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Sustainable Landscapes for Eastern Madagascar – A Midterm Impact Evaluation☆

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ABSTRACT

The Sustainable Landscapes in Eastern Madagascar project aims to increase the resilience of smallholder farmers and reduce carbon emissions by implementing climate-smart agriculture and more sustainable forest management in the two remaining large blocks of forest in the eastern part of Madagascar, covering 660,000 hectares in 15 districts. We present findings from a midterm clustered phase-in evaluation. Baseline data was collected in early 2019 from 1822 households in local community associations. A total of 1654 were successfully re-interviewed in late 2022. Midline results show widespread adoption of a range of conservation agriculture practices, with early project recipients showing increased adoption rates of up to 20 percentage points greater than comparison households, including soil conservation measures (2–13 pp), agroforestry (2–6 pp) and the use of drought-resistant crops (2–6 pp). Further, household food security using the consolidated approach for reporting indicators of food security shows improvement across intention-to-treat, local average treatment effect and difference-in-differences specifications. In terms of forest use, fewer beneficiaries report deriving income from unsustainable activities in both summer (1 pp) and winter (4–7pp) seasons.

1. Context and challenges

Madagascar remains one of the poorest countries in Africa, with 75 per cent of the population living on less than USD 1.90 a day in 2019 and a per capita gross national income (in constant 2015 USD) of USD 471.95 (World Bank, 2020). The country is particularly vulnerable to climate hazards. It has been ranked twelfth of 183 countries in terms of the Climate Risk Index for the period 2000–2019 (Eckstein, 2018), and the severity of climate hazards is expected to increase in the following years. In terms of impacts on natural systems, Ingram and Dawson (2005) have highlighted how Madagascar's vegetation cover is highly correlated with the El Nino Southern Oscillation. This meteorological phenomenon is likely to become more frequent with climate change, leading to thinner vegetation cover and increasing the likelihood of droughts and wildfires. More recent estimates by Hending and others (2022) suggest that forest cover is likely to reduce under four climate scenarios by 2080 due to higher temperatures and more variable precipitation (with one exception in the northwest of the country).

1.1. *Forest corridors under threat*

Currently, the two remaining large areas of forest in the eastern part of Madagascar are the *Ankeniheny-Zahamena* Forest Corridor (CAZ) and the *Ambositra-Vondrozo* Forest Corridor (COFAV) (Ministère de l'Environnement, de l'Ecologie, de la Mer et des Forêts 2015a, b). CAZ consists of 370,000 ha covering five districts, whereas COFAV covers 290,000 ha

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in 10 districts. Both are characterized by a mosaic of lowland, humid tropical forests and agricultural lands with an extremely rich diversity of flora and fauna. In the last 10 years, both corridors have experienced several anomalies in precipitation patterns with several periods wetter than usual and some drier than usual. The frequency and intensity of cyclones are expected to increase by the end of 2100 because of climate change (Hending and others, 2022).

1.2. Vulnerability of smallholders

The unsustainable use of forest resources threaten these natural areas due partly to poverty and the lack of alternative livelihoods for citizens surrounding the boundaries of the protected areas. In CAZ, Malagasy citizens collect yams, sweet potatoes, honey and forest material for handicrafts. They also collect shrimps, fish and eels from local waterways. Forest products, including firewood, also complement income-generating activities. In COFAV, most citizens cultivate rice, cassava, coffee, beans, lychees and bananas. In addition, they collect crayfish and cultivate brown sugar for brewing alcoholic beverages. Ginger cultivation has become popular in the past few years. Vanilla and pepper have also been introduced.

Harvey and others (2014) assessed smallholder vulnerability to sources of risk in three areas of Madagascar, including CAZ and *Nosivolo* in the east of the country. Their findings highlight how smallholders rely heavily on agriculture, suffer from long-term food insecurity, and are often far from urban services. Further, they tend to have limited access to formal safety nets. For example, survey evidence from 600 households illustrates how smallholders are subject to substantial crop losses and limited income. Cinner and others (2022) offer recent estimates from a survey of 339 households in coastal communities in Madagascar, which highlight the chronic poverty of many smallholders and how climate impacts will be differentiated across and within communities. Weiskopf and others (2021) outline how tackling forms of vulnerability relies on the sustained engagement of communities with multiple stakeholders across sectoral and institutional boundaries to relieve multiple binding constraints.

The Sustainable Landscapes for Eastern Madagascar (SLEM) project, started in 2018 and implemented by Conservation International Madagascar, aims to reduce the vulnerability of households to climatic shocks and their dependence on forest resources in CAZ and COFAV, thereby safeguarding forest areas. We present findings from a midterm evaluation which used a clustered randomized phase-in design. The midline evaluation of SLEM impacts enables us to gauge the project's progress towards its longer-term objectives.

The article is presented in the following order. Section 2 describes the SLEM project, and introduces key evaluation questions and indicators used in this study. Section 3 describes the evaluation strategy. Section 4 presents the results, followed by a discussion. Section 5 appraises and presents concluding remarks.

2. Introduction to the SLEM project

The SLEM project's overarching goal is to implement sustainable landscape measures to enhance smallholders' resilience, reduce GHG emissions from deforestation, and make climate-smart investments on agricultural lands (Independent Evaluation Unit, 2020). Adaptation activities include the provision of training, inputs and mentoring to smallholder farmers to promote sustainable agricultural production, ecosystem-based adaptation, alternative sources of livelihood and enhance market access. In addition, mentoring from experienced farmers, field agents, and technicians use demonstration plots and communities have worked alongside the project team to develop proposals for coping mechanisms based on needs and interests related to the project's main objectives (Green Climate Fund and Conservation International, 2020, 2021, 2022).

Regarding mitigation activities, the project provides training, stipends and equipment to conduct forest patrolling activities and physically demarcate the limits of the protected areas. Local *Vondron'Olona Ifotony* (VOI – local forest management groups), also referred to as

Communautés de Base (COBAs – local communities), have conducted forest patrolling activities as part of wider forest management practices. Where significant illegal activities occurred, multiple stakeholders conducted forest control measures under the lead of the *Directions Régionales de l'Environnement et du Développement Durable* (DREDD – Regional Directorates for the Environment and Sustainable Development) law enforcement agency. Furthermore, forest nursery workers have been produced forest and agroforestry seedlings, while local communities have participated in tree planting for forest restoration.

Project activities have engaged 23,800 households, including members of COBAs for local forest management and local associations (notably, women associations and people affected by the creation of protected areas groups). COBAs were created under Decree No 2000–027 in which local communities are responsible for managing renewable natural resources. Volunteers create these COBAs from either hamlets of the same village or several villages. Most COBA members are involved in agricultural activities and rely on forest resources. Since 2012, the *Ministère de l'Environnement et du Développement Durable* (MEDD – Ministry of Environment and Sustainable Development) has delegated CI to oversee the Protected Areas Management of both CAZ and COFAV. In this respect, the SLEM project is responsible for supporting the management plans of CAZ and COFAV-protected areas, supporting the sustainable use of natural resources, forest protection and reducing carbon emissions. Project implementation was affected by the COVID-19 pandemic. CI-M followed government instructions and imposed COVID-19 travel restrictions for the entire country between March 2020 and December 2020. Therefore, only a small subset of the planned activities was implemented during this period including a limited number of forest control and local forest patrols and a limited number of assessment missions in late 2020. Limited travel to the field reduced forest patrols, with 1104 out of 4400 target forest patrols conducted in 2020 by 69 COBAs. In 2020, no new household beneficiaries received project inputs. Limited patrolling, combined with social and economic factors emanating from the COVID-19 pandemic, led to an increase in the illegal exploitation of forest natural resources and illegal mining

3. Evaluation approach

As part of the Learning Orientated Impact Assessment (LORTA) programme of the Green Climate Fund (see Puri et al., 2020), the evaluation team used an experimental design to capture the project's short-term impacts at midline through deploying a clustered randomized phase-in evaluation.

Project activities were delivered in three phases. For this SLEM midline evaluation, we compared the first phase of beneficiaries (Phase 1) with the final phase (Phase 3). There are two main reasons for this clustered phase-in design. First, the project's outcomes of primary interest, namely food security, vulnerability and deforestation, will likely evolve slowly over time. Hence, comparing Phase 1 with Phase 2 after only one year of project implementation did not seem cost-effective. Instead, focusing on the first and third phases of the roll-out allows us to measure the project's impacts after 30 months of intervention in Phase 1 areas. Second, some groups were ineligible for randomization and were excluded from the evaluation. We allocated these groups to the second phase of the project implementation.

To account for the geographic heterogeneity of the intervention area and the size of the forest covered by the COBA, and following discussions within the project team, we opted for stratified randomization. The stratification comprises three levels: geographic location, the area of forest surface the COBA is responsible for, and the number of COBA members. The geographic location stratification was based on four geographic areas: the northern and the southern regions of COFAV and the eastern and western regions of CAZ. The latter two levels of stratification are determined as follows: (i) three quantiles of the surface of the forest covered by the COBA, measured in hectares and (ii) two quantiles of the size of the COBA, measured by the estimated number of group members. The stratification ensures that the proportion of these regions and groups is similar across the phases. Two advantages arise from this approach. First, by gaining control of the sample's composition, we improve the precision in estimating the programme's impacts and achieve more balance on important characteristics between treatment and control COBA. Second, it ensures the representativity of these subgroups in each phase. From the pool of COBAs eligible for randomization, we randomly assigned 51 COBAs to the programme's first phase and 50 COBAs to the third phase.

CAZ and COFAV areas differ in geographic location, population and biodiversity. As such, the impacts of SLEM adaptation activities are also analysed separately by CAZ and COFAV locations to examine whether the project's ability to affect households' livelihoods differs according to the location of the residence. To explore gender differences, the impacts are also estimated separately by the gender of the household head. Finally, two other dimensions of heterogeneity are considered: (i) initial level of vulnerability and (ii) distance to forests. Each of these variables is interacted with the treatment dummy to assess whether the impacts of SLEM adaptation activities differ with greater vulnerability and distance to forests. Households with differing levels of vulnerability and distance to forests may face different constraints and opportunities, limiting or enhancing the project's impacts. The sample size was intentionally designed to detect impacts in the whole sample. Hence, every subgroup analysis will suffer from a reduction in statistical power.

A cluster randomized phase-in design assumes that with a sufficiently large number of units – individual COBAs in this case – randomly assigned to Phase 1 are, on average, similar to those assigned to Phase 3 on both pre-treatment observable and unobservable characteristics. A clustered randomized phase-in design also guarantees bias-free estimation of the causal effects of the SLEM adaptation activities even in cases where treatment and control units differ on at least one observable characteristic, a result that could occur by chance (Mutz, Pemantle and Pham, 2019). If statistically significant differences in baseline characteristics are identified, the robustness of the results is assessed by estimating regression specifications, with and without the unbalanced characteristics as covariates. Details on the exact regression specifications estimated are outlined below. Further risks within the design include anticipation effects, contamination of the control group, attrition and imperfect compliance, which were mitigated to the extent possible. For example, there is some evidence of contamination due to the delays in implementing the midline survey. In this respect, the project's impact estimates may represent a lower bound of the programme's potential impact in the absence of these effects. We present details on differential attrition below as well as the specifications used.

4. Identification strategy and empirical strategy

The causal effects of the SLEM project were identified by comparing the average outcomes in treatment COBAs in Phase 1 with average outcomes in comparison COBAs in Phase 3. As COBA members may choose not to participate in the SLEM activities, the estimated impacts correspond to intention to treat (ITT) effects. ITT are the impacts of having randomly assigned COBAs into Phase 1, irrespective of the actual reception of SLEM benefits.

$$\beta = \overline{y_{p1}} - \overline{y_{p3}} \tag{1}$$

β captures the causal effect of being randomly assigned to receive the SLEM activities on the outcomes of interest. In this equation, this causal effect is obtained by comparing the average outcome in treatment COBAs, $yp1$, with the average outcome of comparison COBAs, $yp3$. β was formally estimated within a linear regression framework, with the most basic specification shown in Eq. (2).

$$y_{ji} = \alpha + \beta T_i + Strat_i + \varepsilon_i \tag{1a}$$

where $Strat_i = N\_COFAV_i + S\_COFAV_i + E\_CAZ_i + S1_i + S2_i + N1_i$

In (2), y_{ji} represents each respective outcome of interest in household $_j$ located in COBA$_i$, α is a constant while β represents the difference in the average outcome of interest between treatment and comparison households and will be obtained as the coefficient of a treatment dummy T_i, which takes the value 1 if household $_j$ is located in a Phase 1 COBA and 0 otherwise. In order to account for the stratification in the randomization, various sets of stratification dummies, represented by $Strat_i$ are included.

Specifically, N_COFAV_i, S_COFAV_i and E_CAZ equalled 1 if COBA$_i$ was located in either the north (N) or the southern (S) regions of COFAV or the eastern (E) regions of CAZ, respectively, and 0 otherwise. COBAs in the western regions of CAZ served as the omitted reference category.

Additionally, stratification dummies $S1_i$ and $S2_i$ equalled 1 if COBA$_i$ was located in the largest two categories of the forest surface area that the COBA was responsible for and 0 otherwise. For this stratification, the forest surface area for which the COBA was responsible was divided into three categories of equal size based on its distribution, with stratification dummies for the first and second largest categories included in the above specification and the smallest category being the omitted reference category. The first category includes forest surface areas, ranging from (i) 40 to 936 hectares, (ii) 1000 to 2500 and (iii) 2506 to 11,108. Similarly, the number of COBA members was also divided into two categories of equal size based on its distribution. Thus, a stratification dummy $N1_i$ equalled 1 if COBA i was located in the largest category $N1_i$ and 0 otherwise was also included, with the smaller category as the omitted reference category. The first category includes COBA with 15 to 70 members, while the second includes 73 to 500 members. ε_i in Eq. (2) represents the error term clustered at the COBA level.

While estimating Eq. (2) within the context of a cluster randomized phase-in design guaranteed that β could be estimated free of any selection bias, the precision of estimates of this parameter could be increased by including control variables highly correlated with each outcome of interest. Such a regression specification is shown in equation (3), where X_{ji} represents characteristics of household $_j$ located in COBA$_i$ that was included as control variables in the regression.

$$y_{ji} = \alpha + \beta T_i + X_{ji} + Strat_i + \varepsilon_i \tag{2}$$

X_{ji} are selected based on their correlation with outcomes of interest. We include variables that showed an imbalance at baseline (see 4.1), those highlighted in the attrition analysis (see 4.3). strata fixed effects (4.2) as well as the baseline value of the outcome of interest.

Estimating the causal effects of the SLEM activities was based on a representative sample of households with at least one member taking part in a COBA in CAZ and COFAV and not the entire populations in these areas. To ensure the estimates based on this sample are representative of the target population in CAZ and COFAV (i.e., Phase 1 and Phase 3 COBA members) from which they are sampled, sampling weights equivalent to the inverse probability that an observation in the target population is sampled, were included in the analysis.

4.1. Robustness

At baseline, while treatment COBAs randomized to Phase 1 and comparison COBAs randomized to Phase 3 were broadly similar in terms of sociodemographic characteristics, several differences in other observable characteristics were noted, including differences in the distribution of some types of livestock raised, forest products (including coffee), and strategies implemented to reduce sensitivity to climate-related hazards (such as using rice during a drought in the off season). Differences were also found for multi-cropping, improving or creating grain storage, animal production, forest and tree products, shocks and household fruit consumption. Equation (3) above permits us to directly control for these observable differences between the Phase 1 treatment group and the Phase 3 comparison group in the analysis.

Due to the potential for substantial non-compliance with treatment assignment in the treatment and/or comparison groups, we utilise an instrumental variable (IV) analysis. This is because actual treatment take-up, represented by T_i in Eqs. (2) and (3) above can no longer be considered randomly assigned. In the IV analysis, the random assignment to treatment (to Phase 1) will first be regressed on actual treatment take-up T_i and fitted values from this regression will then be regressed on the outcomes of interest as per Eqs. (2) and (3). In this way, randomized assignment to treatment was used as an instrument for treatment actually taken up. This implies randomized assignment to treatment impacts the outcomes of interest only through its causal impact on actual treatment take-up, T_i. Estimates obtained this way are interpreted as Local Average Treatment Effects (LATE) on the compliers

The availability of data at two different time periods (baseline and midline) and two separate groups (treatment COBAs randomized to Phase 1 and comparison COBAs randomized to Phase 3) allows us to test the robustness of our results to different identifying assumptions. Specifically, we utilize a random effects regression specification within a Difference-in-Differences (DiD) design, which relies on the parallel trends assumption. Estimating this specification permits us to explicitly account for any time-invariant unobservable differences between the two groups and to assess if our results remain similar to those obtained based on the cluster randomized phase-in design. To summarize, we report three sets of midline impacts: (i) estimation of the ITT, (ii) estimation of the LATE, and (iii) estimation of DiD impacts with random effects (RE).

4.2. Sample strategy and sample size

4.2.1. Sampling strategy and rationale

As explained above, to account for the geographic heterogeneity of the intervention area and the varying size of forest covered by COBAs, the team used a stratified randomization for sample selection. The stratification ensures that the proportion of each of these regions and groups is similar across the phases of project implementation. Two advantages arise in doing so. First, gaining control of the sample's composition improves the estimation of the project's impacts. Second, it ensures that subgroups are represented in each phase. The number of households interviewed in the survey was determined at baseline by power calculations and the limited budget for the evaluation. Through the evaluation design, we account for differences between the first beneficiary group (COBA members from Phase 1) and the comparison group within the area of intervention (COBA members from Phase 3). At a later stage, an endline survey will allow further estimates of long-term impact between the first beneficiary group (Phase 1) and a comparison group outside the areas covered by COBAs through a DiD with matching approach).

4.2.2. Power calculations and statistical assumptions

The sample size was estimated for a power of 80 per cent and a level of statistical significance of 5 per cent. Since we considered a clustered design, we accounted for the similarity of members within the same COBA, as measured by the intra-cluster correlation coefficient, which compares the variance in outcomes of interest (for this calculation, food insecurity) within and between clusters. To estimate the variance of outcomes of interest, the evaluation team used the Afrobarometer (2018), a nationally representative household survey. As we are considering three groups (Phase 1 COBAs, Phase 3 COBAs, and the outside comparison group for the endline survey), sample size calculations returned 2,478 households to be interviewed at baseline.

4.2.3. Group breakdown and operationalization

The target number of 826 per group was increased by 10 per cent to account for potential attrition. As such, a total sample of 2730 households were interviewed at baseline. An equal number of households per cluster (i.e., COBA for the project's intervention area and fokontany for the outside comparison group) was randomly selected from lists of COBA members and fokontany inhabitants. Among the latter, households not involved in crop farming were excluded from the survey and replaced by the next household randomly selected in the same fokontany. The baseline sample comprised 1822 households from the SLEM's intervention area (966 households from Phase 1 and 846 from Phase 3) and 908 households outside SLEM's intervention area, giving us a total of 2730 households.

4.3. Attrition

The majority of households interviewed at baseline could be interviewed at midline, with an attrition rate of 9.2 per cent (168 observations). This rate is lower than the anticipated buffer of 10 per cent and the loss in sample size does not reduce power. The two main reasons why these households could not be surveyed at midline were migration (33.3 per cent) and not being available at the time of the survey due to a family event, family visit, travel or hospitalization (32.7 per cent). The reasons vary slightly between Phase 1 and Phase 3 households. We explored differential attrition by running a probit regression for the whole sample interviewed at baseline. The independent variables are taken from the baseline survey and, as is widespread in the literature, consist of key sociodemographic characteristics of the baseline household head, household characteristics and livelihood indicators. Our final regressions include 1803 out of 1822 households interviewed at baseline because of missing values on some independent variables.

4.3.1. Reasons for treatment households staying in the sample

For Phase 1 households, a number of variables decrease the probability of dropping from the sample such as being a household from the Betsileo ethnic group. We also find two variables statistically significant at the 10 per cent level: households residing further from the closest forest and households with more children were less likely to drop from the sample.

4.3.2. Reasons for control households staying in the sample

For Phase 3 households, being marginally or moderately food insecure or having more land decreased the probability of dropping from the sample. Moreover, being a resident in the CAZ decreased the likelihood of taking part in the midline. In addition, distance to the closest forest was significant at the 1 per cent level with distant households less likely to participate in the midline survey.

Overall, the more food insecure the household at baseline, the lower the likelihood of departure from the sample. One way to understand this is that more food insecure households saw future benefits from the programme and were thus more likely to remain within the sample. Further, results from the logged land variable suggests that households with more land were more likely to continue to participate in the survey. A 10 per cent increase in the size of land ownership at baseline increases the probability of participating in the midline survey by 2.2 percentage points. All significant variables were included as covariates in equation (3) above, and were corrected for in estimations.

4.4. Data

The midline questionnaire was developed from the baseline instrument with additional questions on COVID-19, participation in project activities and perceptions about the project. A total of 37 enumerators and supervisors, including both men and women, oversaw data collection. In total, 1822 households were highlighted to take part in the midline survey for (732 for CAZ and 1090 for COFAV). The questionnaire was translated into Malagasy, and all interviews were conducted in this language. Enumerators used a mobile phone or tablet to record information. The technical specifications required were a mobile phone or tablet with at least Android 9 to support Kobo toolbox, 2GB RAM and available memory to store the data. Enumerators used solar panels and power banks to ensure they had enough power to collect the data. The data quality process followed four levels. All levels were supervised by CI Madagascar staff. The first level was performed directly during the interviews by enumerators. The second level of control was performed by chief enumerators, who checked that the implementing enumerators fully and accurately filled out the questionnaire. In particular, they checked whether there were missing or unclear responses. The chief enumerators also checked that the respondents' names were reported correctly. Two consultants and CI's monitoring and evaluation manager performed a third level of control in Antananarivo. Data calculation was verified, and calls with enumerators/chief enumerators were organized for clarification or additional elements. Finally, during the fourth level, monitoring and evaluation staff checked that the *fokontany*, commune, region and households coding was accurate and highlighted irregularities in the responses. SPSS software was used to clean the data set and highlight inconsistencies in the responses.

5. Results

We report three sets of midline estimates which cover both adaptation and mitigation indicators (see Prowse and Snilstveit, 2010,) The estimation of the Intention-to-Treat effects, estimation of the Local Average Treatment Effects using initial randomisation as an instrument, and Difference-in-Differences impacts with random effects. The ITT estimates measure the impacts of belonging to a household member of a COBA assigned to receive SLEM interventions in 2019 (Phase 1 COBAs), irrespective of the actual reception of SLEM interventions. In contrast, the LATE estimates measure the impacts of the SLEM on households of the sample that reported having benefited from one or several SLEM activities. The DiD estimates also measure the impacts of belonging to a household member of a COBA assigned to receive SLEM interventions in 2019 (Phase 1 COBAs). In contrast to the ITT estimates, this method compares changes in outcomes between Phase 1 and Phase 3 households before and after the start of SLEM intervention in Phase 1 areas. DiD estimates account for initial differences between Phase 1 and Phase 3 households. We display results from the specification with the widest range of covariates. The main specification presented below includes the following set of covariates: randomization strata fixed effects, key household characteristics at baseline (gender of head, age, ethnicity, number of adults, number of children, education level, land ownership in logged hectares), key baseline outcome variables (food security status and logged expenditures) as well as variables that differed significantly at baseline and those that did so when testing for differential attrition. Estimates from three further specifications are available on request. Results are reported according to the evaluation questions and indicators in Tables 1 and 2, showing adaptation and mitigation activities respectively.

5.1. EQ1 – types and number of livelihood strategies

Our first evaluation question assesses whether the project changed the types and numbers of livelihood strategies conducted by households. We assess changes in the main sources of livelihoods across farm livelihoods (crop farming, livestock farming), off-farm livelihoods (fisheries, harvesting wild forest products, harvesting timber) and non-farm livelihoods (public work, construction and other non-farm livelihoods activities such as running a grocery, a hair salon or a repair shop). We also look at the number of crops households grew and average livestock holdings.

Table 3 shows the results of our impact estimates on the proportion of households conducting farm, off-farm and non-farm livelihood strategies within treatment and control groups. The increase in the proportion of treatment households conducting farm activities across both seasons is limited (1 to 2 percentage points). We observe a more meaningful increase for non-farm activities, with Phase 1 households 2–7 percentage points more likely to participate in non-farm activities (wet season) and 7–8 percentage points in the dry season as shown by ITT and LATE estimates. The DiD estimates did not show significance. Changes in off-farm activities show a mixed pattern, with treatment households showing a very small increase in the wet season (1 percentage point) and a broadly similar decrease in the dry season.

Table 1
Adaptation evaluation questions and indicators.

Activity	Question	Indicator
Adaptation	EQ1. Does implementing adaptation activities lead to an increase in the number of livelihood strategies used?	EQ1.1. Livelihood diversification
		EQ1.2. Number of crops and livestock used by the household
	EQ2. Does implementing adaptation activities lead to an increase in the number of conservation agriculture practices implemented?	EQ2.1. Implementation of conservation agriculture practices
		EQ2.2. Number of conservation agriculture practices used by farmers
	EQ3. Does implementing adaptation activities lead to a reduction in damages to livelihood products following climate hazards?	EQ3.1. Damages in agricultural, forest and livestock products following climate hazards
	EQ4. Does implementing adaptation activities lead to an increase in agricultural (crops and livestock) production?	EQ4.1. Quantities produced of three main crops, animals, forests/tree products
		EQ4.2. Share of the agricultural production not used for household consumption
	EQ5. Does implementing adaptation activities lead to an increase in income/expenses?	EQ5.1. Household expenditures
		EQ5.2. Income
	EQ6. Does implementing adaptation activities lead to an increase in food security?	EQ6.1. Food security index based on food consumption, food expenditure shares and the number of strategies to cope for a lack of food
		EQ6.2. Number of days members of the household did not eat three meals a day
	EQ7. Does implementing adaptation activities lead to a reduction of households' vulnerability to climate hazards?	EQ7.1. Vulnerability index based on exposure, sensitivity and adaptive capacity of farmers
		EQ7.2. Strategies used to respond to hazards

Source: Authors.

Table 2
Mitigation evaluation questions and indicators.

Activity	Question	Indicator
	EQ8. Do patrolling interventions lead to better enforcement of regulations in the forest protected area?	EQ8.1. Law enforcement
	EQ9. Do patrolling interventions result in a reduction in deforestation?	EQ9.1. Quantity of deforestation
		EQ9.2. Charcoal consumption

Source: Authors.

Table 3
. Impact estimates for participation in livelihood activities.

EQ1	ITT Impact		ITT Control mean	ITT Obs.	LATE Impact		LATE Control mean	LATE Obs.	DiD Impact		DiD Control mean	DiD Obs.
Participation in farm livelihoods in the wet season at midline	0.01	***	0.98	1640	0.03	***	0.98	1194	0.00	***	0.99	2410
	(0.01)				(0.02)				(0.01)			
Participation in off-farm livelihoods in the wet season at midline	0.01	***	0.02	1260	0.01	***	0.02	1068	0.01	***	0.02	3278
	(0.01)				(0.02)				(0.01)			
Participation in non-farm livelihoods in the wet season at midline	0.07	***	0.57	1640	0.06	***	0.52	1627	0.02	***	0.45	3278
	(0.04)				(0.06)				(0.02)			
Participation in farm livelihoods in the dry season at midline	0.02	***	0.93	1640	0.03	***	0.91	1616	0.02	***	0.96	3256
	(0.02)				(0.03)				(0.01)			
Participation in off-farm livelihoods in the dry season at midline	−0.01	***	0.04	1640	−0.02	***	0.04	1450	0.00	***	0.04	3278
	(0.01)				(0.02)				(0.01)			
Participation in non-farm livelihoods in the dry season at midline	0.08	***	0.54	1640	0.07	***	0.54	1627	0.00		0.43	3278
	(0.04)				(0.06)				(0.02)			

Notes: *, **, and *** represent statistical significance at the 10 %, 5 %, and 1 % level respectively. Impacts represent the marginal effects from OLS or probit regression, depending on the nature (continuous or binary) of the indicator. Sampling weights are included and standard errors are clustered at the COBA level. The control mean represents the mean indicator value within Phase 3 households. Standard errors are indicated in parentheses.

5.2. *EQ2 – conservation agriculture practices adopted*

Table 4 reports adoption of conservation agriculture techniques promoted by the project. It shows a consistent range of coefficients illustrating an increase across seven techniques and a decrease for one technique:

- Soil conservation (2 to 12 percentage points at the 1 per cent level)
- Agroforestry (4 to 5 percentage points at 1 per cent level, except for DiD)
- Terracing (1 to 5 percentage points at 1 per cent level)
- Resistant crops (2 to 4 percentage points at the 1 per cent level)
- Off-season rice (5 to 16 percentage points at the 1 per cent level)
- Storage (6 to 8 percentage points at the 1 per cent level, except for DiD)
- Pest management (reduction of 7 to 13 percentage points at the 1 per cent level)
- Savings groups (4 to 10 percentage points at the 1 per cent level)

Two further techniques did not show significance – multi-cropping and use of irrigation. The proportion of households which implementing at least one practice at midline did not show a consistent direction.

Table 4
. Midline impacts on the number of conservation agriculture practices implemented.

EQ2	ITT Impact		ITT Control mean	ITT Obs.	LATE Impact		LATE Control mean	LATE Obs.	DiD Impact		DiD Control mean	DiD Obs.
Soil conservation used at midline	0.09	***	0.44	1640	0.12	***	0.37	1627	0.02	***	0.41	3278
	(0.04)				(0.06)				(0.02)			
Agroforestry used at midline	0.04	***	0.35	1640	0.05	**	0.30	1627	0.00		0.37	3278
	(0.04)				(0.06)				(0.02)			
Terracing used at midline	0.04	***	0.22	1640	0.05	***	0.20	1627	0.01	***	0.20	3278
	(0.05)				(0.07)				(0.01)			
Resistant crops used at midline	0.04	***	0.09	1640	0.04	***	0.09	1627	0.02	***	0.14	3278
	(0.03)				(0.04)				(0.01)			
Multi-crops used at midline	−0.01		0.48	1640	−0.04		0.43	1627	−0.02	***	0.42	3278
	(0.04)				(0.06)				(0.01)			
Irrigation used at midline	−0.01		0.56	1640	−0.01		0.55	1627	−0.02		0.62	3278
	(0.05)				(0.08)				(0.02)			
Off-season rice used at midline	0.13	***	0.36	1640	0.16	***	0.38	1627	0.05	***	0.35	3278
	(0.05)				(0.07)				(0.02)			
Storage used at midline	0.06	***	0.20	1640	0.08	***	0.22	1627	0.00		0.25	3278
	(0.04)				(0.07)				(0.02)			
Pest management used at midline	−0.10	***	0.39	1640	−0.13	***	0.31	1627	−0.07	***	0.40	3278
	(0.04)				(0.06)				(0.02)			
Saving groups used at midline	0.06	***	0.06	1640	0.10	***	0.08	1616	0.04	***	0.06	3278
	(0.03)				(0.04)				(0.01)			
Percentage of households (HH) that implement at least one practice at midline	0.02	***	0.91	1640	0.02	***	0.89	1627	−0.02	***	0.92	3278
	(0.02)				(0.03)				(0.01)			
Number of conservation agricultural practices adopted at midline	0.33		3.15	1639	0.45		2.93	1626	0.04		3.21	3277
	(0.23)				(0.34)				(0.07)			

5.3. EQ3 - reduction in damage following a climate hazard

The third evaluation question covers the degree to which the project reduced damage following a climate hazard. Table 5 illustrates that while Phase 1 (treatment) households show a reduction in the percentage of harvest damaged due to any climate shock, the differences are not statistically significant. The percentage of livestock that perished due to a shock also does not show any significance.

5.4. EQ4 - agricultural production and sales

Evaluation question 4 cover agricultural production and sales, covering crops, livestock and forest products. As indicators of agricultural production display a left-skewed distribution, we applied an inverse hyperbolic sine transformation to these indicators. This transformation reduces the sensitivity of the results to extreme upper values and allows us to accommodate for zero values. In contrast to the output level differences observed in adopting livelihood and conservation agriculture strategies, these outcome-based indicators do not show a consistent direction or level of change. Only one indicator shows consistent significance (at the 5 per cent level): ginger production (shown in Table 5). Table 5 also shows the share of crop, livestock and forest production that was sold. These indicators show consistent signs (with more crop production being sold and less livestock and forest products) but do not show statistical significance across the three specifications.

5.5. EQ5 - agricultural production and sales

The fifth evaluation question (Table 5) focuses on how implementing adaptation interventions increased income or expenditure. From five project-supported crops (rice, beans, groundnuts, Bambara peas, ginger), only one crop showed a meaningful difference: Phase 1 households showed a statistically significant decrease in income from the sale of beans, corresponding to close to a quarter of the Phase 3 control group mean. Yet this was only the case for one of the three specifications (ITT) with the LATE estimates not showing significance and DiD was not available due to a lack of baseline data. Neither indicators for income nor expenditure showed consistent significance.

5.6. EQ6 – food security

Evaluation question 6 focuses on food security (Table 5), specifically household status on the CARI Food Security Index, alongside the number of days each month during which the household did not have enough food to eat. CARI is a summary indicator that captures multiple dimensions of food security quantitatively, systematically and transparently. It represents the overall food security status of households. It has four levels. A score closer to 1 denotes greater food security, and closer to 4 represents severe food insecurity. Phase 1 (treatment) households showed an improvement of 0.05 to 0.14 points compared to the Phase 3 control group mean of 2.47–2.61 on the index. Two of the three coefficients were significant at the 5 per cent level with the LATE estimate showing significance at the 10 % level. In terms of the number of days without food in the last 12 months, Table 5 does not show significance across any of the 3 specifications.

5.7. EQ7 – climate vulnerability index

The climate vulnerability index ranges from 1, indicating a marginally vulnerable household, to 4, indicating an extremely vulnerable household. Table 5 shows no statistically significant difference between Phase 1 and Phase 3 households at midline. To assess the climate change vulnerability of the target population (smallholder farmers located in the target area of the GCF project), the evaluation team developed a climate change vulnerability index that builds on data collected in the household survey. As there is no standardized way to measure climate change vulnerability, the evaluation team identified the variables from the household survey that best assess the three components used to assess the vulnerability to climate change: exposure, sensitivity and

Table 5
. Midline impacts on the reduction in agricultural damage following a climate hazard.

	ITT				LATE				DiD			
EQ3	Impact		Control mean	Obs.	Impact		Control mean	Obs.	Impact		Control mean	Obs.
Percentage harvest decrease due to any shock at midline	−1.98		53.16	1626	−2.94		55.46	1613	−1.20		49.88	3263
	(3.52)				(5.15)				(1.21)			
Percentage of harvest decrease due to any shock at midline	−0.95		5.08	790	−0.35		5.18	783	−2.99	***	9.00	2427
	(1.80)				(2.67)				(0.89)			
Percentage of livestock that perished due to any shock at midline	0.53		6.45	1471	0.27		6.58	1459	−0.18		4.78	3110
	(1.37)				(2.01)				(0.58)			
EQ4												
Ginger production at midline (in kg, inverse hyperbolic sine transformation)	0.24	**	0.05	1640	0.23	**	0.09	1627	0.24	***	0.05	3278
	(0.11)				(0.11)				(0.05)			
Share of crop production that was sold	0.36		12.44	1640	0.53		11.25	1627	2.21	***	13.30	3278
	(1.03)				(1.67)				(0.57)			
Share of livestock production that was sold	−0.21		4.84	1637	−0.50		4.70	1624	−0.14		7.68	3275
	(0.70)				(1.00)				(0.41)			
Share of forest product harvest that was sold	−0.20		1.45	1633	−0.51		1.18	1620	−1.06	***	4.24	3271
	(0.50)				(0.84)				(0.41)			
EQ5												
Income from bean selling at midline (in MGA, inverse hyperbolic sine transformation)	−1.70	**	6.93	750	−1.89		6.19	741				
	(0.78)				(1.30)							
Total annual household income at midline (in MGA, inverse hyperbolic sine transformation)	−0.06		14.18	1612	−0.14		14.03	1599				
	(0.11)				(0.17)							
Household expenditures at midline (in MGA, inverse hyperbolic sine transformation)	0.14	*	15.08	1608	0.09		14.95	1595	0.06	**	14.96	3193
	(0.08)				(0.11)				(0.03)			

adaptive capacity. The evaluation team developed composite indices for each one of those components, which were computed based on the questions collected during the baseline. These were then aggregated into a final climate change vulnerability index for each household. Full details are available upon request.

5.8. EQ8 – enforcement of regulations

Evaluation question eight focuses on the degree to which patrolling leads to better forest area protection. The midline survey offers two indicators, as described in Table 5. The first of these refers to household satisfaction level with the level of forest corridor protection. Here we see mixed directions and no significance. The second is household perceptions of the importance of the COBA in helping manage forests and natural resources. For this indicator we see a slight increase within Phase 1 (treatment) households but no statistical significance.

5.9. EQ9 – enforcement of regulations to reduce unsustainable practices

Evaluation question 9 concerns the degree to which patrolling interventions result in a reduction in deforestation. Table 5 details three indicators, the first two of which describe participation in income-generating unsustainable activities, such as making charcoal, in the summer or winter.

Table 5 show that a lower proportion of treatment (Phase 1) households report deriving income from unsustainable activities than Phase 3 households, with a reduction of 1 percentage point from the control group mean of 0.06 in summer and a reduction of 4–7 percentage points from the control group mean of 0.09–0.13 in the winter. Both results are significant at the 1 per cent level. In contrast, the third indicator, the quantity of charcoal produced at midline, does not show any statistical significance.

5.10. Heterogeneity

This section describes the differences between Phase 1 and Phase 3 household subgroups (see Table 6). We describe heterogeneity analysis by gender of household head, location in CAZ or COFAV, distance and the initial level of vulnerability. In terms of the proportion of households engaged in livelihood strategies (EQ1), increased adoption of non-farm livelihoods is driven by women-headed households in both wet and dry seasons. It is also driven by households (by household heads of either gender) in COFAV. Regarding the number of conservation agriculture practices (see Table 6), the heterogeneity analysis illustrates that women-headed households drive the adoption of soil conservation practices and terracing. In contrast, households headed by men drive the adoption of resistant crops, off-season rice, the reduction of pest management practices, and the adoption of saving groups (although all of these apart from pest management are only at the 10 % level of significance).

We also observe considerable differences between CAZ and COFAV landscapes. Households' resident in CAZ are driving the increase in adoption of all the conservation agriculture techniques that show statistical significance apart from terracing and pest management. The reduction of adoption of pest management techniques is driven by household's resident in COFAV. The dominance of CAZ households in terms of adoption of conservation agriculture techniques is reflected in the proportion of households practising one or more conservation agricultural practices, showing an increase of 69 percentage points in CAZ, which is significant at the 1 per cent level compared to an insignificant difference of 14 percentage points in COFAV (not shown).

Differences in adopting conservation agricultural practices are also moderated by the distance from the forest and the initial level of vulnerability. In contrast, the observed reduction of pest management techniques is driven by households closer to the forest. Our results on the CARI FSI, and the initial level of vulnerability show no consistent, significant differences by subgroup, nor do mitigation indicators (Table 7).

6. Discussion

This section summarizes the key impacts of the SLEM interventions at midline and interprets these results. We structure this section according to evaluation questions with significant estimates as presented in the results section.

Table 6

. Food security, level of vulnerability, enforcement of regulations and unsustainable activities.

	ITT				LATE				DiD			
EQ6	Impact		Control mean	Obs.	Impact		Control mean	Obs.	Impact		Control mean	Obs.
CARI at midline (units)	−0.14	**	2.47	1640	−0.17	*	2.61	1627	−0.05	**	2.53	3278
	(0.07)				(0.10)				(0.02)			
Number of days without food in the last 12 months at midline	2.54		48.43	1637	2.01		59.33	1624	0.06		29.72	3272
	(6.44)				(9.17)				(0.03)			
EQ7												
Vulnerability index at midline (units)	0.01		2.34	1214	0.03		2.41	1206	−0.03		XX	2809
	(0.06)				(0.09)				(0.02)			
EQ8												
Satisfaction level with the level of forest corridor protection at midline (units)	0.04		3.00	1617	0.06		2.91	1604	−0.06		3.13	3255
	(0.09)				(0.14)				(0.04)			
Importance of the COBA in helping manage forests and natural resources at midline (units)	0.08		3.88	1602	0.06		3.71	1589	0.05		4.06	3240
	(0.13)				(0.23)				(0.05)			
EQ9												
Deriving income from unsustainable activities in the wet season at midline	−0.01	***	0.06	1640	−0.03	***	0.06	1616	−0.01	***	0.06	3256
	(0.01)				(0.02)				(0.01)			
Deriving income from unsustainable activities in the dry season at midline	−0.04	***	0.12	1640	−0.07	***	0.13	1616	−0.04	***	0.09	3256
	(0.02)				(0.04)				(0.01)			
Quantity of charcoal produced at midline (kg)	7.24		11.51	1626	16.24		1.15	1613				
	(11.55)				(19.83)							

Table 7
. Heterogeneity - adoption of conservation agriculture practices at midline.

	Women HH	Men HH	CAZ	COFAV	Far from forest	Close to forest	More vulnerable HH at baseline	Less vulnerable HH at baseline
Soil conservation	***		**		**		**	(-) *
Agroforestry			**					
Terracing	*							
Resistant crops		*	**					
Multi-crops			*					
Irrigation					**			
Off-season rice		*	*					
Storage								
Pest management		(-)**		(-)*		(-)**		
Saving groups		*	***			**	(-)**	**

Source: Authors.
Notes: *, **, and *** represent statistical significance at the 10 %, 5 %, and 1 % level respectively, based on the heterogeneity estimates discussed in Section 3. (-) indicates the estimated impact was negative for this subgroup.

6.1. Impact on livelihoods strategies – farm, non-farm and off farm

This sub section covers findings on farm, non-farm and off farm livelihood activities. The reported increase farm livelihood strategies, albeit very slight, aligns with project expectations and implementation. We see a more substantial increase in non-farm livelihood activities. Phase 1 households are 2–7 percentage points more likely to participate in non-farm activities in the wet season and 7–8 percentage points more likely to participate in the dry season (as shown by ITT and LATE estimates). This suggests Phase 1 households, especially women-headed households and household in COFAV, may be investing in livelihood strategies outside of agriculture, such as small-scale businesses or services. Project staff interpreted this finding by suggesting households use surplus agricultural income to diversify income-generating activities by opening small local shops and businesses. This is especially the case during the dry season, which coincides with harvest time when wealthier farmers have surplus income. At this time, wealthier farmers also hire poorer farmers to work in the forest to collect forest resources (including for charcoal production) or to work in agriculture. This enables poorer farmers to supplement their incomes and make additional purchases of food and consumer goods.

It is important to note that, in terms of climate resilience, non-farm activities may have a different and possibly lagged climate risk profile, reducing or at least delaying the influence of climate shocks on household well-being. Descriptive statistics show a greater proportion of women-headed households are engaged in non-farm livelihoods at midline (around 58.5 per cent) compared to baseline (around 30.9 per cent). The degree to which demand for non-farm goods and services provides a stable and consistent source of income may be limited in more remote locations where markets are thinner. The greater proportion of households in COFAV are engaging in non-farm activities suggests more stable and consistent demand for goods and services here.

Changes in off-farm activities show a mixed pattern, with treatment households showing a very small increase in the wet season (1 percentage point) and a broadly similar decrease in the dry season. This increase in off-farm activities in the wet season (specifically fishing, harvesting wild forest products, and harvesting timber) deserves attention. These activities are based on collecting natural resources from common pool resources and are often understood as coping mechanisms instead of activities to improve resilience. Indeed, there may be a tradeoff between allocating labour resources to off-farm activities and agricultural production in the wet season (in terms of less attention to crop care and maintenance, leading to a reduction in production, yields and sales). Some off-farm activities may also influence deforestation rates, such as charcoal making.

6.2. Adoption of conservation agriculture techniques

Turning to conservation agriculture techniques, estimates illustrate a greater proportion of Phase 1 households are practising a range of conservation agriculture techniques. Specifically, Phase 1 households show adoption rates 2–20 percentage points greater than Phase 3 households across seven of ten techniques. Four areas deserve some discussion here. First is the considerable uptake of climate resistant crops and savings groups, which can be partially explained by the limited prevalence of these activities at baseline. Second is the lack of significant differences in irrigation and multiple cropping. In terms of irrigation, while we can see a meaningful increase in off-season rice production, we do not see any increase in the use of irrigation (although the subgroup analysis suggests that the adoption is taking place by households further from the forest).

Third, the result that Phase 1 households do not show any meaningful increases in multiple cropping is slightly surprising, as is the reduction in the proportion of households conducting pest management practices (−7 to −10 percentage points at the 1 per cent level). Fourth, key subgroups of Phase 1 households are driving the adoption of certain conservation agriculture practices. Project staff report women-headed households adopt soil conservation measures more easily on their smaller plots (with an average of 0.90 hectares) than households led by men (with an average of 2.24 hectares). Table 6 also shows how distance from the forest is moderating the project's impact on the adoption of social conservation measures.

6.3. Agricultural production

In terms of agricultural production, estimates show how only one crop, ginger, was significantly influenced by the project at midline, with production increasing by 23 to 36 percentage points at the 5 per cent level or lower. Project staff reported that extension workers initially promoted ginger but later curtailed it due to concerns about its impact on long-term soil fertility. The project subsequently promoted a wider range of cash crops which required a number of years before harvesting, including vanilla, cloves and coffee.

6.4. Food security

Turning to food security, the impact table shows an improvement in food security status as represented by the CARI index of 0.05 to 0.14 points compared to the Phase 3 control group mean of 2.47–2.61 for two of the three specifications. However, it was not reflected in the number of days without food in the last 12 months, which did not show statistical significance. Moreover, the descriptive statistics (not shown) illustrate how severe food insecurity has worsened since the baseline survey (due partly to the COVID pandemic).

6.5. Enforcement of regulations – participation in unsustainable income-generating activities

In terms of the influence of the project on unsustainable activities, the midline estimates show that patrolling interventions have led to a reduction in unsustainable activities. The impact table shows that a lower proportion of treatment (Phase 1) households report deriving income from unsustainable activities, with a reduction of 1 percentage point from the control group mean of 0.06 in summer and a reduction of 4–7 percentage points from the control group mean of 0.09–0.13 in the winter. Both results are significant at the 1 per cent level. This suggests the project has been supporting mitigation outcomes as well as contributing to enhancing the resilience of smallholders. Yet, the longevity of this reduction in the unsustainable use of the forest may be short-lived. For example, one key indicator, the quantity of charcoal produced at midline, does not show any statistical significance between Phase 1 and 3 households. Further, the switch away from unsustainable activities relies on households being able to derive sufficient income from agriculture and from the sustainable use of forest resources. For example, households could readily switch back to using unsustainable practices following a significant covariant shock such as a cyclone as immediate household needs will likely over-ride other concerns.

6.6. Gains made by women-headed households

The heterogeneity analysis shows women-headed households are driving greater non-farm livelihood activities in both wet (2–7 percentage points) and dry seasons (7–8 percentage points). Further, women-headed households drive the adoption of soil conservation practices and terracing. Such gains are particularly important as women-headed households are the poorest and most vulnerable households. Further, recent research on agriculture in Africa shows that when we use panel data to compare the same households with the same characteristics through time, women-headed households are able to match the productivity gains of married households (see Andersson Djurfeldt and others, 2018).

7. Conclusion

The SLEM project aims to enhance the resilience of smallholder farmers, reduce GHG emissions from deforestation, and make climate-smart investments on agricultural lands. Through COBAs, households have been invited to work alongside the CI project team to develop proposals for climate risk coping mechanisms based on their needs and interests.

The midline results presented in this article show a substantial increase in non-farm livelihood activities with beneficiary households 2–7 percentage points more likely to participate in non-farm activities in the wet season and 7–8 percentage points in the dry season. Results also show widespread adoption of a range of conservation agriculture practices. Early project recipients show adoption rates of up to 20 percentage points higher than comparison households, including soil conservation measures (2–13 pp), agroforestry (2–6 pp) and the use of drought-resistant crops (2–6 pp). Further, the results show an improvement in the food security status of treatment households as measured by the CARI index of 0.05 to 0.14 points compared to the Phase 3 control group. The midline results also highlight a reduction in households' reliance on forest resources, with fewer beneficiaries deriving income from unsustainable activities in both summer (1 pp) and winter (4–7pp) seasons.

The SLEM project shows early, tentative signs of tackling the extreme and chronic vulnerability of smallholder households around the CAZ and COFAV protected areas (see Weiskopf and others, 2021; Bene, 2017). The reduction in unsustainable activities offers an indication that the use of common pool resources, such as foraging and fishing, can be placed on a longer-term footing. Yet, smallholders reliance on subsistence agriculture, their long-term food insecurity, and distance from urban density can lead to substantial crop losses especially through the interaction with a natural hazard such as a cyclone (Harvey and others, 2014). Smallholder households' vulnerability to such shocks are differentiated according to asset holdings, livelihood profiles and social safety nets (on this point see Prowse and Scott, 2008; Cissé and Barrett, 2018; Weldegebriel and Prowse, 2013, and Kidane and others, 2019; on Madagascar see Cinner and others, 2022).

The SLEM project supports the tailoring of adaptation activities via its participatory approach which incorporates the needs and interests of smallholder communities. Whether the impacts reported in this article will be sustained and enhanced in communities adjacent to CAZ and COFAV may depend on the severity of climatic shocks including the frequency and intensity of cyclones (Hending and others, 2022). This will be measured by the endline impact evaluation impact between the first beneficiary group (Phase 1) and a comparison group outside the areas covered by COBAs through a DiD with matching approach. The endline will assess the project's impacts on longer-term outcomes, with will pay particular attention to the sustainability of project impacts and whether the gains realised by women-headed households have been maintained.

CRediT authorship contribution statement

Camila I. Donatti: Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Giacomo Fedele:** Formal analysis. **Rocky Marcellino:** Supervision, Conceptualization. **Alea Muñoz:** Data curation, Conceptualization. **Martin Prowse:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis. **Clarck Rabenandrasana:** Supervision, Methodology, Formal analysis, Data curation. **Zo Lalaina Rakotobe:** Supervision, Project administration, Data curation, Conceptualization. **Justice Frederic Rakotonandrasana:** Supervision, Project administration, Data curation. **Andoniaina Mialisoa Rambeloson:** Supervision, Project administration, Methodology, Data curation, Conceptualization. **Mamy Ramparany:** Supervision, Project administration, Methodology, Data curation. **Clementine Sadania:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Clara Velontrasina:** Project administration, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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