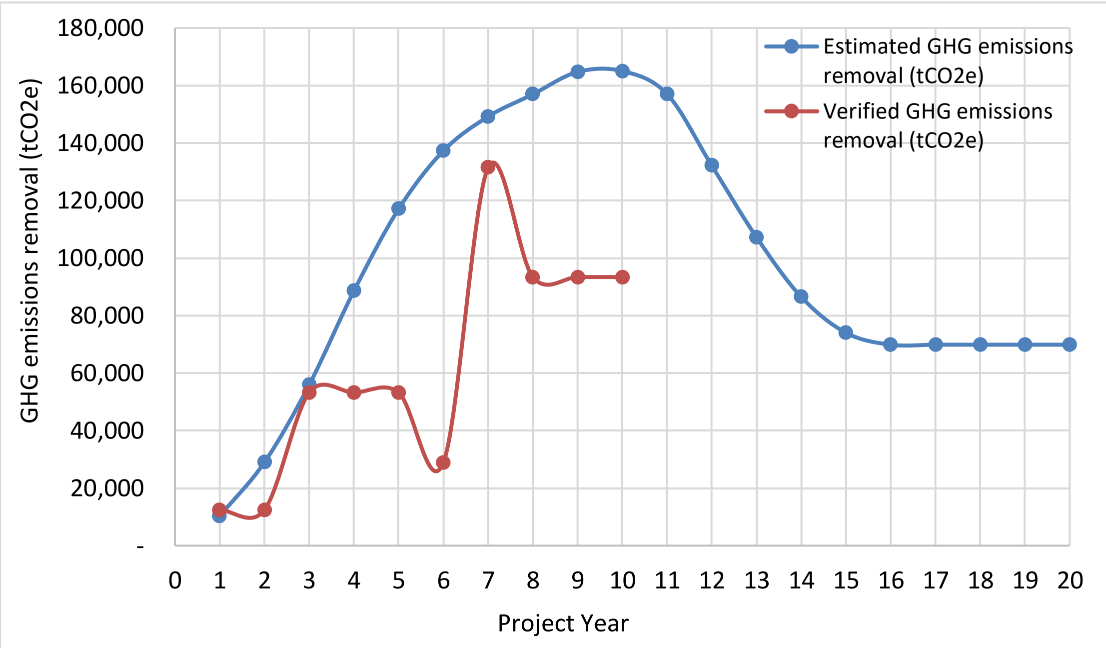

Figure 6. Estimated and verified GHG emissions reductions from the agricultural carbon credit project in Kenya

The estimated GHG reduction from the TGB piloted by ECOTRUST in Uganda was 170,000 t CO_2e per year. Around 9,000 smallholder farmers have participated to date and received 1,326,447 tCO2e worth of verified emissions reduction certificates from 2010 to 2019. The emissions reduction certificates were issued by the Plan Vivo Foundation through Environmental Market Registry (ECOTRUST 2019). The number of carbon credit certificates has been significantly increased from 2010 to 2019 (Table 4). The average price per tCO_2 ranges between US$5 and US$6 over the last 10 years. The number of community groups involving in the project was 85 as of December 2019.

Table 4. Total number of carbon credit certificates sold in 2010-2019

Year	tCO_2e	Average price/tCO_2e (US$)	Total Price (US$)
2010	80,896	6.07	491,302
2011	82,298	5.63	463,149
2012	148,411	5.11	758,637
2013	34,598	5.96	206,170
2014	179,872	5.93	1,066,073
2015	257,842	5.91	1,523,937
2016	29,451	5.82	171,340
2017	119,897	5.94	694,467
2018	166,848	5.92	988,056
2019	226,334	5.92	1,339,897
Total	1,326,447	5.82	7,703,030

Source: ECOTRUST 2019 (Trees for Global Benefits: 2019 Plan Vivo Annual Report)

Economic return

The KACP promotes SALM practices to improve soil fertility, enhance crop and livestock yields, and increase farm income. The income received from the sale of carbon credit does not directly go to the individual farmers. This direct benefit from carbon revenue is shared between farmer groups (60%) and cover costs of administrative work and advisory services (40%). The average amount of payment for the carbon credit was ~US$ 17 per hectare in a year. Farmer groups in the KACP project receive payments for the carbon credits and use them for community development activities such as tree nursery development, restoration of degraded lands, capacity building activities, and community ceremonies.

Between 2016-2019, the TGB carbon credit project in Uganda distributed US$ 817,260 in payments to the farmers in the project areas. In 2019, a total of 8,996 farmers in 85 groups received payment for carbon credits generated in their farmlands (Table 5). The average amount of payment to the carbon credits (2016-2019) was around US$ 35 per hectare in a year. Carbon projects managed by ECOTRUST largely include tree plantation and agroforestry compared to the agricultural carbon projects manged by Vi Agroforestry. The tree-based carbon credit projects in ECOTRUST were able to generate more carbon credits and payments (per hectare) to the farmers than the crop and grass land management based carbon credit generation in Vi Agroforestry. The Vi Agroforestry program supported payment to the farmer groups and ECOTRUST preferred to make payments to individual farmers.

Table 5. Number of farmers, groups, area under SALM practices and payment (2016-2019)

Year	Number of farmers	Number of Groups	Area (ha)	Total payment (US$)
2016	5,316	81	4886.81	107,313
2017	6,104	81	5410.92	147,312
2018	6,996	83	5967.21	278,832
2019	8,996	85	6512.19	283,804
Total				817,260

Source: ECOTRUST 2019 (Trees for Global Benefits: 2019 Plan Vivo Annual Report)

The farmers' survey indicates that majority of SALM practice adopters realize a gain in farm productivity and income (Figure 7). All adopters of some practices such as restoration of degraded lands, planning basins and pits, improved irrigation, and improved fallow reported some gain in productivity. Similarly, all farmers gained farm income by implementing trees in rangelands, trees in cropland, minimum tillage, and trees on boundaries.

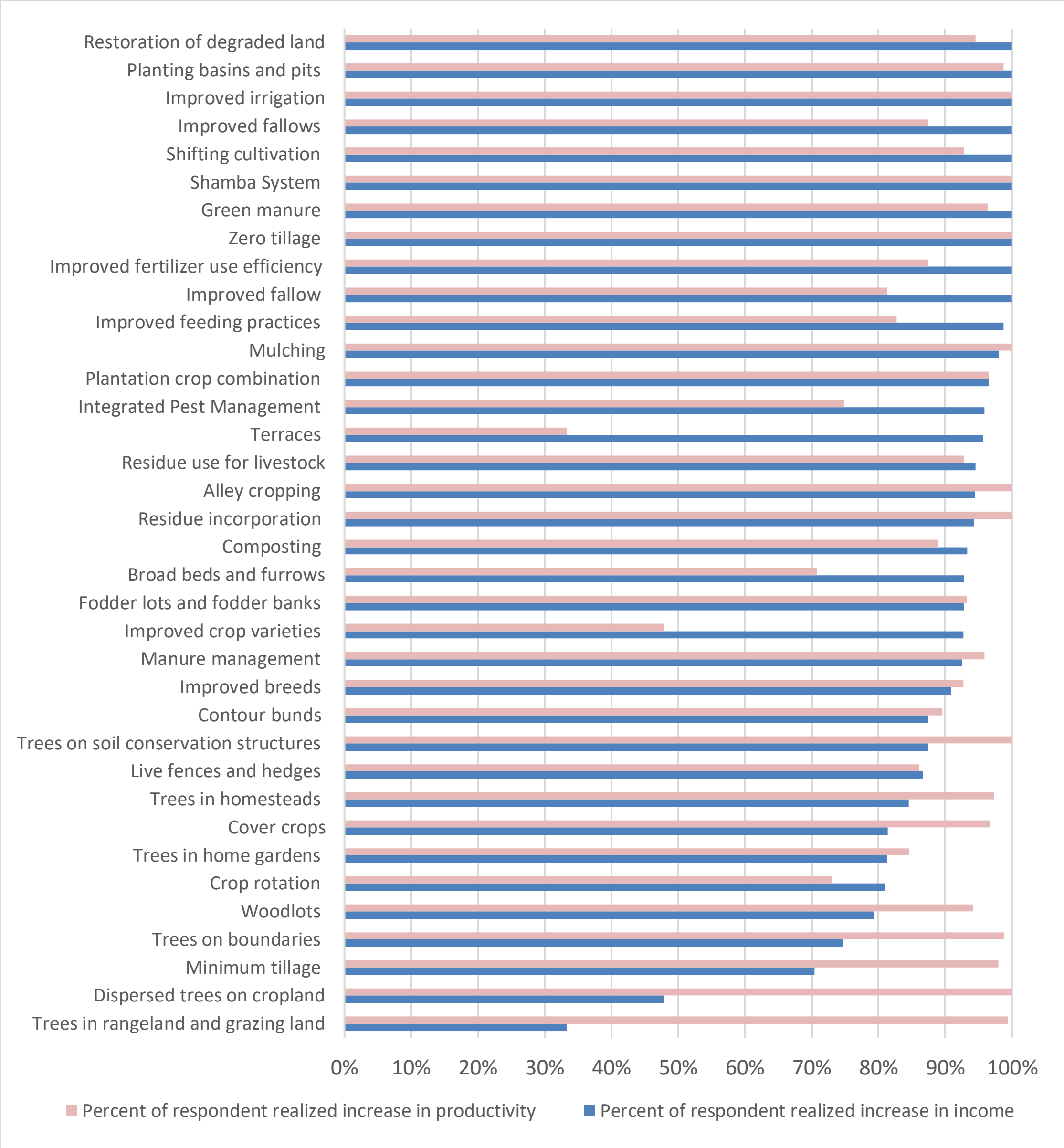

Figure 7. Percent of respondent realized increase in productivity and farm income

Social inclusion

Strengthening institutional capacity, increasing smallholder farmers' access to the carbon market, and promoting women's involvement are the social benefits of the agriculture carbon project in Kenya and Uganda. In the KACP, many women participants (70%) are directly involving in the capacity building activities, farmers group management, and implementation of various SALM practices in the crop and grasslands. The agriculture carbon project is bringing women into leadership positions and increasing the active and meaningful participation of women in monitoring and evaluating agricultural carbon projects in the field (Vi Agroforestry 2019).

Many farmers in the agriculture carbon project are smallholders. The average landholding size of the farmers in the project is 0.74 ha. The sample surveys also showed that about 70% of farmers participating in the agriculture carbon project have less than 0.5 ha in landholdings. The KACP project includes 1,730 institutions (i.e., farmers groups) and has strengthened their capacity to design and implement agriculture carbon projects, monitor and evaluate SALM practices in the fields, and coordinate with the farmers to use carbon credit payments for the benefit of group members. This shows that the agriculture carbon project's key success hinges on building institutional capacity and strengthening group members.

Factors affecting adoption of SALM practices

Some SALM practices, for example, the use of manure in crop cultivation, crop rotation, and agroforestry, have been practiced for a long time, while others have recently been implemented in the project locations. Relatively new practices such as minimum tillage, residue incorporation, restoration and rehabilitation of degraded lands, tree plantation in crop and grasslands were promoted by the Government of Kenya as well as Vi Agroforestry and other development organizations in Kenya. Despite the adaptation and mitigation benefits of SALM practices and continued support from national and international organizations, adoption by the farmers is still varied and relatively limited. This study assessed the factors that influence the adoption of multiple SALM practices and adoption intensity in the agriculture carbon credit project areas.

Farmers usually consider the use of several SALM practices to get multiple benefits that improve soil health, water conservation, and fodder and fuelwood supply. This study applied a multivariate ordered probit model to estimate the intensity of SALM practice adoption. This model estimated the possibility of adopting multiple SALM practices under different socioeconomic and biophysical conditions. Table 6 presents the results of the multivariate ordered probit model estimated using the maximum likelihood method. Results show probability of adopting multiple practices under six different SALM categories (Table 6). For instance, participants in the agriculture carbon credit project are more likely to implement TRM, AP, SWM, and ILM in their crops and grasslands. Similarly, gender and age of farmers, education level, landholding size, secondary income sources, and family size have impacts on the adoption of multiple practices under different SALM categories.

Table 6. Factors affecting the adoption of SALM practices (Multivariate Ordered Probit Model).

Variables	SNM	TRM	AP	AFP	SWM	ILM
Respondent Type (Participant = 1, 0 Otherwise	0.127 (0.119)	**0.489*** (0.134)**	**0.486*** (0.130)**	- 0.012 (0.114)	**0.973*** (0.140)**	**1.070*** (0.189)**
Gender (1= Women, 0 Otherwise)	-0.042 (0.123)	- 0.058 (0.137)	**- 0.325** (0.133)**	- 0.152 (0.117)	- 0.131 (0.140)	0.181 (0.160)
Main Occupation (1= Agriculture, 0 Otherwise)	0.100 (0.264)	0.157 (0.284)	- 0.397 (0.276)	- 0.177 (0.242)	- 0.321 (0.285)	- 0.083 (0.304)
Age (1= below 45 years, 0 Otherwise)	0.179 (0.121)	-0.312 (0.136)	**-0.286** (0.131)**	**- 0.328*** (0.115)**	**- 0.354** (0.141)**	- 0.061 (0.160)
Education	**0.133** (0.052)**	**0.146** (0.058)**	**0.116** (0.055)**	**0.127*** (0.049)**	- 0.040 (0.060)	**0.229*** (0.070)**
Agriculture land (ha)	0.014 (0.028)	**0.052* (0.031)**	-0.039 (0.030)	**0.116*** (0.027)**	**0.056* (0.031)**	-0.006 (0.032
Secondary Income (1 = other than agriculture, 0 agriculture	**0.038*** (0.116)**	0.132 (0.132)	**0.207* (0.126)**	**0.267*** (0.110)**	**0.251* (0.136)**	0.080 (0.156)
Family size (number of family members)	**0.038* (0.022)**	0.014 (0.024)	-0.004 (0.027)	0.008 (0.021)	0.012 (0.025)	0.019 (0.028)
Total livestock (livestock standard unit)	0.006 (0.024)	0.005 (0.027)	0.012 (0.027)	0.012 (0.023)	- 0.017 (0.028)	**0.083*** (0.030)**
Training on SNM	**0.326*** (0.048)**					
Training on TRM		**0.607*** (0.066)**				
Training on AP			**0.767*** (0.063)**			
Training on AFP				**0.273*** (0.028)**		
Training on SWM					**0.772*** (0.070)**	
Training on ILM						**1.153*** (0.120)**
	N = 407 LL = -403 LR chi^2 =81 P> chi^2= 0.0	N = 407 LL = -276 LRchi^2=124 P> chi^2 =0.0	N = 407 LL = -312 LRchi^2=204 P> chi^2 =0.0	N = 407 LL = -503 LRchi^2=174 P> chi^2 =0.0	N = 407 LL = -253 LRchi^2=199 P> chi^2 =0.0	N = 407 LL = -204 LRchi^2=174 P> chi^2 =0.0

SALM categories: soil nutrient management (SNM), tillage and residue management (TRM), agronomic practices (AP), agroforestry practices (AFP), soil and water management (SWM), and improved livestock management (ILM).

Interestingly, capacity building training on all categories of SALM practices has a significant impact on the adoption of multiple practices. This indicates that trainings on SALM practices are more likely to increase the implementation of many SALM practices in the crop and grasslands. These results show that the use of training manuals has significant impacts on the designing and implementation of SALM practices in agricultural carbon credit projects.

The key incentives and factors affecting the implementation of SALM practices in the agriculture carbon projects are presented in Table 7. Capacity building trainings and service provision from the private sector are the major incentives to motivate farmers and their groups to implement the SALM practices in the crop and grasslands. About 50% of key informants indicate that increase in production, developing organizational linkages, and landholding size influence implementation of the SALM practices. Similarly, 35% of key informants mention that technical feasibility of SALM practices affects the implementation of the SALM practices in the farmers' fields. Only about 20-25% of key informants refer to the cost of SALM practice implementation, gender friendliness, synergy with government programs and policies, and generation of carbon credits can influence the adoption of SALM practices. A majority of surveyed institutions plan to increase the number of capacity-building trainings to scale-out SALM practices in the agriculture carbon credit project areas. Some of them are planning to allocate funding to scale-out SALM practices and increase collaboration with government ministries, departments, and donor agencies.

Table 7. Key informants' response to incentives and factors affection implementation of SALM practices in the agriculture carbon projects.

Key incentives and factors for adoption of SALM practices	Percent of Response
Key incentives to motivate farmers and farming communities to implement the SALM practices	
Provision of government support	5%
Service provision from the private sector	65%
Credits from financial institutions	5%
Capacity building trainings	90%
Increase market linkages for technologies	5%
Increase market linkages for carbon credits	20%
Key factors affecting the implementation of the SALM practices	
Technical feasibility of SALM practices	35%
Cost of implementation	25%
Gender friendliness	20%
Synergy with government programs/policies	20%
Generation of carbon credits	20%
Other (increase in production, organizational linkage, landholding)	50%
Institutions' plan to scale out SALM practices	
Allocate funding to the SALM practices and carbon credit project	20%
Collaboration with donor agencies	25%
Collaboration with other Government Ministries and Departments	20%
Capacity building training	55%

Discussion

Impact of management innovations

The main challenges for success of the agricultural carbon projects were reducing project implementation costs and to ensure farmers' livelihood improvement from the participation (Shames et al. 2016). Given the low price of carbon, the projects must motivate farmers with long-term yield increase, reduction of production cost, and introduce new income sources to the farmers (Tennigkeit et al. 2010). The carbon projects need to recruit many farmers and implement SALM practices in large areas to reduce the per-unit cost of carbon credits and generate more significant livelihood and ecosystem co-benefits (Shames et al. 2012). Therefore, changes in knowledge, attitude, and skills of farmers and other key actors are necessary to design and implement the agricultural carbon projects.

The key actors for implementation of low emissions SALM practices were field officers in the Vi Agroforestry and ECOTRUST, community facilitators, government extension officers, and farmers group leaders. These key actors conducted training of trainers (ToT) activities using manuals and hold annual field days to introduce farmers to the agricultural carbon credit projects and to demonstrate practices. The training activities and field days encouraged farmers to implement SALM practices and empower them to participate in decision-making throughout the project design and implementation processes including negotiations and contracting, strengthening institutional capacity, and financing opportunities. The use of management innovations included in the training manuals helped to gradually transfer management authority of the agricultural carbon projects to the local communities through institutionalization of project activities. This management transition was able to bring many existing and new farmer groups into agricultural carbon projects. This also helped to decrease project cost by devising farmer-based monitoring systems and increased the area under SALM practices over time.

Linking smallholder farmers to the carbon market

The voluntary carbon markets are gradually becoming important for agriculture and forestry projects. Carbon credits generated from the agriculture and forestry sector are mainly purchased by the private sector under a corporate social responsibility model. Many private companies either purchase carbon credits directly from the projects and companies, or carbon funds (e.g., BioCarbon Fund). Agriculture carbon projects are usually highly valued for their social and environmental benefits, as they directly deal with smallholder farmers' livelihoods and protection of natural ecosystems.

The agriculture carbon projects were built on Vi Agroforestry and ECOTRUST’s long experience of working with farming communities in East Africa. The core business of these organizations has been the provision of extension services to the farmers on sustainable land management jointly working with government agencies, local communities, research and development organizations, and the private sector (Shames et al. 2012). These two organizations have played a bridging role by helping to reduce mismatched timing, payment, and knowledge between smallholder farmers and carbon credit buyers (Lee et al. 2016). As bridging organizations, they offered insight for how to design and implement agriculture carbon projects that can meet both GHG mitigation and livelihood management objectives in the agriculture sector.

Vi Agroforestry and ECOTRUST’s cooperative carbon offset projects link the rural smallholder farmers to the voluntary carbon market using the Plan Vivo Standard. These projects showcase social and environmental low carbon enterprise with smallholder farmer-led cropland and landscape restoration programs. These are promising examples of promoting smallholders’ growth, institutional development, and environmental protection.

Conclusions

The main challenge in designing and managing agricultural carbon projects is to reduce GHG emissions while increasing social and environmental co-benefits for the agriculture-dependent communities. The carbon market in the agriculture, forestry, and other land use (AFOLU) sector is envisioned as a mechanism to effectively achieve these multiple goals. This impact assessment shows that an institutional approach of transferring management authority to the local communities, including capacity building activities and social inclusion, can generate multiple benefits to the smallholder farmers. This success hinges on capacity building of project staff, agriculture extension officers, farmers group leaders, and supporting a more active role played by smallholders and women. In addition, local institutions (i.e., farmers groups) and intermediaries (i.e., non-governmental organizations) can play a leading role in the use of innovations (i.e., training manuals) for more effective design and management of agricultural carbon projects.

The agriculture carbon credit projects implemented by Vi Agroforestry and ECOTURST generated economic, social, and environmental benefits in the project areas. These two projects have received total GHG reduction credits of 1,951,437 tCO2e from 2010 to 2019. In Vi Agroforestry, about 30,000 farm households in 1,725 farmers groups were benefited from the implementation of the agriculture carbon credit projects. They have received a total of 624,960 tCO2e GHG reduction credits in the last 10 years. Similarly, in ECOTRUST, around 9,000 smallholder farmers have participated so far and received 1,326,447 tCO2e worth of verified emissions reduction certificates from 2010 to 2019.

Payments for carbon credits (in the group or individual farmers), increase in crop productivity, and reduced production costs are direct economic benefits to the farmers. Many SALM practices implemented by the farmers also enhance soil health and ecosystem services in the project areas, not accounted for in the impact assessment. The agricultural carbon projects can mobilize smallholders and women to implement SALM practices in crop and grasslands and take a leadership role in many farmer groups. With these results, the institutionalization of management and implementation activities at the local level remains critically important for agricultural carbon projects' success. This is also crucial to cultivate ideal partnerships with local governments, community-based organizations, and the private sector.

This impact assessment shows that management innovation in the agricultural carbon projects can enhance farmers' participation and adoption of sustainable agriculture and land management practices in the crop and grasslands. This participation gradually expands economic, social, and environmental benefits to the local communities. This study also indicates that the AFOLU sector is well-positioned to capitalize on the growing trend towards carbon management and investment from the public and private sectors.

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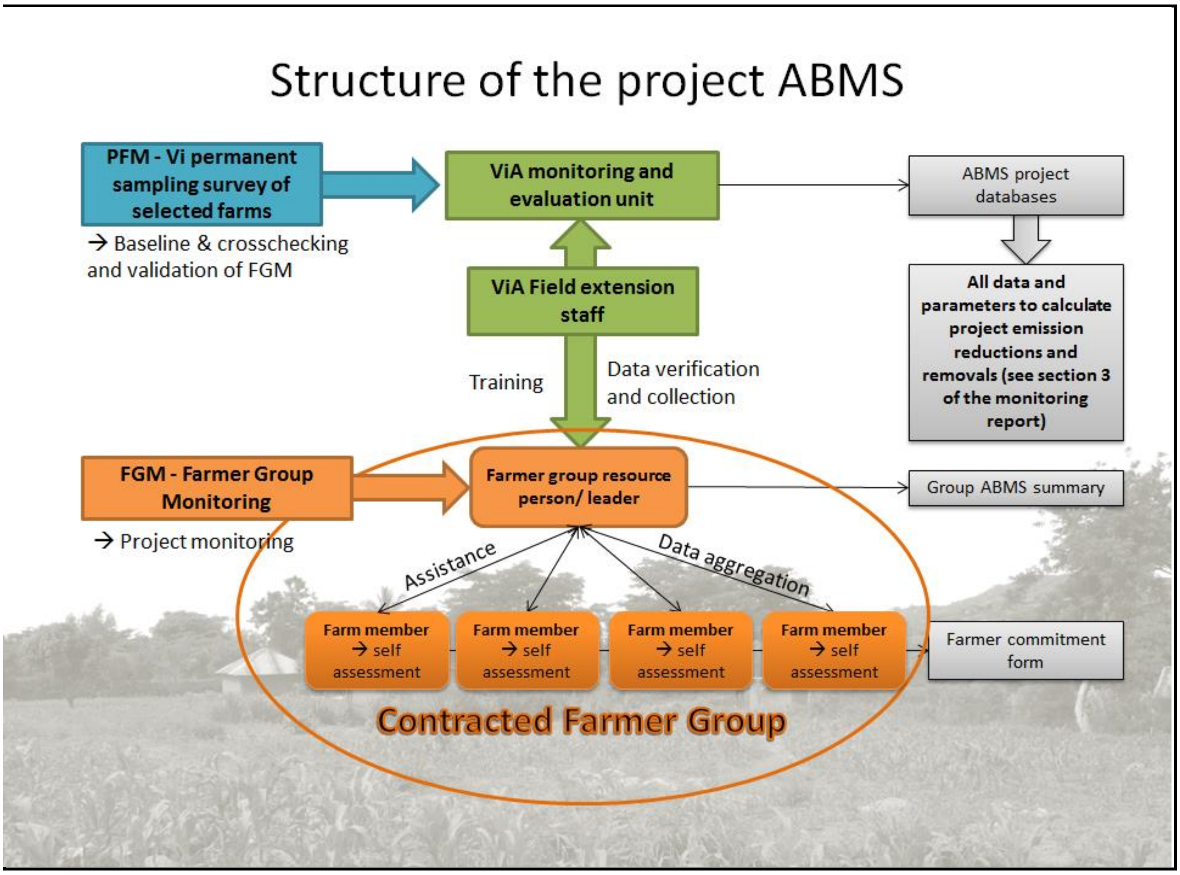
Appendix A: List of SALM categories and practices

SALM Category	SALM practice
1. Soil nutrient management	1. Mulching
	2. Improved fallow
	3. Manure management
	4. Composting
	5. Improved fertilizer use efficiency
2. Tillage and residue management	6. Minimum tillage
	7. Zero tillage
	8. Residue incorporation
	9. Residue management (use for livestock)
3. Agronomic practices	10. Cover crops
	11. Green manure
	12. Crop rotation
	13. Improved crop varieties
4. Agroforestry practices	14. Dispersed trees on cropland
	15. Buffer zone agroforestry
	16. Alley cropping
	17. Trees on boundaries
	18. Live fences and hedges
	19. Shamba System
	20. Shifting cultivation
	21. Fodder lots and fodder banks
	22. Trees in rangeland and grazing land
	23. Trees in homesteads
	24. Plantation crop combination
	25. Improved fallows
	26. Woodlots
	27. Trees in home gardens
	28. Trees on soil conservation structures
5. Soil and water management	29. Improved irrigation
	30. Terraces
	31. Planting basins and pits
	32. Broad beds and furrows
	33. Contour bunds
	34. Half-moon micro-catchments
	35. Restoration and rehabilitation of degraded land
6. Improved livestock management	36. Improved feeding practices
	37. Improved breeds

Appendix B: KACP Project's Activity Baseline Monitoring System



Source: KACP Monitoring Report 2017

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