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Bridging credit gaps for sustainable agriculture: The role of rural savings and credit cooperatives among smallholder farmers

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Abstract: Despite the recognised benefits of climate smart agriculture (CSA) in enhancing farmers' adaptive capacity to climate risks, adoption rates remain low in Sub-Saharan Africa. This disparity can be attributed, in part, to the significant challenges smallholder farmers face in accessing credit from the formal financial sector. In response, Rural Saving and Credit Cooperatives (RUSACCOs) have emerged as crucial sources of funding for both household expenses and agricultural activities. However, despite their increasing importance in improving financial inclusion, little is known about whether participation in RUSACCOs can help alleviate existing credit constraints and promote the adoption of CSA among smallholder farmers. To address this knowledge gap, we employ a recursive bivariate probit (RBP) and propensity score matching (PSM) analysis using data from 400 randomly selected smallholder farmers in Zambia. The analysis controls for three main sources of endogeneity: program placement, endogenous covariates, and self-selection. Our findings indicate that participation in RUSACCOs has the potential to mitigate farmers' credit constraints by 42% and facilitate CSA adoption by 25%. Notably, the alleviation of existing credit constraints is associated with a 14% increase in CSA adoption. These results underscore the previously overlooked role of RUSACCOs in promoting agricultural sustainability. By effectively addressing financial inclusion barriers and providing access to practical agricultural knowledge, RUSACCOs can contribute to reducing the vulnerability of agriculture while fostering sustainable production. Our study suggests that repurposing RUSACCOs to emphasise financial inclusion and promote access to agricultural learning platforms can yield triple benefits: agricultural, environmental, and livelihood sustainability.

Keywords: climate-smart agriculture; credit constraints; financial inclusion; rural development; sustainable intensification; Zambia

Enhancing access to credit is pivotal to improving agricultural productivity and promoting sustainable agriculture, making it a top priority for developing nations around the globe (Batista and Vicente 2020; Missiame et al. 2021; Batung et al. 2023). Despite this recognition, a significant gap persists between farmers' demand for financing and credit available from banks, amounting to an alarming EUR 62 billion

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in 2022 among European countries (European Commission 2023). Nearly half of the world's farmers and 1.4 billion adults remained unbanked in 2014 and 2021, respectively, according to the World Bank Global Findex reports (2019). In Sub-Saharan Africa (SSA), credit market imperfections and rationing exacerbate these challenges, often resulting in resource misallocation, suboptimal input use, and reduced productivity (Stiglitz and Weiss 1981; Jappelli 1990; Petrick 2004; Ali et al. 2014; Guiso 2018). Consequently, rural smallholder farmers rely largely on personal resources to finance their input purchases (Scheidel and Farrell 2015). At the same time, farmers struggle with the risks associated with climate change while contending with ecological challenges such as water scarcity, deforestation, and declining soil productivity (Wheeler and Von Braun 2013; Nkomoki et al. 2018).

Recognising these challenges, SSA countries have emphasised the adoption of environmentally friendly agricultural innovations, such as climate-smart agriculture (CSA) (Arslan et al. 2018; Piñeiro et al. 2020). As a promising solution, CSA provides both ecological and economic benefits, including reduced reliance on synthetic inputs, efficient natural resource use, lower input costs, improved yields, and increased household income (Kassie et al. 2013; Mazumder and Wencong 2013; Teklewold et al. 2013; Manda et al. 2016; Owusu 2017; Akter et al. 2022; Mgomezulu et al. 2023). However, despite policymakers' efforts to popularise and advocate CSA, adoption rates remain low, prompting growing interest in understanding how alleviating credit constraints can incentivise farmers to embrace CSA practices (Abate et al. 2016; Abdallah 2016; Donkoh 2019; Amadu et al. 2020). In this context, access to credit could play a critical role by empowering farmers to increase their purchasing power for inputs and operating expenses in the short term while also enabling profitable long-term investments (Conning and Udry 2007). Yet, for most rural farmers, access to formal credit remains unattainable due to systemic and socioeconomic barriers such as high lending rates, bureaucratic application processes, and unfavourable risk perceptions. Financial institutions often cite high agency costs, lack of collateral, and concerns over the diversion of funds towards non-agricultural needs as justifications for excluding poor rural farmers (Vicente et al. 2020). These barriers highlight the urgent need for innovative financial mechanisms tailored to smallholder farmers' unique challenges, enabling them to overcome credit constraints and effectively adopt sustainable agricultural practices.

To address the issue of financial exclusion, non-governmental organisations (NGOs) have advocated the gradual institutionalisation of informal savings and loan groups, known as Rural Saving and Credit Cooperatives (RUSACCOs), and village banks (Ashe and Neilan 2014; Asamoah and Amoah 2015; Balana and Oyeyemi 2022). These community-driven microfinance associations aim to provide essential savings and credit services to rural populations, which are often overlooked by formal financial institutions. RUSACCOs, which are managed by their members, have gained widespread adoption across 75 countries in Africa, offering secure channels for savings, emergency support, and loans tailored to borrowers' ability to repay (Cameron and Ananga 2013; Amponsah et al. 2023). Although farmers' participation in RUSACCOs has been extensively studied, a significant gap remains in the literature on the role of RUSACCOs in facilitating sustainable agriculture. For instance, although previous studies have highlighted the operational challenges of RUSACCOs (Karlan et al. 2017; Bannor et al. 2020; Amponsah et al. 2023), they have largely overlooked how RUSACCO participation can alleviate credit constraints, specifically for the adoption of CSA practices. Furthermore, while recent studies have examined the economic effects of RUSACCO participation, including farm productivity and income (Lakhan et al. 2020; Missiame et al. 2021; Haryanto et al. 2023), there has been little focus on how RUSACCOs can be structured or optimised to directly support the adoption of sustainable agricultural practices, such as CSA. This research gap emphasizes the need for further exploration into how RUSACCOs can be effectively leveraged to enhance access to credit and facilitate CSA adoption among smallholder farmers.

This study explores how participation in RUSACCOs alleviates farmers' existing credit constraints and facilitates the adoption of CSA. We use data from 400 randomly selected farmers in the Making Agriculture a Business (MAB) project sites in Zambia. We make three significant contributions that can improve financial inclusion, promote sustainable agricultural development, and enhance rural livelihoods. First, we provide novel insights into the nature and extent of credit constraints, which are essential for identifying systemic gaps in rural financial systems and designing targeted interventions to enhance farmers' access to credit and improve resource allocation. Second, we contribute to policymakers' understanding of the relationship among credit constraints, RUSACCO participation, and sustained CSA adoption. We thus

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offer evidence-based recommendations for scaling up RUSACCOs to promote resilience and sustainability in rural farming systems. Additionally, this study provides guidance on how RUSACCOs should be effectively organised to optimise CSA adoption, the absence of which undermines progress towards sustainable development goal (SDG) 13, which calls for urgent action to combat climate change. Finally, we offer methodological advancements by adjusting the recursive bivariate probit (RBP) model to address endogeneity, self-selection bias, and program placement. Thus, we ensure a robust and credible analysis that strengthens the validity of the findings and provides a replicable framework for future research.

Background

Country context. Agriculture is the backbone of Zambia's economy, contributing approximately 40% to GDP, employing 80% of the workforce, and accounting for 80% of exports (Chapoto et al. 2011; Mwalupaso et al. 2019). Like many other countries in SSA, Zambia's agricultural sector is predominantly composed of small-scale farmers who cultivate over 90% of the total agricultural land and rely heavily on rainfed farming (Workman 2018).

Despite its pivotal role, Zambia's agricultural sector receives less than 10% of bank lending, with the majority directed towards the more developed export subsector. This disparity is primarily attributed to the predominance of the rural economy and limited distribution of financial services (Sebatta et al. 2014; Samboko et al. 2018). While indicators of financial access and inclusion have improved over the past decade owing to the proliferation of financial service providers, Zambia still lags behind other developing countries in this regard (World Bank 2019). For instance, the percentage of rural smallholder farmers holding accounts at financial institutions remains minimal, with only 3.16 bank branches per 100 000 inhabitants as of 2020. Consequently, farmers have turned to RUSACCOs; however, empirical evidence of their impact on credit constraints and welfare improvements is lacking (Samboko et al. 2018; Sishumba and Mulonda 2019).

Given Zambia's susceptibility to adverse weather conditions, particularly recurrent droughts, achieving sustained food security has proven to be challenging. The agricultural sector faces numerous hurdles, including threats from climate change, land degradation, low soil fertility, and the prevalence of pests and diseases. Despite government interventions, such as the Farmer Input Support Program (FISP), which provides chemical fertilisers and disease-resistant, high-yield seeds, the adoption rates of CSA, including crop rotation, intercropping, soil and water conservation, integrated pest management, and organic farming methods, remain low due to significant credit constraints among farmers (Manda et al. 2016; Mason et al. 2020). Therefore, efforts to optimise CSA may potentially improve productivity, eradicate poverty, achieve zero hunger, enhance household food security, and ensure long-term agricultural sustainability.

The Making Agriculture a Business (MAB) project. The MAB project, funded by the Scottish government in collaboration with Christian Aid (CA) and Norwegian Church Aid (NCA), has been operational since October 2017. The project, aptly named 'Making Agriculture a Business', aims to harness the potential of small-scale farmers and entrepreneurs as drivers of economic development in four districts of Central Province, Zambia: Chisamba, Kapiri-Mposhi, Kabwe, and Mumbwa. Its overarching goal is to enhance the livelihoods and resilience of farmers, with a particular focus on marginalised groups such as youth, women, and persons living with disabilities (PwDs).

The project targets a diverse population, ranging from local farmers and community-focused groups to business and market trader groups located around neighbouring bulking centres and markets. It employs two main pathways of change.

i) Formation of common interest groups: These groups enable community members to collaborate and improve the cultivation and marketing of various commodities. Notably, for this study, the savings group stands out as a key example.

ii) Establishment of farmer-training centers (demo sites): These centres serve as hubs for capacity building and skills transfer, empowering farmers to learn agricultural innovations that aid climate change adaptation and yield improvement.

The project initially aimed to involve 4 000 small-scale farmers in its activities, focusing on farmer training centres and savings groups. Farmer training centres provide instruction on the best agronomic practices to enhance yield and marketing skills, while savings groups aim to bolster financial capacity and access to finance at the individual level.

Participation in the savings groups is voluntary, with each group limited to a maximum of 30 members. All the groups in the MAB project operate under a constitution that governs their operations, including leadership selection, loan terms, and management protocols. Members contribute savings at regular meetings and

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those seeking credit must register in advance to secure a guarantor. Loans without collateral have defined repayment periods and mandatory interest payments.

Confidence within groups is fostered by regular community interactions at agricultural demonstration sites, where farmers meet and share knowledge. Capacity building, leadership training, and access to financing are facilitated by responsible NGO, which may inject seed capital into groups to enhance their borrowing capacity. Information on borrowing procedures is regularly disseminated and funds are distributed among members at the end of each cycle.

The project promoted CSA practices aimed at sustainable agricultural intensification based on five key features, consistent with the definition of the Food and Agricultural Organisation (FAO): technical appropriateness, environmental sustainability, resource conservation, economic viability, and social acceptability (Mgomezulu et al. 2023). These practices encompass farming techniques that deliver significant environmental benefits, including enhanced biodiversity, improved water and soil quality, better land management, and climate change mitigation, compared to conventional farming methods (Teklewold et al. 2013; Nkomoki et al. 2018). Common CSA practices include improved seed, crop rotation, conservation tillage, integrated pest management and drip irrigation.

MATERIAL AND METHODS

Data

This study focuses on smallholder farmers in the four rural districts (Mumbwa, Chibombo, Chisamba, and Kapiri Mposhi) where the MAB project operates. Employing a descriptive research design, this study utilised a quantitative approach to collect data from May to July 2022. A multistage sampling technique was employed to select a sample of farm households. Initially, two agricultural villages with similar socioeconomic conditions and infrastructural services were selected in each district following consultations with farmers and local leadership. These villages were chosen based on criteria such as crop cultivation, livestock farming, availability and quality of infrastructure (roads, transportation facilities, electricity, and water supply), market access, land tenure systems, access to extension services, climate and environmental conditions, as well as social networks and institutions. Within the selected villages, two groups were identified based on the intensity of MAB activities: areas with active MAB initiatives were categorised as 'vibrant RUSACCO areas', while those with limited or no MAB activities were labelled as 'inactive RUSACCO areas' (Figure 1). Following the recommendations of Tambo and Wünscher (2018), this approach helped mitigate program placement bias. Subsequently, to ensure the representativeness of the sample, we conducted sample size calculations using Cochran's criteria (1977) for a known population (N = 3 600), as outlined in Equation (1), at a 95% confidence interval. Although Cochran's criteria suggested a sample size of 450 households, the final analysis used 400 observations because of missing data from 50 respondents. The sample was randomly selected, comprising both credit-constrained and unconstrained farmers, with 300 households from vibrant areas and 100 households from inactive areas, maintaining a proximity of approximately 35–40 kilome-

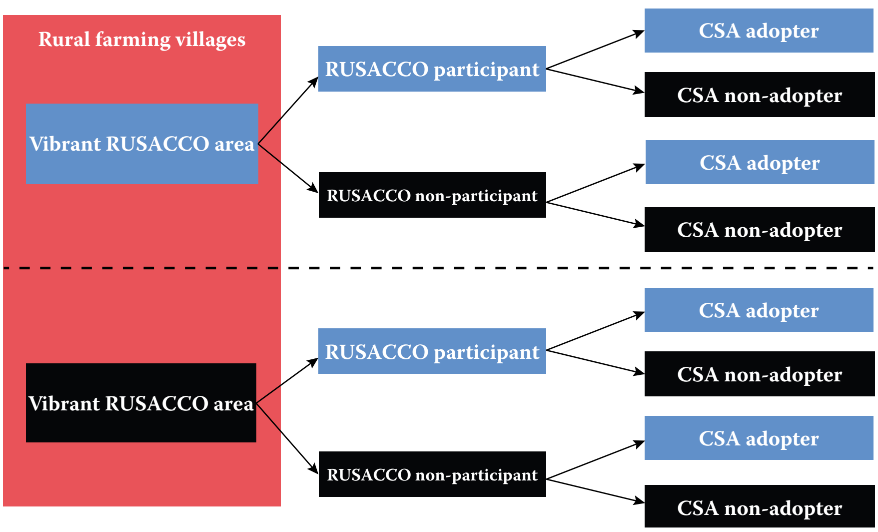

Figure 1. Selection and distribution of sample

RUSACCO – Rural Saving and Credit Cooperative; CSA – climate smart agriculture

Source: Author's own elaboration

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tres between the two groups. Ultimately, the sample consisted of 200 RUSACCO participants (45% from vibrant and 5% from inactive RUSACCOs areas) and nonparticipants (30% from vibrant and 20% from inactive RUSACCOs areas):

$$n = \frac{N \times Z^2 \times p \times (1-p)}{E^2 \times (N-1) + Z^2 \times p \times (1-p)} \quad (1)$$

where: n – sample size; N – population size; Z – Z-value (1.96); p – estimated proportion of an attribute present in the population (50%); E – margin of error (5%).

Experienced enumerators administered a structured and pretested questionnaire to minimise measurement errors. Pre-testing of the questionnaire was conducted in Kapiri Mposhi, one of the districts of the study, to ensure clarity, accuracy, and relevance. During the pretest, the questionnaire was administered to a small sample of farmers who resembled the target population. This allowed the research team to assess respondents' understanding of the questions, identify any ambiguities, and make necessary amendments based on feedback. The pre-test also helped ensure that the questions elicited the intended responses and were culturally appropriate, ensuring that the final version of the questionnaire was well-suited for the main study. Additionally, key informant interviews (KIIs) were conducted with various stakeholders, including project staff, agronomists, training centre community facilitators, and lead farmers, to provide triangulation and deeper insights. To further enhance the reliability of the data and mitigate potential recall bias, we collected information pertaining to the immediate past farming season, consistent with the recommendations of Tarrant et al. (1993) and Connelly et al. (2000).

Table 1 provides the summary statistics of the sample, highlighting the significant differences in various variables between RUSACCO participants and nonparticipants. For instance, nonparticipants tend to utilise more chemical fertilisers, whereas participants exhibit greater experience and have increased access to demo sites and markets. Given these disparities in observable characteristics, employing a naïve estimator may lead to incorrect attributions of the impact of credit constraints and SAPs adoption on RUSACCO participation.

Operationalisation of key variables

In this study, we define credit constraints following the categorisation proposed by Mukasa et al. (2017), encompassing four distinct categories – quantity, risk, transaction cost and price constrained. Details on measurement are provided by Aminkeng et al. (2024). Credit constraints are represented as a binary variable, with 1 denoting a farm household facing any form of credit constraint outlined above, and 0 otherwise. Additional details on measurement are provided by Aminkeng et al. (2024).

Sustained adoption is evaluated using a two-dimensional framework. First, farmers are deemed to have adopted CSA if they consistently practice any of the mentioned SAPs for a minimum of three years. Second, they must not reduce their land area under CSA adoption during this period. This is represented as a binary variable, where a value of 1 indicates that farmers have adopted at least one of the three main principles: minimum soil disturbance, crop rotations and associations, or permanent soil cover, whereas a value of 0 indicates no adoption. This is consistent with the definition proposed by Mgomezulu et al. (2023).

RUSACCO participation is represented as a binary variable, with 1 denoting farm household where at least one adult participates in RUSACCOs for three consecutive cycles, and 0 otherwise. This approach to capturing participation was also adopted by Amponsah et al. (2023).

Empirical strategy

To assess the impact of participation in RUSACCOs on alleviating credit constraints and promoting CSA adoption, we use a recursive bivariate probit (RBP) regression. This econometric technique, which employs full information maximum likelihood, is particularly useful in addressing endogeneity and selectivity bias (Li et al. 2019). Additionally, propensity score matching (PSM) is applied for robustness checking and to assess the potential gains in CSA adoption resulting from alleviating credit constraints and quantifying the spillover effects of participation on CSA adoption.

Recursive bivariate probit. The RBP model, as outlined by Coban (2022) and Abdulai (2016), is commonly employed to estimate the impact of a binary treatment variable (RUSACCO Participation) on binary outcome variables (credit constraint status and SAPs adoption). This model is particularly suitable for simultaneously addressing the selection bias captured as Rho (ρ) in treatment assignments (Li et al. 2019).

To account for this, we specify the following jointly estimated equations for RUSACCO participation and credit constraints in the first case and RUSACCO participation and SAPs adoption in the second case:

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Table 1. Descriptive statistics and variable definition

Variable	Description	Participants (N = 200)	Non-participants (N = 200)	Difference
Agricultural inputs				
Land	cultivated land for maize in ha	6.79	6.85	–0.06 (0.35)
Fertiliser	chemical fertiliser used in kg per ha	150.62	230.59	–79.97*** (22.95)
Socioeconomic characteristics				
Age	age of the household head	42.36	43.78	–1.42 (1.22)
Education	number of years of schooling for the household head	7.24	7.15	0.09 (0.50)
Family size	number of members in a household	4.70	4.83	–0.13 (1.09)
Farming experience	number of years of farming experience	18.62	15.89	2.73** (1.05)
Gender	sex of the household head (1 = man)	0.88	0.92	–0.04 (0.29)
Residence	years of living in community	25.61	23.93	1.68* (0.95)
Access characteristics				
Market	access to the market (1 = have access)	0.58	0.27	0.31** (0.13)
Demo sites	participation at agricultural demonstration site (1 = participant)	0.87	0.35	0.52*** (0.12)
FISP	membership of a household to a FISP cooperative (1 = member)	0.94	0.95	–0.01 (0.21)
ICT	possession – radio, TV and/or mobile phone (1 = possesses)	0.78	0.46	0.32* (0.17)
Wealth characteristics				
Asset	self-reported value of assets possessed in Zambian kwacha	7 136.68	5 640.97	1 495.71*** (356.21)
Off-farm	engagement in off-farm activities (1 = engaged)	0.78	0.49	0.29* (0.15)
IVs	–	–	–	–
Prior RUSACCO *perception*	prior RUSACCO perception (1 = positive)	0.88	0.59	0.29*** (0.08)
Off-farm work perception	availability of off-farm work perception (1 = positive)	0.68	0.7	–0.02 (0.03)

*, **, ***P < 0.1; 0.05; 0.01; respectively; the figures in parentheses are the standard errors of the coefficients; RUSACCO – Rural Saving and Credit Cooperative; *FISP* – Farmer Input Support Program; *ICT* – information and communication technology; *IVs* – instrumental variables

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First stage:

$$RSA_i^* = \beta M_i + \gamma_i \text{ for } P = 1 \text{ } if \text{ } RSA_i^* > 0 \quad (2)$$

Second stage:

$$Y_i^* = \alpha X_i + \omega RSA_i + \varepsilon_i \text{ for } Y_i^* \text{ represents } CCS_i^* \text{ and } CSA_i^* \quad (3)$$

where: RSA_i*, CCS_i*, and CSA_i*– latent variables representing RUSACCO participation, credit constraint status, and CSA adoption, respectively; M_i and X_i – vectors of determinants for RUSACCO participation and the outcome variables (credit constraints and CSA adoption), comprising agricultural inputs and socioeconomic, access, and wealth characteristics, as defined in Table 1; Y_i*, α, β, and ω – parameters to be estimated; ε_i, γ_i, and μ_i – random error terms.

Because accounting for selection bias is fundamental, vector M_i includes at least one variable that is not in X_i, which is an instrumental variable (*IV*) that should not directly affect the outcome variables in the second stage presented by Equation (3). In our case, the *IV* was the respondents' self-reported perception of RUSACCO under the MAB initiative before implementation, represented as a binary variable, where 1 indicates a positive perception and 0 otherwise. To validate *IV*, we conducted a falsification test to satisfy the exclusion criteria. Results indicated that prior perception of RUSACCOs correlated significantly with RUSACCO participation (β = 0.281; $P < 0.01$) while exhibiting weak and statistically insignificant correlations with credit constraints (β = 0.035; $P = 0.782$) and CSA adoption (β = 0.936; $P = 0.242$).

While we addressed program placement using the sampling framework and self-selection through the RBP, we employed the control function (CF) technique to handle endogenous covariates. The rationale for selecting this method has been well documented by Tadesse and Bahiigwa (2015). Therefore, we adopted a two-stage endogeneity test. Initially, a Probit function with *IV*s for off-farm activities was estimated before estimating Equations (2). Subsequently, generalised residuals (GR) were calculated and included as regressors when jointly estimating Equations (2) and (3). Endogeneity is detected if the GR is statistically significant, in which case the use of CF is validated (Wooldridge 2010). Conversely, to ensure robust estimates, we derived the predicted values of demo-site participation from the control function (CF), given that some factors influencing demo-site participation also affect RUSACCO participation within the MAB framework. This approach aligns with the methodology of Dubbert (2019).

Finally, in our empirical strategy, we computed the average treatment effect on the treated (ATT) which measures the impact of participation on outcomes (credit constraints and CSA adoption) compared to a hypothetical scenario where participants had not been involved. Intuitively, if Y_1 is the outcome for participants and Y_0 is the outcome if the household didn't participate in RUSACCO, $ATT = Y_1 - Y_0 \mid RSA_i = 1$. However, unlike other models such as PSM, in the RBP framework, *ATT* is obtained directly without explicitly calculating the factual (Y_1) and counterfactual outcomes (Y_0) separately. Instead, it was derived from the model identification process as follows:

$$ATT = \Phi(\alpha X_i + \omega) - \Phi[\alpha X_i + \rho\lambda(\beta M)] \quad (4)$$

where: Φ(.) – cumulative distribution function of the standard normal distribution; $\alpha X_i + \omega$ –expected outcome for treated individuals (RUSACCO participants); $\alpha X_i + \rho\lambda(\beta M)$ – expected outcome adjusted for selection bias using the inverse Mills ratio [$\rho\lambda(Z\gamma)$]. Other variables were defined as previously described.

Propensity score matching. This section employs PSM to conduct robustness checks on the treatment effects estimated from the RBP. Additionally, it provides actionable policy insights into the potential gains in optimising CSA adoption by alleviating credit constraints and evaluating the effectiveness of the RUSACCO programs through a spillover analysis.

Generally, PSM relies on two key assumptions, and when these are met, we can estimate the *ATT* (Abadie and Imbens 2006). The first, known as the conditional independence assumption (CIA), posits that, given a set of observable covariates, the potential outcome (credit constraints and CSA adoption) is independent of the allocated treatment (RUSACCO participation). Mathematically, this is expressed as:

$$(Y_1),(Y_0) \perp RSA_i \mid M \quad (5)$$

The second assumption is that perfect predictability is prevented by overlap or common support, which is expressed as:

$$0 < P(RSA_i = 1 \mid M) < 1 \quad (6)$$

where: P – propensity score with all other variables as already defined.

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Consequently, to verify the robustness of the estimates obtained from the RBP, we applied three matching algorithms – nearest neighbour matching (NNM), kernel matching (KM), and radius matching (RM) – to calculate *ATT*. Unlike the RBP, where the *ATT* is derived directly, the PSM method explicitly calculates the outcome values for both factual and counterfactual scenarios as follows:

$$ATT = Exp\left[\left(Y_1 = 1 \mid RSA_i = 1\right) - \left(Y_1 = 0 \mid RSA_i = 1\right)\right] \quad (7)$$

Furthermore, we investigated the heterogeneity effects of CSA adoption based on credit constraints. Specifically, we compared the *ATT* in terms of CSA adoption across credit-constrained and credit-unconstrained groups. Intuitively, if CSA adoption is significantly lower among credit-constrained households ($ATT_{costrained}$) than among their unconstrained counterparts ($ATT_{uncostrained}$), it suggests that alleviating credit constraints could substantially enhance CSA adoption. Therefore, the difference in adoption between these two groups represents the potential gain ($P\text{gain}_{\text{CSA}}$) in optimising CSA adoption by addressing financial barriers. To deepen this analysis, we examined the specific dimensions of credit constraints, including price, risk, quantity, and transaction costs, to provide a comprehensive understanding of how these factors limit CSA adoption among households participating in RUSACCOs. By isolating the effects of each constraint, we offered targeted policy recommendations for improving CSA uptake among vulnerable households. Mathematically, the potential gain from CSA adoption can be specified as follows:

$$P\text{gain}_{CSA} = ATT_{uncostrained} - ATT_{constrained} \quad (8)$$

Finally, we evaluated the spillover effect of RUSACCO participation on CSA adoption by analysing the *ATT* in CSA adoption rates across three distinct scenarios:

i) participants and non-participants in vibrant areas,

ii) non-participants in vibrant areas versus participants in inactive areas and,

iii) participants versus non-participants in inactive areas. The spillover effects were evaluated based on the following criteria.

Strong spillover effect. No statistically significant difference in CSA adoption across all scenarios. This indicates that the influence of RUSACCO participation extends widely, with CSA adoption diffusing from direct participants to non-participants.

Moderate spillover effect. No statistically significant difference in scenarios *i*) and *iii*), but a significant difference in scenario *ii*). This suggests that spillover effects are present, but vary across contexts, with CSA adoption being notably higher in vibrant areas.

Limited spillover effect. A statistically significant difference in scenarios *i*) and *iii*), but no significant difference in scenario *ii*). This implies that while RUSACCO participants adopt CSA at a higher rate, non-participants in vibrant areas exhibit adoption levels comparable to that for participants in inactive areas, indicating a constrained spillover effect.

Weak spillover effect. Statistically significant differences in all scenarios except scenario *iii*). This suggests that CSA adoption is predominantly driven by direct participation in RUSACCO, with minimal spillover effects, and is largely confined to vibrant areas.

This classification provides a structured approach to understanding the extent to which CSA adoption benefits extend beyond direct RUSACCO participation, offering insights into the effectiveness of these programs in fostering a broader agricultural transformation. For further methodological details, please refer to Tambo and Wünscher (2018). A summary of the framework is presented in Table 2.

These scenarios provide important empirical insights into the mechanisms driving CSA adoption. Scenario *i*) captures the combined effect of RUSACCO participation (credit access) and information dissemination, reflecting the program's intended design, where both financial and informational support are expected to influence adoption. Scenario *ii*) isolates the effect of information dissemination because it is assumed that knowledge about CSA practices is more likely to diffuse within vibrant areas, even among non-participants. Scenario *iii*) primarily reflects the impact of RUSACCO participation (credit access) alone because inactive areas generally lack strong information dissemination mechanisms in their meetings. This framework allows for a systematic assessment of how credit access and information dissemination in-

Table 2. Criteria for spillover effect categorisation

Spillover effect category	Statistical significance of the *ATT*		
	scenario *i*)	scenario *ii*)	scenario *iii*)
Strong	X	X	X
Moderate	X	√	X
Limited	√	X	√
Weak	√	√	X

The cross represents statistical insignificance, whereas the tick represents statistical significance; *ATT* – average treatment effect

Source: Author's elaboration

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teract to influence CSA adoption, contributing to a nuanced understanding of the spillover dynamics within RUSACCO-affiliated communities.

RESULTS AND DISCUSSION

Incidence of credit constraints and SAPs adoption intensity

Incidence of credit constraints. The results presented in Table 3 indicate that 65% of the surveyed farmers experienced some form of credit constraint, with 33% located in vibrant RUSACCO areas and 67% in inactive RUSACCO areas. However, when we examined data based on participation in RUSACCOs, only 15% of the participants faced credit constraints, whereas 85% of non-participants experienced various forms of credit constraints. This suggests that participation in RUSACCOs may play a significant role in alleviating credit constraints, particularly when considering that fewer than 20% of participants are constrained in any way apart from transaction costs. However, it is essential to note that these findings do not conclusively demonstrate that RUSACCO participation leads directly to reduced credit constraints, as there could be underlying systematic differences between RUSACCO participants and non-participants.

The analysis also reveals that a relatively low proportion of participants are constrained by transaction costs and quantity constraints, which are notably lower than those of nonparticipants. However, for the affected participants, challenges within RUSACCOs, such as cumbersome loan application procedures and the requirement for guarantors, are likely contributing factors. Despite the potentially lower interest rates offered by RUSACCOs, these barriers may result in unmet credit needs because the loan application process could still be cumbersome for some individuals (Sharma and Zhao 2017; Schoofs 2022; Amponsah et al. 2023). Moreover, the findings suggest that the credit available within RUSACCOs may be inadequate, as evidenced by a considerable proportion of farmers facing quantity constraints. This highlights the ongoing need for credit among farmers to support their agricultural activities, indicating a gap between credit demand and the resources available through RUSACCOs, as acknowledged by key informants.

Furthermore, the injection of seed capital by NGOs into vibrant RUSACCO areas appears to positively influence the borrowing scale, leading to a reduction in quantity constraints among participants. This outlines the importance of external support and investment in RUSACCOs to enhance their effectiveness in addressing credit constraints among rural farmers (Appiah-Twumasi et al. 2022). Understanding whether credit constraints arise from demand or supply is crucial for designing and implementing effective rural financial policies and interventions that support agricultural investment and rural livelihoods. Therefore, addressing both quantity constraints, which are supply side issues, and transaction costs, which are demand-side challenges, is essential for optimising the role of RUSACCOs in alleviating credit constraints among participants.

Intensity of CSA adoption. Table 4 presents the intensity of CSA adoption. Participants in vibrant RUSACCO areas exhibited the highest adoption rates, whereas non-participants in inactive RUSACCO areas exhibited the lowest. Notably, the number of CSA adopters among nonparticipants in the vibrant areas surpassed that of participants in the inactive RUSACCO areas. Overall, 81% of farmers in vibrant RUSACCO areas adopted CSA, compared with only 33% in inactive areas.

Table 3. Incidence of credit constraints (%)

Credit constrains status	Pooled	Vibrant RUSACCO Areas		Inactive RUSACCO Areas		Combined	
		participants	non-participants	participants	non-participants	participants	non-participants
General	65	6	27	9	58	15	85
Quantity	28	5	31	14	50	19	81
Price	24	5	31	11	52	17	83
Transaction cost	27	6	28	15	52	21	79
Risk	21	6	27	9	57	16	84

The general variable captures households that have experienced at least one credit constraint; RUSACCO – Rural Saving and Credit Cooperative

Source: Author's elaboration

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Table 4. Distribution of CSA adoption

Area	Group	CSA adoption status	Number of adopter and non-adopters		CSA adoption per group (%)	CSA adoption in the area (%)
			N	percent		
Vibrant RUSACCO	participants	adopter	155	39	86	81
		non adopter	25	6		
	non-participants	adopter	88	22	73	
		non adopter	32	8		
Inactive RUSACCO	participants	adopter	12	3	60	33
		non adopter	8	2		
	non-participant	adopter	21	5	26	
		non adopter	59	15		

CSA – climate smart agriculture; RUSACCO – Rural Saving and Credit Cooperative
Source: Author's own elaboration

The explanation for the higher adoption rates in vibrant areas lies in the well-supported agricultural demonstration sites, which provide hands-on skill development and knowledge transfer and facilitate market linkages. Numerous scholars have emphasised the role of information in agricultural technology adoption, as both demonstration sites and markets serve as crucial information centres for farmers (Guiso 2018; Mwalupaso et al. 2019; Neștian et al. 2020; Cariolle 2021; Liu et al. 2021). Access to credit is another critical factor influencing the adoption of agricultural innovations, particularly for farmers constrained by credit. Thus, since the majority of non-participants are credit-constrained, one would expect lower CSA adoption rates. However, this was not the case for non-participants in vibrant areas.

This raises questions about the relative effectiveness of access to information compared with access to credit in stimulating CSA adoption. Although RUSACCOs were primarily established as platforms for credit access for participants, they may indirectly address credit constraints among non-participants, albeit at a relatively higher cost. In support, key informants indicated that some non-participants in vibrant areas are sceptical about the operation of RUSACCOs and may instead seek credit through informal channels, such as shylocks, or by borrowing from RUSACCO participants (particularly since participants are often required to borrow even when they do not need funds at the time), thereby bypassing the formal cooperative system. This informal credit access, combined with the robust information dissemination system of the MAB project, may contribute to higher CSA adoption rates in vibrant areas compared with RUSACCO participants in inactive areas. While other reasons for nonparticipants in vibrant areas not directly joining RUSACCOs and avoiding the relatively higher costs associated with informal borrowing remain unclear, key informants unanimously indicated that some individuals may face challenges in securing a guarantor because of their poor reputation, which could hinder their ability to become cooperative members.

Nonetheless, this finding underscores the importance of credit access and active information centres in designing effective agricultural development interventions. This suggests that interventions aimed at promoting CSA adoption and improving agricultural productivity should prioritise access to credit and the dissemination of relevant information and skills.

Impact of RUSACCOs participation on credit constraints and CSA adoption

Table 5 presents the determinants of RUSACCO participation in Column 1, along with the effects of participation on the outcome variables, which are detailed in Columns 2 and 3. Several factors positively influence RUSACCO participation. These include land size, female-headed households, education (ability to read and write), farming experience, and a longer duration of residence in the community. Market access also plays a significant role, as do participation in demo site activities, possession of information and communication technology (ICT), and involvement in off-farm activities. In addition, a prior positive perception of RUSACCOs was associated with increased participation. These factors also suggest that RUSACCO participation is influenced by individual characteristics

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Table 5. RBP estimations on the determinants of RUSACCO participation, credit constraints and CSA adoption

Explanatory variables	Outcome variables					
	RUSACCO participation (1)		Credit constraints (2)		CSA adoption (3)	
	coefficient	SE	coefficient	SE	coefficient	SE
Constant	–1.052***	0.301	1.991***	0.647	1.582**	0.660
Primary independent	–	–	–	–	–	–
RUSACCO participation	–	–	–0.605***	0.085	0.963**	0.409
Agricultural inputs	–	–	–	–	–	–
Land	0.497***	0.057	–0.453***	0.164	–0.914***	0.123
Fertiliser	0.605	0.564	0.379***	0.100	–0.418***	0.118
Socioeconomic characteristics	–	–	–	–	–	–
Gender	–0.934**	0.367	0.762	0.551	0.222	0.300
Age	–0.297	0.556	0.401	0.330	–0.567	0.365
Education	0.269***	0.077	–0.124***	0.012	0.503***	0.165
Family size	0.357	0.753	0.411	0.423	0.277	0.260
Farming experience	0.034**	0.016	–0.332***	0.061	0.619*	0.338
Residence	0.218***	0.051	0.211	0.134	0.070	0.235
Access characteristics	–	–	–	–	–	–
Market	0.156*	0.086	–0.847***	0.189	0.459**	0.197
Demo site (predicted)	0.754***	0.154	–0.107	0.104	0.248***	0.096
FISP	0.285	1.073	–0.045**	0.022	0.015	0.030
ICT	0.277**	0.107	–0.256	0.570	0.673**	0.279
Wealth characteristics	–	–	–	–	–	–
Asset	0.446	0.351	–0.720***	0.053	0.081*	0.043
Off-farm	0.946*	0.480	0.400	0.438	0.153	0.190
Instrumental variables	–	–	–	–	–	–
Prior RUSACCO perception	0.099***	0.012	–	–	–	–
Off farm residual	0.068	0.974	–	–	–	–
Model diagnostics	–	–	–	–	–	–
Number of observations	–	–	400	–	400	–
Log pseudolikelihood	–	–	–507.436	–	–536.900	–
ρ	–	–	1.773**	0.266	2.211	0.142

*, **, ****P* < 0.1; 0.05; 0.01; respectively; the figures in parentheses are the standard errors of the coefficients; ρ – captures selection bias; CSA – climate smart agriculture; *FISP* – Farmer Inpur Support Programme; *ICT* – information and communication technology; RUSACCO – Rural Saving and Credit Cooperatives; RPB – recursive bivarite probit

Source: Author's elaboration

and is also deeply rooted in the community and economic context in which members operate, consistent with the views of the key informants. This highlights the importance of addressing both social and economic barriers to participation to enhance the accessibility and effectiveness of RUSACCOs.

Application of the RBP model to study the impact of RUSACCO participation on credit constraints and CSA adoption revealed statistically significant associations. Participation in RUSACCOs shows a tendency to alleviate credit constraints and promote CSA adoption. Additionally, factors such as education, participation at demonstration sites, and the use of *ICT* significantly influenced CSA adoption. Education has long been recognised as a key facilitator for learning new skills and information, whereas *ICT* use serves as a valuable source of information, albeit dependent on content, connectivity, and capacity.

Moreover, land size and fertiliser usage are significant determinants of CSA adoption (see Column 3). Specifi-

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cally, households with lower fertiliser use were more likely to adopt CSA practices than those with higher fertiliser use. This suggests that input-constrained households may turn to CSA as a sustainable alternative for improving soil fertility and enhancing productivity. This finding is particularly important given the environmental risks associated with excessive chemical fertiliser use, such as soil degradation and greenhouse gas emissions, which contribute to climate change and threaten long-term agricultural sustainability. Thus, promoting CSA adoption is beneficial for resource-limited farmers, and also crucial for mitigating these adverse environmental effects and fostering sustainable agricultural practices (Arslan et al. 2018; Akter et al. 2022; Mustafa et al. 2024).

Importantly, the positive and statistically significant ρ coefficient indicates the presence of a selection bias, thereby justifying the application of the RBP model. This suggests that unobservable factors influence both RUSACCO participation and outcome variables. Consequently, the estimated results account for potential endogeneity concerns and enhance robustness and reliability.

Table 6 presents the *ATT* estimates derived using the approach developed by Coban (2021). The results indicate that RUSACCO participation significantly alleviates credit constraints by approximately 43% and enhances CSA adoption by approximately 25%. This finding aligns with the insights provided by a key informant, who highlighted that RUSACCO participants from vibrant areas benefit from knowledge acquisition through expert-led sessions hosted by RUSACCOs. These sessions cover topics such as financial literacy, entrepreneurship, and food processing to enhance participants' skills and understanding. Additionally, the injection of seed capital by NGO into RUSACCOs improves borrowing opportunities, contributing to reduced credit constraints among participants.

Table 6. Treatment effects from RBP

Treatment effects	Coefficient	SE
RUSACCO participation on credit constraints	–0.426**	0.205
RUSACCO participation on CSA adoption	0.254***	0.020

**, ***$P < 0.05$; 0.01; respectively; RBP – recursive bivarite probit; RUSACCO – Rural Saving and Credit Cooperatives; CSA – climate smart agriculture

Source: Author's elaboration

Participation in RUSACCOs offers farmers several benefits. First, it provides access to credit, particularly in rural areas, where formal banking services are limited. Second, the flexibility of borrowing funds from a group based on individual needs and repayment capacities allows farmers to invest in sustainable practices when needed. Third, savings groups operate on a smaller scale, with lower overhead costs, making credit more accessible and affordable for farmers. Finally, participation in savings groups fosters the development of financial management skills including budgeting, savings, and debt management. By learning these skills and building a positive credit history within the group, farmers become better equipped to adopt CSA, make informed investment decisions, and manage resources efficiently (Haryanto et al. 2023). Overall, savings groups empower farmers to invest in more sustainable and prosperous futures for themselves and their communities.

Robustness checks

This section presents the robustness checks based on the PSM approach. Before discussing the results, it is essential to verify that an adequate match was achieved by ensuring a balance in observable characteristics between the treated and untreated groups, thereby reducing bias in observable characteristics (Rosenbaum and Rubin 1983; Sianesi 2001). Figure 2 demonstrates that the matching process successfully balances the characteristics of the treated and untreated groups, thereby establishing a region of common support. Figure 3 illustrates a significant reduction in bias after matching, confirming the comparability of the two groups and enhancing the reliability of the estimated effects.

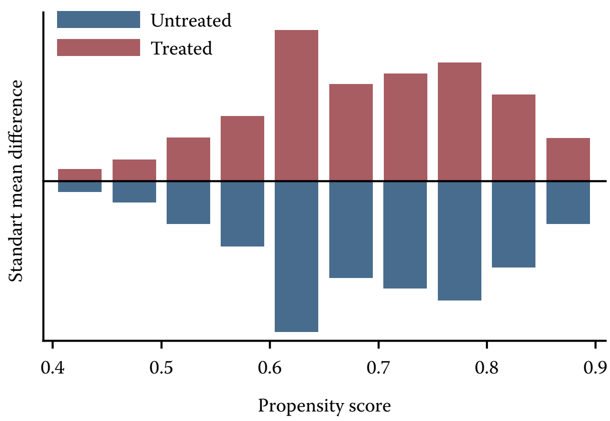

Figure 2. Balancing of covariates between the treated and untreated groups

Source: Author's own elaboration

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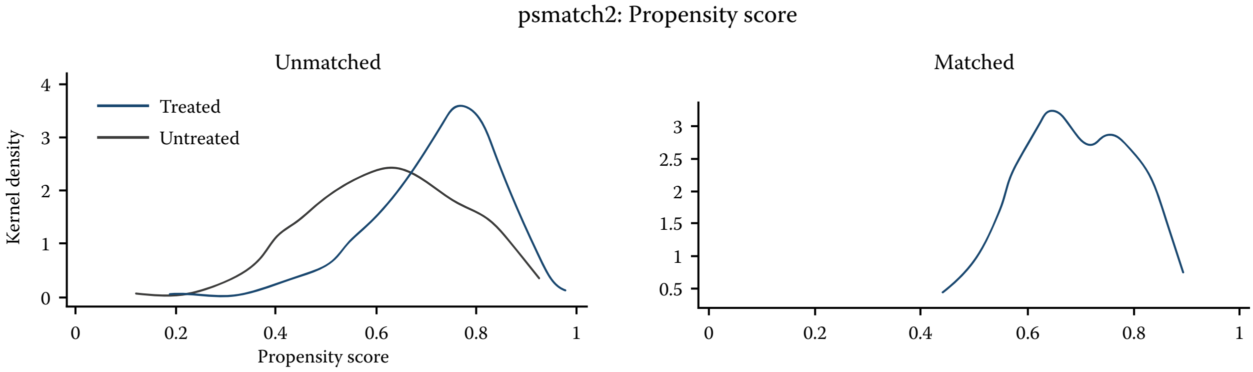

Figure 3. Bias reduction before and after matching

Source: Authors own elaboration

The robustness check using PSM, shown in Table 7, further supports the empirical evidence that participation in RUSACCOs leads to higher CSA adoption. Although there are some differences in the values because PSM does not account for unobserved characteristics, the general trend indicates a positive association between RUSACCO participation and CSA adoption. This finding is logical because if RUSACCO participation helps alleviate farmers' constraints, participants would be expected to show significant CSA adoption. Notably, the presence of a demonstration site within the MAB project areas, functioning as an information hub for sustainable agricultural practices and market linkages, reinforces this argument (Singh et al. 2018). This underscores the need to move beyond enhancing farmers' access to credit. While the latter is crucial, it does not guarantee market access, the provision of necessary inputs, or the adoption of agricultural technologies on its own. Equally important is the provision of relevant and timely information to enable farmers to make informed credit decisions. This critical aspect is often overlooked in credit access initiatives and the academic literature; however, it plays a fundamental role in ensuring the effectiveness and long-term sustainability of agricultural development efforts (Belay 2003; Adamsone-Fiskovica et al. 2021).

Implications for policy

The analysis of treatment effects was extended by considering both constrained and unconstrained farmers, as shown in Table 8. Across all cases and categories, participants demonstrated higher adoption levels than in the counterfactual scenario, in which they had not participated. To further understand the relationship among RUSACCO participation, credit constraints, and CSA adoption, we calculated the potential effects of alleviating existing credit constraints.

Overall, if credit constraints were alleviated among farmers participating in the constrained USACCO,

Table 7. Treatment effects from PSM

PSM approach	Impact of RUSACCO on credit constraints				Impact of RUSACCO on CSA adoption			
	mean		*ATT* (SE)	change (%)	mean		*ATT* (SE)	change (%)
	treatment	control			treatment	control		
Nearest neighbor	0.336	0.645	–0.309*** (0.040)	–47	0.523	0.410	0.113** (0.040)	28
Kernel	0.287	0.574	–0.287*** (0.090)	–50	0.760	0.523	0.237*** (0.070)	45
Radius	0.250	0.646	–0.396*** (0.020)	–61	0.573	0.408	0.165*** (0.030)	40

*, **, ****P* < 0.1; 0.05; 0.01; respectively; RUSACCO – Rural Saving and Credit Cooperatives; CSA – climate smart agriculture; PSM – propensity score matching; *ATT* – average treatment effect

Source: Author's elaboration

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Table 8. CSA adoption treatment effect by credit constraints status

Status	Mean		*ATT* (SE)	*ATT* (%)	Difference (%)
	CSA adoption with RUSACCO participation	CSA adoption with RUSACCO participation			
Constrained	0.301	0.272	0.030* (0.016)	11	14
Unconstrained	0.613	0.490	0.123** (0.050)	25	
Price constrained	0.350	0.313	0.037** (0.016)	12	4
Unconstrained	0.624	0.539	0.084*** (0.031)	16	
Quantity constrained	0.373	0.312	0.060* (0.032)	19	14
Unconstrained	0.729	0.549	0.180*** (0.040)	33	
Risk constrained	0.213	0.195	0.018** (0.009)	9	12
Unconstrained	0.541	0.447	0.093*** (0.020)	21	
Transaction cost constrained	0.270	0.266	0.004 (0.010)	2	30
Unconstrained	0.561	0.425	0.136*** (0.070)	32	

*, **, ****P* < 0.1; 0.05; 0.01; respectively; the figures in parentheses are the standard errors of the coefficients; difference is the impact of alleviating credit constraints ($ATT_{Unconstrained} - ATT_{Constrained}$); RUSACCO – Rural Saving and Credit Cooperatives; CSA – climate smart agriculture; *ATT* – average treatment effect

Source: Author's own elaboration

the CSA adoption rate would increase by approximately 14%. The significant impact of reducing transaction costs, which could potentially improve CSA uptake by 30%, is particularly noteworthy. This finding highlights the critical need to simplify the process of securing guarantors at RUSACCOs. Although intended as an insurance and risk-management measure, the complexity of this requirement often prevents farmers from accessing credit. Streamlining this process could substantially improve farmers' abilities to adopt CSA.

Additionally, we conducted a spillover regression analysis to explore the impact of RUSACCO participation in facilitating credit access for non-participants, because understanding spillover effects is crucial for the cost-effectiveness of funded projects. We sought to answer the following question: Are there any indications that the benefits of RUSACCO in terms of CSA adoption extend beyond direct RUSACCO participation in the intervention area (MAB)?

Table 9 reveals a statistically significant difference in CSA adoption between participants and non-participants in vibrant RUSACCO areas [scenario *i*)] and between non-participants in vibrant RUSACCO areas and participants in inactive RUSACCO areas [scenario *ii*)]. Although non-participants in vibrant areas exhibit lower levels of CSA adoption than participants in inactive areas, they still demonstrate significantly higher adoption rates. Furthermore, there is no significant difference in CSA adoption between participants and non-participants in inactive areas [scenario *iii*)], indicating that non-participants from vibrant areas adopted CSA more than those in inactive areas. This points to weak spillover effects, suggesting some degree of cost-effectiveness of the program. Ideally, to fully demonstrate

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Table 9. Spillover effect estimation

Participant – vibrant	Non participant – vibrant[a]	*ATT*	%
0.546	0.486	0.060* (0.035)	12
Non participation – vibrant	participant – inactive[a]	*ATT*	%
0.486	0.461	0.025* (0.015)	5
Participant – Inactive	non participant – vibrant[a]	*ATT*	%
0.461	0.456	0.006 (0.010)	1

*$P < 0.1$; the figures in parentheses are the standard errors of the coefficients; the percentage was calculated by dividing *ATT* by [a]

Source: Author's own work

the cost-effectiveness of a program, CSA adoption must show no statistically significant difference between participants and non-participants in vibrant areas. Ideally, to fully demonstrate a program's cost-effectiveness, CSA adoption should show no statistically significant difference between participants and non-participants in vibrant areas. While this ideal scenario has not yet been achieved, the current findings represent a positive step forward as non-participants in vibrant areas already exhibit significant CSA adoption.

On the other hand, the results in Table 9 provide valuable scholarly and policy insights. First, the *ATT* of 12% in scenario *i*) reveals that CSA adoption in vibrant areas is significantly influenced by credit access and information dissemination, which are more pronounced in these areas. Second, scenario *ii*) highlights the significant role of information dissemination in CSA adoption, contributing to a 5% higher adoption rate. Third, scenario *iii*) suggests that focusing solely on financial inclusion is likely to lead to a modest 1% increase in CSA adoption. It is important to note the limited diffusion of innovation, as evidenced by the relatively lower CSA adoption rate among participants in inactive areas compared with non-participants in vibrant areas. This emphasises the minimal impact of credit access alone in the absence of hands-on knowledge dissemination. Thus, both access to credit and provision of information are critical factors driving CSA adoption.

The findings highlight four crucial policy implications: enhancing RUSACCO activities, intensifying hands-on agricultural extension services, stimulating participation in off-farm activities, and improving market access and *ICT* usage.

First, it is evident that RUSACCO, when coupled with vibrant hands-on field schools, such as demo sites and other agricultural extension services facilitated by lead farmers, significantly improves CSA adoption. Importantly, merely improving credit access could stimulate CSA adoption by 1%, but when combined with hands-on extension, there is an additional 11% potential. Given the increasing vulnerability of agriculture to climate risk due to climate change, farmers require extensive information regarding useful adaptation strategies and farm resource management (Jensen 2010; Mwalupaso et al. 2021). The wide adoption of CSA can facilitate agricultural sustainability, environmental conservation, and livelihood improvement, contributing to the achievement of SDGs 2 (poverty alleviation) and 13 (climate action).

Second, stimulating participation in off-farm activities, particularly entrepreneurship, could facilitate participation in RUSACCO. Many smallholder farmers in rural Africa lack the innovation to start business ventures that could support their main farming activities, leading to credit constraints. Policy support measures aimed at promoting farmers' participation in income-generating off-farm activities, such as tax incentives, can facilitate participation in RUSACCO, improve cash availability for credit, and increase interest in savings.

Finally, ensuring effective market linkages and ICT integration is essential for repurposing the role of RUSACCO in farming communities. Many smallholder farmers face challenges in selling their products at favourable prices because of limited market information and the strong bargaining power of buyers, which subsequently reduces their likelihood of participating in RUSACCO (Brunie et al. 2017; Sharma and Zhao 2017; Balana and Oyeyemi 2022; Schoofs 2022). Therefore, policies designed to enhance market linkages and ICT utilisation for mobile banking and access to market information can significantly improve financial inclusion and alleviate farmers' credit constraints.

CONCLUSION

Agriculture serves as a crucial livelihood for many people worldwide; however, a significant proportion

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of rural farmers encounter challenges in accessing formal credit, exacerbated by the impacts of climate change. In response, NGOs in developing nations are increasingly promoting RUSACCOs; however, there is a dearth of empirical evidence on their efficacy in addressing credit constraints and facilitating CSA adoption. Given the growing prevalence of RUSACCOs, this study aimed to provide micro-level evidence on the impact of RUSACCO participation in alleviating credit constraints and promoting CSA using data from four MAB districts in Zambia. We exploited our sampling framework and used two-stage RBP and PSM approaches to control for bias stemming from program placement, selection, and endogenous covariates.

Our findings from Zambia reveal that 65% of farmers experience credit constraints, with 33% located in vibrant and 67% in inactive RUSACCO areas. Importantly, participation in RUSACCOs helped mitigate these constraints by approximately 43%, thus significantly reducing the financial barriers faced by farmers. Furthermore, participation in RUSACCOs was associated with a 25% increase in CSA adoption. Notably, a reduction in credit constraints, especially those related to transaction costs, appeared to play a crucial role in optimising CSA adoption.

Our study also highlighted that improving credit access alone was insufficient to drive CSA adoption. Credit access must be coupled with practical hands-on information dissemination to facilitate the adoption of new agricultural technologies. Additionally, market linkages play a critical role in motivating RUSACCO participants to adopt CSA, as they contribute to increased crop productivity, savings, and improved cash flow within rural communities.

The results indicated a notable difference between the vibrant and inactive RUSACCO areas. Farmers in vibrant areas with better access to both credit and information demonstrated higher CSA adoption rates than their counterparts in inactive areas. This highlighted the importance of creating vibrant, well-supported RUSACCOs that provide financial resources, as well as market and information linkages.

Importantly, although RUSACCOs have the potential to significantly alleviate credit constraints and promote CSA adoption, their impact is maximised when accompanied by effective knowledge-sharing initiatives and improved market access. These findings suggest that integrated approaches that combine credit access, information dissemination, and market linkages are essential for building the resilience and prosperity of rural farming communities in Zambia and other similar contexts.

Finally, although our study employed a robust empirical strategy, it has limitations. It relied on self-reported measures from farmers regarding their participation in agricultural demonstration sites and *ICT* usage, which could affect the accuracy of the estimates (Wossen et al. 2019; Amadu 2020). Furthermore, this study did not account for whether RUSACCOs influence the adoption of multiple CSA practices or specific CSA portfolios, potentially overlooking key decision-making factors faced by farmers. Despite these limitations, our study provides compelling empirical evidence that controls for key sources of endogeneity. Future research should consider using panel data to deepen our understanding of RUSACCO dynamics and their impact on farmers' crop production efficiency.

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