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Learning-Oriented Real-Time Impact Assessment Programme (LORTA)

Impact evaluation endline report for FP026: Sustaniable Landscapes in Eastern Madagascar

Executive Summary

This report presents the endline findings of an impact evaluation of the "Sustainable Landscapes in Eastern Madagascar" project, which aimed to reduce deforestation and enhance climate resilience by equipping communities near protected forest areas with sustainable local forest management practices and climate-resilient agriculture. The impact evaluation employs a rigorous difference-in-differences design with matching, analysing panel data from 1,603 households surveyed in both 2019 and 2025. The endline findings show reductions in deforestation, a transition toward year-round farming systems, and higher agricultural incomes driven by promoted crops. However, sustaining complex conservation practices remains a challenge, particularly among female-headed households. A Triple Difference analysis indicates that project participants were more resilient during the 2022 cyclone, likely due to more diversified livelihoods.

These findings suggest that integrated mitigation-adaptation programmes can deliver dual benefits, but sustaining gains requires longer-term support, investments in infrastructure, and gender-responsive design. Future programming should prioritize institutional support, gradual exit strategies, and targeted assistance to address structural barriers faced by women and remote communities.

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Foreword

Scientific knowledge has the power to provide critical elements for project management. Following the awarding of the Nobel Prize in Economics in 2019 to Abhijit Banerjee, Esther Duflo and Michael Kremer for their experimental approach to addressing complex economic challenges in developing countries, the importance of measuring impact in development projects with experimental and quasi-experimental methods is widely acknowledged. The immense contribution of experimental and quasi-experimental methods to policy-making and resource allocation is well known. For an organization, learning from implementation in the field is very important, as it allows continuous improvement in project management. Rigorous impact evaluation allows for increased transparency regarding the effects of investments. It also helps design and implement projects more effectively by providing a rigorous monitoring and evaluation system using innovative approaches while ensuring full stakeholder participation and ownership.

The Independent Evaluation Unit's Learning-Oriented Real-Time Impact Assessment (LORTA) programme strengthens the capacity of accredited entities, implementing partners and project staff in assessing the impact of their interventions. The objective is to measure the change in key indicators that can be attributed to the project and inform stakeholders, including the GCF, in real-time about the progress of project implementation. Since the beginning of the Sustainable Landscape in Eastern Madagascar project, in the Ankeniheny-Zahamena Forest Corridor (CAZ) and the Ambositra-Vondrozo Forest Corridor (COFAV), LORTA has been an essential part of the monitoring and evaluation system, using an exacting scientific methodology to assess the project's impact through household surveys.

This endline report was completed to improve learning within CI and the GCF and to highlight project achievements and long-term impacts. We are grateful for the work of the LORTA team members from the IEU and Center for Evaluation and Development, and for the support of staff from Moore Center for Science - Natural Climate Solutions Division, CI's GEF/GCF Agency and across CI more broadly.

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Table of Contents

List of Tables

List of Figures

Abbreviations

BNCCREDD+	National Office for Climate Change, Carbon and the Reduction of Emissions from Deforestation and Forest Degradation
CARI	Consolidated Approach for Reporting Indicators of Food Security
CAZ	Ankeniheny-Zahamena Forest Corridor
CI	Conservation International
COBA	*Communautés de base* (local communities)
COFAV	Ambositra-Vondrozo Forest Corridor
DID	Difference-in-differences
FGD	Focus group discussion
FSI	Food Security Index
GCF	Green Climate Fund
GCF-IEU	Green Climate Fund's Independent Evaluation Unit
GDP	Gross domestic product
GIS	Geographic information system
IPWRA	Inverse probability weighted regression adjustment
LORTA	Learning-Oriented Real-Time Impact Assessment
MEDD	Ministry of Environment and Sustainable Development
MGA	*Malagasy Ariary* (Madagascar's national currency)
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SLEM	Sustainable Landscapes in Eastern Madagascar
USAID	United States Agency for International Development
VOI	*Vondron'Olona Ifotony*
WFP	World Food Programme

I. Introduction

Madagascar is an ecologically unique country but also one of most economically and environmentally vulnerable countries in the world. In 2022, approximately 75 per cent of the population lived below the national poverty line of about 4,000 ariary (MGA) per person per day.[1, 2] Poverty is most pronounced in rural areas, where around 60 per cent of the population lives, and where most households depend on subsistence agriculture. Although the agricultural sector employs over 60 per cent of the workforce, it contributes less than a quarter of national gross domestic product (GDP), reflecting low productivity.[3] This structural limitation, combined with heavy reliance on rain-fed farming and natural resource extraction, leaves rural households highly exposed to both market fluctuations and environmental shocks, with limited coping mechanisms to manage such risks. Consequently, food insecurity remains a major challenge: approximately 68.6 per cent of Madagascar's population experienced moderate to severe food insecurity between 2021 and 2023.[4]

These economic vulnerabilities intersect with acute climate risks. Madagascar faces an average of three to four cyclones annually, making it one of Africa's most cyclone-prone countries. Cyclones are especially detrimental for smallholder farmers, as the peak cyclone season (January–February) coincides with the agricultural lean season, a period when household food stocks are already low. Beyond damaging homes and infrastructure, cyclones can wipe out entire harvests, cutting off both food supplies and the primary source of income for rural households. Persistent droughts over the past five years have also affected large parts of country, with the Grand Sud experiencing the worst drought in 40 years between 2020 and 2021.[5] Research shows that these recurrent hazards erode livelihoods and often lead households to rely more heavily on natural resources, particularly forests, for food, fuel and income.[6] This growing dependence drives forest degradation, which in turn undermines household resilience, making communities even more vulnerable to the next shock.

These pressures are most acute in Madagascar's eastern forest corridors: the Ankeniheny-Zahamena Forest Corridor (CAZ) and the Ambositra-Vondrozo Forest Corridor (COFAV). CAZ spans 369,000 hectares across five districts, while COFAV covers 314,000 hectares across 10 districts. Both areas are biodiversity hotspots and major carbon sinks, providing essential ecosystem services such as water regulation, soil protection and climate regulation. Despite formal protection since 2015, these forests continue to experience degradation as communities with limited livelihood alternatives resort to unsustainable land use practices, such as slash-and-burn cultivation, fuelwood collection and small-scale logging, often driven by population growth, land scarcity and the need to generate cash income.

The Sustainable Landscapes in Eastern Madagascar (SLEM) project was designed to address this cycle of poverty and environmental degradation through targeted investments in climate-resilient livelihoods. Funded by the Green Climate Fund (GCF) (USD 15.2 million) and implemented by Conservation International (CI) Madagascar from 2018 to May 2025, the project aims to improve the climate change resilience of vulnerable farmers, and to reduce greenhouse gas emissions through forest protection and restoration. On the adaptation side, SLEM supports farmers to adopt climate-smart agriculture and agroforestry systems and to diversify incomes by providing training, mentoring, seeds and equipment, demonstration plots, seasonal weather bulletins, and improved market access, often through cooperative development. On the mitigation side, the project strengthens community-based forest management by equipping and supporting local patrols, demarcating protected area boundaries, and restoring degraded land through tree nurseries and reforestation efforts. By advancing

[1] World Bank, 2025c.
[2] World Bank, 2025c.
[3] World Bank, 2025a.
[4] FAO and others, 2024.
[5] Hending and others, 2022; USAID, 2024.
[6] Harvey and others, 2014.

these complementary strategies, SLEM seeks to both improve household resilience and protect Madagascar's globally significant forests.

This endline impact assessment examines SLEM's long-term impact on household agricultural practices, income and resilience. Conducted through the GCF's Learning-Oriented Real-Time Impact Assessment (LORTA) programme, the impact assessment employs a rigorous difference-in-differences (DID) design with matching, analysing panel data from 1,603 households surveyed in both 2019 and 2025. The analysis compares outcomes between households who participated in SLEM activities and those from comparable non-project areas.

The results show that integrated strategies combining forest conservation with livelihoods development can yield measurable benefits. In project areas, annual deforestation rates declined markedly from 3.2 per cent to 0.8 per cent, a reduction driven by community-led patrolling, reduced reliance on forest extraction, and improved local governance. Household survey evidence suggests that the SLEM programme facilitated a shift toward more diverse and climate-resilient agricultural systems. Participating households broadened the range of crops cultivated, including both short-cycle beans and high-value cash crops, supported by cooperative development and increased access to markets. During the 2022 cyclone, SLEM households were significantly less likely to resort to negative coping strategies such as skipping meals or harvesting wild food, signaling an improvement in short-term resilience in the face of shock.

These findings are important in light of evidence from other conservation programmes. Forest conservation programmes often face a trade-off: they may succeed in reducing deforestation but struggle to improve household welfare, particularly when new activities do not compensate for the loss of traditional income sources. Moving away from long-established livelihood practices can reduce immediate income opportunities and create hardship if alternatives are weak or unsustainable. For example, Jayachandran et al. (2017) show that a payment-for-ecosystem services programme in Uganda, evaluated through a randomized controlled trial, substantially reduced deforestation but had no detectable effect on household income. Against this backdrop, the SLEM experience illustrates a case where livelihood activities appear to have taken hold alongside conservation efforts and contributed to greater climate resilience.

While these outcomes signal important progress toward sustainability, the gains remain uneven. Agricultural incomes increased, but food security did not improve proportionally, and adoption of climate-resilient agricultural techniques declined when project support tapered off. Persistent structural barriers, including limited market infrastructure, weak irrigation systems, and poor road connectivity, posed challenges to sustaining impacts. This pattern is consistent with broader evidence that the sustained uptake of new agricultural technologies often depends on whether commercial markets and service providers are effectively crowded in to support adoption.[7] Gender disparities also emerged: female-headed households faced particular challenges in adopting labour-intensive practices, as they frequently needed to hire additional labour while also managing household and caregiving responsibilities. These findings suggest that without a supportive enabling environment and deliberate attention to gender-specific barriers, the benefits of conservation-linked livelihood interventions may not be fully realized or equitably distributed.

Taken together, these findings offer important lessons for future climate investments. Sustained engagement beyond initial project cycles is critical for consolidating gains. Complementary interventions, such as seasonal safety nets, infrastructure development, and gender-responsive programming, are necessary to ensure that income growth leads to lasting improvements in resilience and well-being. The results also demonstrate that community institutions, such as forest management associations (VOIs) and women's groups, are key drivers of long-term adoption and can amplify the impact of technical interventions.

The rest of this report is organized as follows. Section II describes the background and section III describes the project and its theory of change. Section IV outlines the evaluation questions and

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[7] Omotilewa and others, 2019.

indicators. Section V explains the methodology. Section VI presents the findings, and section VII concludes with discussions and policy implications.

II. Background

The SLEM project supports communities around the two largest remaining forest corridors in eastern Madagascar, areas critical for biodiversity that are increasingly threatened by a vicious cycle of climate pressures and human-driven degradation. These corridors are especially exposed to cyclones, which are more frequent and intense than in other parts of the country. Widespread poverty and heavy reliance on agriculture and natural resources make local populations highly vulnerable to shocks. During project implementation, the region faced multiple crises, including major cyclones in 2022 and 2023 and the COVID-19 pandemic, further challenging livelihoods and resilience. By supporting local associations to sustainably manage forest resources and decrease reliance on environmentally harmful practices, the project supports Madagascar's national efforts to reduce GHG emissions.

Madagascar is an agrarian economy, with agriculture including forestry and fishing contributing to around 21 per cent of GDP,[8] and employing the vast majority of the population.[9] Export earnings are concentrated in a few primary commodities, most notably vanilla, which accounts for roughly 8 per cent of total export value, alongside cloves, coffee, and other cash crops. Yet the agricultural system is highly fragile, shaped by weak markets and infrastructure constraints. Over 80 per cent of Malagasy people depend on smallholder subsistence farming, and poverty rates remain high.[10] Rural households primarily cultivate rice, cassava, beans, bananas, and cash crops such as ginger and vanilla. However, declining soil fertility and recurrent climate shocks keep yields consistently low. Forest resources, including honey, firewood, and wild tubers, provide essential supplements, particularly during lean seasons, while livestock rearing remains limited by high disease burdens. Infrastructure challenges deepen this vulnerability. Only a fraction of the population has reliable access to all-weather roads, and those that exist are often poorly maintained and highly prone to cyclone damage. These challenges isolate rural communities and raise transport costs, undermining farmers' income and resilience.

Madagascar faces some of the world's highest risks from climate shocks, threatening the livelihoods of millions of farmers. The island ranks among the most vulnerable countries due to its geographic exposure, economic fragility and heavy reliance on natural resources, while it is one of the least prepared to cope with climate change.[11] Over the past two decades, the country has endured 35 cyclones, eight floods, and five severe droughts, which is three times more than in the 20 years prior.[12] In recent years, eastern Madagascar has been particularly hit by major cyclones (including Batsirai and Emnati in early 2022, Freddy in 2023 and Gamane in 2024) which destroyed thousands of homes and heavily damaged infrastructure and crops.[13] Climate-related disasters now cause average annual losses exceeding USD 100 million, with cyclones accounting for about 85 per cent of those losses.[14] Projections indicate continued warming and greater rainfall variability, increasing both the frequency and intensity of extreme events.[15] Widespread poverty, weak infrastructure, and limited public resources further constrain Madagascar's ability to adapt, increasing its overall vulnerability.

Vulnerability to climate shocks is intensified by severe environmental degradation, particularly deforestation. The country has lost over 80 per cent of its original forest cover, with forest area declining from 29 per cent in 2000 to 21 per cent in 2020, and about 35 per cent of land degraded over the past 30 years.[16] Forest loss, driven by slash-and-burn agriculture, logging, and charcoal production, reduces the land's ability to regulate water, protect soil, and withstand floods and droughts. The CAZ and COFAV corridors are two of the largest remaining forest areas in eastern

[8] World Bank, 2025a.
[9] World Bank, 2025b.
[10] WFP, 2024.
[11] World Bank, 2024.
[12] World Bank, 2024.
[13] USAID, 2023; USAID, 2024.
[14] UNDRR and CDRI, 2024.
[15] World Bank, 2024.
[16] World Bank, 2022.

Madagascar, forming essential ecological links that are now under serious threat. Growing population pressure, poverty, and repeated climate shocks fuel this cycle of environmental decline.

The COVID-19 pandemic exposed and deepened these vulnerabilities. Beginning in 2020, travel restrictions, market closures, and rising prices disrupted food systems and income generation across the region. Some communities responded by increasing their dependence on forest products, while others resorted to illegal clearing and mining within protected areas.[17] These shocks and negative coping measures underscored the urgent need for integrated solutions that simultaneously address poverty, build resilience and protect irreplaceable natural resources.

In face of these challenges, the country has taken multiple steps to preserve its natural resources, balancing biodiversity protection with sustainable socio-economic development. Madagascar's environmental strategy combines climate finance mechanisms, like the Reduction of Emissions from Deforestation and Forest Degradation (REDD+) Strategy, with domestic conservation programmes to protect ecosystems and reduce greenhouse gas emissions. Strengthening local governance is central to this strategy, including the creation of local associations (*communautés de base* (COBAs) or VOIs) under Decree No. 2000-027, which empower community groups to manage forests sustainably, access resources for subsistence, and participate in ecotourism.[18] Madagascar began engaging with REDD+ in the early 2010s, and the National REDD+ Strategy, launched in 2018, outlines measures to reduce deforestation and promote sustainable forest management, highlighting the country's commitment to climate action.[19]

[17] GCF and CI, 2021.
[18] Government of Madagascar, 2000.
[19] Ramamonjisoa and others, 2018.

III. Project Intervention

The SLEM project was launched in 2018 to reduce deforestation and strengthen smallholder resilience through climate-smart landscape management. The project supports farmers in adopting sustainable agriculture and alternative livelihoods, while also enhancing community-led forest protection. Funded by the GCF with a budget of USD 15.2 million, SLEM is implemented by CI Madagascar in partnership with the National Office for Climate Change, Carbon and the Reduction of Emissions from Deforestation and Forest Degradation (BNCCREDD+), as well as the Ministry of Environment and Sustainable Development (MEDD). Originally planned for 2018–2023, the project was extended to 2025 due to COVID-19 disruptions.

The project's core objectives are to improve the climate change resilience of vulnerable farmers, and to reduce greenhouse gas emissions through forest protection and restoration. SLEM operates in the CAZ and COFAV forest corridors, targeting 23,800 households. It integrates adaptation and mitigation activities that include training on sustainable agriculture, in-kind input support, forest patrolling, agroforestry promotion, and strengthening local community-based natural resource management (COBAs or VOIs).

Adaptation interventions focus on building resilient farming systems and diversifying livelihoods. Activities include farmer training on sustainable agriculture production, mentoring by lead farmers and field agents, distribution of seeds and equipment, development of demonstration plots, and market access support. Communities co-designed climate coping strategies and received seasonal weather bulletins. These efforts aim to enhance climate awareness, crop production, and long-term resilience.

Mitigation interventions strengthen forest protection through local patrolling, community training, and forest restoration. Community patrols were supported with stipends and field equipment. Protected area boundaries were marked, and forest law enforcement efforts were coordinated with regional agencies. Nurseries produced seedlings for agroforestry and reforestation, with active community participation.

COVID-19 disruptions in 2020 delayed implementation and constrained enforcement, leading to increased forest pressure. Travel restrictions and reduced project activity contributed to higher rates of illegal logging and mining, although remote support activities, such as nursery work, procurement planning, and patrol stipends, continued. A strong collaboration with local key partners was developed to conduct these activities. A proposed Climate Change Trust Fund was ultimately cancelled in 2024 due to changes in national priorities.

The project aligns with Madagascar's climate policy priorities, including the National Adaptation Programme of Action, National Climate Change Policy, and REDD+. Social and environmental safeguards were applied through an Environmental and Social Management Framework, and all activities were designed to be gender sensitive.

IV. Theory of Change

The SLEM programme was designed to address two interlinked problems: unsustainable land use and household vulnerability to climate risks. It operated through two complementary pathways:

1. **The adaptation pathway**, which aimed to strengthen smallholder livelihoods and enhance their capacity to cope with climate change impacts.
2. **The mitigation pathway**, which focused on reducing deforestation by improving forest governance, limiting reliance on environmentally harmful activities, and restoring damaged forest and agroforestry areas.

This section outlines the causal logic for each pathway, tracing the link from programme inputs to expected outcomes and impacts.

4.1 Adaptation component

4.1.1. Inputs

Project funds were allocated to support the adoption of sustainable agricultural practices among eligible farmers. These resources were used to develop training modules and deliver in-kind support. In-kind grants included seeds, seedlings of both food and cash crops, small livestock, fingerlings, and basic agricultural tools and equipment.

4.1.2. Activities

The adaptation activities focused on promoting sustainable agricultural practices and supporting alternative livelihood strategies through a mix of training, input distribution, ongoing technical assistance, and efforts to increase access to markets. Farmers received hands-on training on conservation agriculture, complemented by climate change communication materials and continuous follow-up support from project staff. Key practices promoted included agroforestry and tree planting, micro-irrigation and drainage canals, intercropping and multi-cropping systems, off-season rice cultivation, mulching, no-tillage farming, terracing, and market access. These practices were tailored to local needs, with each COBA identifying priority activities in collaboration with project teams. In parallel, the project distributed weather bulletins to lead farmers and association leaders, who were expected to share this information with their communities through oral communication. Progress in implementing these activities was tracked through indicators such as the number of trained lead farmers and household beneficiaries, distribution of in-kind grants, adoption of sustainable agricultural practices, hectares under agroforestry, and changes in crop yields.

4.1.3. Outputs

The adaptation activities were expected to result in the dissemination of risk-reduction practices and improved knowledge of sustainable agricultural techniques and alternative livelihoods. Outputs include the number of households that participated in training sessions, received in-kind support (e.g. seeds, tools, livestock), and benefited from technical assistance. Additional output indicators included the adoption of promoted practices, and participant understanding of climate change and risk management strategies, as measured through post-training feedback and monitoring data.

4.1.4. Outcomes

Households that benefited from the training, inputs, and technical assistance provided are expected to see changes in behaviour and livelihood strategies to better cope with climate change impacts. Anticipated outcomes included:

- Adoption of promoted conservation agriculture practices

- Use of distributed inputs as intended
- Increased production of both subsistence and cash crops
- Diversification of livelihood sources including market access
- Uptake of weather forecasts and market information to guide farming decisions
- Adjustments in agricultural practices

These outcomes depend on whether farmers perceive the new practices as beneficial and feasible. Adoption is more likely when perceived benefits outweigh risks, and when there are no additional barriers other than lack of inputs, knowledge, or access to weather information that prevent implementation. The effective use of weather and market information also depends on whether this information is delivered through accessible and trusted channels.

4.1.5. Goals

The main end-of-project goals of adaptation activities are to increase crop productivity, improve household food security, and reduce vulnerability to climate-related hazards. These impacts are expected to materialize over time, typically five to 10 years after project support, through sustained changes in agricultural practices and livelihood risk coping strategies, including greater integration into value chains. Achieving these goals depends on farmers' continued ability to apply the promoted techniques without external assistance, the availability and affordability of necessary inputs, and the effective use of weather and market information to guide decisions. Persistent challenges, such as inadequate road infrastructure, insecurity, and increasing climate variability, may affect the durability of these impacts over time.

4.1.6. Assumptions and risks

The theory of change for the SLEM project rests on several key assumptions across both the adaptation and mitigation pathways:

- Farmer engagement: It assumes that farmers are willing and available to participate in trainings and adopt promoted practices. This requires that training schedules do not conflict with farming calendars and that farmers understand the potential benefits of the techniques.
- Local delivery capacity: The project assumes the presence of adequate human resources and institutional capacity to deliver high-quality, relevant training and ongoing technical support.
- Access to inputs and information: It is assumed that essential agricultural inputs (e.g. seeds, tools, fertilizers) are locally available and affordable, and that farmers can access and act on timely weather and market information.
- Practice sustainability: For long-term impact, it is assumed that households can maintain the promoted practices independently after project support ends.

The successful implementation and sustainability of outcomes are exposed to several risks:

- Climate shocks: Extreme weather events, particularly cyclones, may disrupt both agricultural activities and forest management efforts, reducing uptake or reversing gains.
- Infrastructure limitations: Poor road conditions and limited access to markets may hinder input delivery, information dissemination, and farmers' ability to sustain practices.
- Security and governance challenges: Rising insecurity in rural areas could limit outreach, weaken community engagement, and disrupt local coordination.
- Social and gender barriers: Constraints faced by women and more remote households may limit their participation in trainings or access to support, thereby affecting equitable outcomes.

4.2 Mitigation component

4.2.1. Inputs

Project funding supported the implementation of community-based forest protection and reforestation activities. Resources were allocated to hire field agents and local trainers, purchase equipment for forest monitoring and patrolling, and provide stipends to community forest patrollers. In addition, the project established forest and agroforestry plantations and supported the identification, training, and equipping of tree nursery workers. Training modules were developed to guide both patrollers and nursery staff in carrying out their roles effectively.

4.2.2. Activities

The project provided stipends and field equipment to community forest patrollers, facilitated the physical demarcation of protected area boundaries, and delivered training on forest legislation to patrollers and local associations. It also supported the development of local capacity in forest restoration through training in technical, legal, and management aspects. In line with the national policies for forest restoration management, the project trained community members to develop and manage tree nurseries and forest plantations.

4.2.3. Outputs

The mitigation activities were expected to result in patrollers receiving stipends and equipment, improved knowledge of forest legislation, and increased awareness of sustainable forest management practices. The physical demarcation of protected areas was intended to enhance the visibility and recognition of forest boundaries. The effectiveness of these outputs depended on the quality of training delivered and the level of participation by community members.

4.2.4. Outcomes

If the outputs are successfully delivered, community patrollers are expected to increase the frequency and effectiveness of forest surveillance, and households are expected to reduce their extraction of forest resources within protected areas and restore damaged forest and agroforestry areas. Achieving these outcomes depends on patrollers receiving sufficient incentives to carry out regular patrols and having the willingness and capacity to report or intervene in cases of illegal activity. Their ability to act also requires that they can do so without fear of retaliation or harm.

4.2.5. Goals

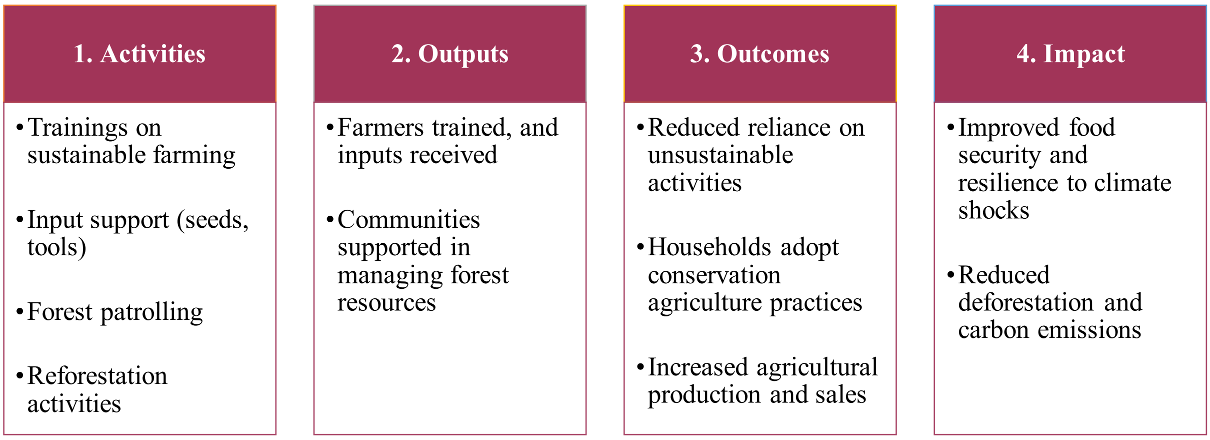
The main goals of the mitigation activities are to reduce deforestation, increase the proportion of reported forest violations that are followed up with prosecution, and restore damaged forest and agroforestry areas. Achieving these goals requires that reported violations are acted upon by the Forestry Department and that penalties are applied consistently. The likelihood of enforcement must be high enough to deter illegal forest use. In addition, households need access to viable alternative income sources and must receive training in tree nursery development and plantation to reduce long-term reliance on forest resources.

4.2.6. Assumptions and risks

This pathway assumes that community patrollers are willing and able to conduct regular surveillance, and that they receive adequate incentives, equipment, and training. It also assumes that reported violations are followed up by the Forestry Department and result in penalties sufficient to deter illegal activity. For long-term change, households must have access to alternative income sources to reduce reliance on forest exploitation. They must also use conservation agriculture that improves the soil fertility of their cropland to reduce slash and burn for agriculture.

Key risks include weak law enforcement, limited government follow-up on violations, and continued economic dependence on forest resources. Insecurity or fear of retaliation may also undermine the effectiveness of community patrols. Additionally, households must perceive tangible benefits from forest protection and be willing to invest in restoration activities by planting trees.

Figure 1: Theory of change



Source: LORTA team.

V. Evaluation Strategy

5.1 Questions and Indicators

The impact evaluation of the SLEM project aims to assess the effectiveness of both adaptation and mitigation activities in achieving intended outcomes. Evaluation questions were designed around key expected results: (i) livelihood diversification, (ii) adoption of conservation agricultural practices, (iii) crop productivity and income, (iv) food security and resilience, and (v) forest protection. Table 1 presents the evaluation questions related to adaptation activities and their corresponding indicators, while Table 2 outlines the evaluation questions and indicators for the mitigation component of the project.

Table 1: Adaptation evaluation questions and indicators

Activity	Questions	Indicators
Adaptation	EQ1: Does implementing adaptation activities lead to an increase in the number of **livelihood strategies** used?	EQ1.1: Livelihood diversification
		EQ.1.2: 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. Damage to 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. Total value of crop production, tropical livestock units, total value of forest production, production of main crops supported by the project
		EQ4.2. Share of the agricultural production sold
	EQ5. Does implementing adaptation activities lead to an increase in **income/expenses**?	EQ5.1. Household expenditures
		EQ5.2. Income and income from sales of main crops supported by the project
	EQ6. Does implementing adaptation activities lead to an increase in **food security**?	EQ.6.1. Food security index based on food consumption, food expenditure shares and the number of strategies to cope with a lack of food
		EQ.6.2. 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

	EQ8. Does improving food security depend on the sustainable management practices implemented in farms?	Food security index based on food consumption, food expenditure shares and the number of strategies to cope with a lack of food
	EQ9. Does reducing climate vulnerability depend on the sustainable management practices implemented in farms?	Vulnerability index based on exposure, sensitivity and adaptive capacity of farmers

Source: LORTA team.

Table 2:Mitigation evaluation questions and indicators

Activity	Questions	Indicators
Mitigation	EQ11. Do patrolling interventions lead to better **enforcement of regulations** in the forest protected area?	EQ11.1. Law enforcement
		EQ12.1. Quantity of deforestation
	EQ12. Do patrolling interventions result in a reduction in **deforestation**?	EQ12.2. Deriving income from non-environmental sustainable activities (e.g. timber, charcoal)
		EQ12.3. Charcoal consumption

Source: LORTA team.

The impact evaluation study uses the Consolidated Approach for Reporting Indicators of Food Security (CARI) index developed by the World Food Programme (WFP) to assess household food security and ensure alignment with other agencies. CARI is a summary indicator that helps capture multiple dimensions of food security quantitatively, systematically and transparently. Here, three food security indicators commonly used by the WFP (food consumption,[20] food expenditure,[21] and coping strategy[22]) are combined into the Food Security Index (FSI). The FSI represents the overall food security status of households and is categorized in an ordinal variable consisting of four levels: i) food secure, ii) marginally food secure, iii) moderately food insecure, and iv) severely food insecure. Following the CARI methodology, the FSI is calculated using the averages of the three subindexes with more weight on the food consumption score than the food expenditure and coping strategy scores.

To assess the climate change vulnerability of the target population, CI developed a climate change vulnerability index based on three subindices: exposure, sensitivity and adaptive capacity. The voluminous literature on vulnerability indicates how susceptibility to loss based on damaging fluctuations can consist of: i) exposure to shocks or stresses, such as meteorological events,[23] ii)

[20] The food consumption score is an indicator for dietary consumption that includes both quantity and quality considerations. Quantity considerations include the frequency of consumption, specifically the number of days, of eight food groups consumed by a household during the 30 days before the survey. Quality considerations include dietary diversity based on the number of different food groups consumed over the last 30 days.

[21] The food expenditure scores estimate the proportion of the household budget spent on food. It is based on food expenditure shares, with the most food insecure spending greater than 75 per cent of their budget on food and food secure spending less than 50 per cent.

[22] The coping strategy score focuses on the frequency and severity of changes in food consumption by households. It assesses whether any member in their households engaged in 10 coping strategies (four stress strategies, three crisis strategies, and three emergency strategies) because there was not enough food or money to buy food during the past 30 days. The 10 coping strategies were selected using CARI and based on known strategies used in the region from previous household surveys.

[23] Chambers, 1989.

sensitivity to these damaging fluctuations, in terms of impacts on natural systems such as ecosystems, and human systems such as agricultural production, and the operation of markets,[24] and iii) the adaptive capacity of households, including forms of human, social, financial, physical, and natural capital, entitlements, institutions and capabilities, knowledge and information, and decision making and governance.[25] Recent contributions to measuring vulnerability and resilience are bifurcated between those that take their point of departure from climate science and adaptation literature,[26] and those based on economic work addressing poverty traps and resilience.[27] A further strand in the literature utilizes different statistical approaches, such as principal components analysis, to create a resilience index.[28] CI's approach has been to create composite indices for each of the three components using an approach that is intelligible to all stakeholders. All variables were categorized in quartiles, ranked from 1 to 4 (1=low, 4=high) and summed for each subindex. A higher number represents higher exposure and sensitivity but lower adaptive capacity (this third component is inverted). CI then aggregated these "sub-indices" into a final climate change vulnerability index for each household. Equal weighting has been used in this report.

5.2 Methodological approach

The SLEM impact evaluation was designed as a longitudinal study with three waves of data collection, baseline (2019), midline (2022), and endline (2024-2025), to assess both short-term and long-term effects of the programme. The evaluation incorporated a randomized phase-in design to enable causal identification of impacts at midline.[29]

For the endline, the impact evaluation was designed to assess the long-term impacts of the SLEM programme by comparing households in Phase 1 communities, which received the earliest and longest exposure to SLEM interventions, with households residing in pure control areas outside of COBA zones, which were never targeted by the programme. This design choice allows us to estimate sustained impacts while minimizing contamination.

Baseline differences between programme participants and the comparison group prevents the direct comparison of outcomes between these two groups (see Baseline Balance in Table A - 1). Instead, we estimate the endline impacts of the SLEM programme using a DID approach, which compares changes in outcomes over time between programme participants and a comparison group. This method accounts for both observable and unobservable baseline differences, provided that these differences follow parallel trends over time. When the assumption holds, DID allows for a causal interpretation of the programme's impact and remains robust to external shocks, as long as these shocks affect both groups similarly.

Our estimation follows the specification in Equation (1):

$$y_{it} = \beta_O + \beta_1 T_t + \beta_2 D_i + \beta_3 (D_i * T_t) + \varepsilon_{it} \quad (1)$$

In this equation, T_t represents the year of the survey, D_i is a treatment dummy which takes the value 1 if household i is located in a Phase 1 COBA and 0 otherwise, and β_O is a constant. The coefficient of interest, β_3, captures the programme's impact at endline. We cluster standard errors at the locality

24 Sinha and Lipton, 1999.
25 Blaike and Brookfield, 1987; Moser, 1998; and Ellis, 2000.
26 Adger, 2006; Folke, 2006; Béné and others, 2017; Béné and others, 2014; Speranza and others, 2014.
27 Carter and Barrett, 2006; Prowse and Scott, 2008; WFP, 2014a; WFP, 2014b; Cisse and Barrett, 2018; D'Errico and others, 2020.
28 Filmer and Pritchett, 2001; Anderson, 2008; Mahmud and Prowse, 2012; Weldegebriel and Amphune, 2017.
29 IEU, 2024.

(fokontany) level. Our estimation includes sampling weights, equivalent to the inverse probability that an observation in the target population was sampled at baseline.

5.2.1. Matching

For outcome variables collected only at the endline, we estimate programme impacts using a matching approach, specifically Inverse Probability Weighted Regression Adjustment (IPWRA). This method helps us construct a credible comparison group by adjusting for baseline differences between households that received the SLEM programme and those that did not.

We first estimate the probability that a household receives the programme (i.e. belonged to a Phase 1 COBA), using a range of observable characteristics that may influence programme participation and/or outcomes of interest. These include baseline measures of remoteness (i.e. distance to the fokontany centre and forest), household wealth, herding activities, baseline rice production, education and gender of the household head, accounting for key differences observed at baseline (Table A1: Baseline Balance). This probability, known as the propensity score, captures how likely each household was to receive the intervention based on those characteristics. The resulting propensity scores are then used to reweight the comparison group to more closely resemble the treatment group.

5.2.2. Transformation of outcomes variables

Agricultural production and monetary outcomes typically display a right-skewed distribution due to a few extremely high values. To address this, we apply an inverse hyperbolic sine transformation, which reduces the sensitivity of our results to outliers while accommodating zero and negative (in the case of net income) values. We then calculate the semi-elasticities of the impact of the SLEM programme on these variables following Bellemare and Wichman (2020).

In the case of yield, measurement error posed a particular concern: many respondents struggled to estimate the size of their cultivated land, resulting in implausibly high or low yield values. To limit the influence of these outliers, we winsorised the yield variable at the 90th percentile.

5.3 Data Collection

The impact evaluation of the SLEM project comprises three waves of data collection: i) baseline, conducted from February to May 2019; ii) midline, conducted in September and November 2022; and iii) endline, conducted between December 2024 and February 2025. During each wave of data collection, ethical standards were strictly followed, with informed consent, privacy safeguards, and adherence to CI and IEU guidelines. Though no Institutional Review Board (IRB) approval was required, the study complied with international research ethics norms. Figure 2 illustrates the impact evaluation timeline in parallel with the project's implementation timeline.

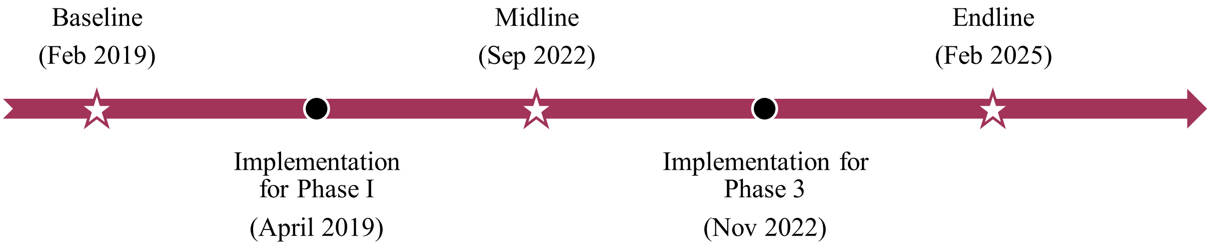
At baseline, a total of 2,730 households were surveyed across CAZ and COFAV landscapes. The baseline sample included sampled households in Phase 1 VOIs, Phase 3 VOIs, and matched external control fokontany outside of COBA areas. The sampling strategy was stratified by geographic area and forest size, and power calculations were conducted to ensure the sample could detect meaningful changes in food security and livelihood outcomes. The SLEM project's baseline report confirms that Phase 1 and comparison households are well balanced across key characteristics.[30]

At endline, the impact evaluation focused on comparing Phase 1 communities with the pure control group (non-COBA fokontany), which remained unexposed. Due to budget constraints, Phase 3 VOIs were not included in the endline survey round. A total of 1,820 households were targeted, and 1,623

30 IEU, 2020.

were successfully re-interviewed, resulting in an attrition rate below 11 per cent. All surveys were administered in Malagasy using Kobo Toolbox, a mobile-based data collection platform that allowed for offline data capture in remote areas.

Figure 2: Impact evaluation timeline



Source: LORTA team

VI. Empirical results

This section presents the result of the endline evaluation of SLEM impacts on VOI members, conducted five years after initial project implementation. The analysis is based on panel data from 1,603 households surveyed in 2019 and again in 2024/2025. Using a DID approach, we compare changes in key outcomes over time between:

- VOI members who have participated in project activities since 2019
- A comparison group from non-eligible areas selected for their similar socio-economic and geographic characteristics

In order to understand the impact on outcomes measured only at endline, we complement the DID approach with matching techniques. In addition, we draw on qualitative insights from focus group discussions (FGDs) with beneficiaries of nearby associations.[31, 32] These additional sources help contextualize the findings, especially where quantitative results are inconclusive.

6.1 Shifting livelihoods and increased farm engagement

The SLEM programme contributed to a relative shift in household livelihoods away from non-farm activities and toward farm-based strategies. While participation in non-farm livelihoods increased for both SLEM and comparison households between 2019 and the endline, reflecting broader economic pressures, the increase was significantly smaller among SLEM participants.

This difference-in-differences result indicates that, relative to the counterfactual, the programme helped curb households' reliance on non-farm income sources, which in this context often include environmentally unsustainable activities such as tree cutting, charcoal production, gold mining, and other forms of forest resource extraction. In the wet season, SLEM participation reduced engagement in non-farm livelihoods by nearly 50 per cent compared to the control group. At the same time, the programme modestly increased farm-based engagement, with a roughly 5 per cent rise during the dry season and a small increase in the number of crops cultivated. Taken together, these results suggest that the project supported a shift toward more **sustainable, resilient livelihoods.**

Table 3: Endline impacts on livelihood strategies

Livelihood strategies	Reference mean	ATT	%change	Method
Participation in farm livelihoods in the wet season at endline n=3206	0.99 [0.11]	0.03 (0.02)	3.03%	DID
Participation in off-farm livelihoods in the wet season at endline n=3206	0.09 [0.28]	-0.03 (0.04)	-33.33%	DID
Participation in non-farm livelihoods in the wet season at endline n=3206	0.35 [0.48]	-0.17 ** (0.08)	-48.57%	DID

[31] CI Madagascar, 2025.
[32] In February 2025, 25 FGDs were held with 193 members of associations other than VOI. Most participants (73 per cent) belonged to a women's association, and nearly half began receiving SLEM benefits in 2023.

Participation in farm livelihoods in the dry season at endline n=3206	0.98 [0.13]	0.05 *** (0.02)	5.10%	DID
Participation in off-farm livelihoods in the dry season at endline n=3206	0.08 [0.28]	-0.04 (0.04)	-50.00%	DID
Participation in non-farm livelihoods in the dry season at endline n=3206	0.34 [0.47]	-0.10 (0.07)	29.41%	DID
Number of crops cultivated by the household at endline n=1602	4.72 (0.34)	0.63 (0.39)	13.35%	IPWRA
Total livestock unit at endline n=1602	0.91 (0.13)	0.38 (0.24)	41.76%	IPWRA

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

Sampling weights are included and standard errors (indicated in parentheses) are clustered at the local level. Standard deviation in brackets. Reference mean refers to baseline mean for the treatment group for DID and the potential outcome mean for IPWRA. ATT = average treatment effect on the treated.

6.2 Decline in conservation practice adoption

The SLEM programme did not lead to a sustained increase in the adoption of conservation agriculture practices (Table 4). While 88 per cent of programme participants reported using at least one conservation practice at endline, this level is nearly identical to the baseline and does not differ significantly from the comparison group. None of the individual practices showed statistically significant differences, and the use of seed storage declined notably, with a statistically significant reduction compared to the control group.

These findings contrast with midline findings, which showed increases in adoption, as well as with qualitative insights from FGDs. FGD participants commonly cited the uptake of practices such as mulching, crop rotation, and diversification, following project support. This discrepancy suggests two possibilities: either the quantitative indicators do not fully capture changes in behaviour, or the adoption of practices was not sustained after the project's relatively short implementation period.

The programme provided support for only two years. Without continued technical or material assistance, many households may have struggled to maintain new practices. FGD participants emphasized the need for sustained and locally adapted support and expressed expectations that government or other institutions would continue assistance beyond the project's duration. Some also mentioned that the effectiveness of certain techniques is limited under severe climate shocks such as cyclones.

Table 4: Endline results on conservation agriculture practices

Conservation agriculture practices	Reference mean	ATT	%change	Method
Used soil conservation at endline n=3088	0.45 [0.50]	-0.08 (0.07)	-17.78%	DID
Used agroforestry at endline n=3088	0.45 [0.50]	-0.01 (0.07)	-2.22%	DID
Used terracing at endline n=3088	0.24 [0.43]	-0.01 (0.06)	-4.17%	DID
Used resistant crops at endline n=3088	0.31 [0.46]	0.02 (0.06)	6.45%	DID
Used multi-cropping at endline n=3088	0.52 [0.50]	-0.02 (0.07)	-3.85%	DID
Used irrigation at endline n=3086	0.67 [0.47]	-0.02 (0.08)	-2.99%	DID
Used off-season rice at endline n=3088	0.29 [0.45]	0.03 (0.06)	10.34%	DID
Used storage at endline n=3088	0.24 [0.43]	-0.12 *** (0.05)	-50.00%	DID
Used pest management at endline n=3088	0.28 [0.45]	-0.05 (0.08)	-17.86%	DID
Used saving groups at endline n=3088	0.11 [0.31]	-0.04 (0.05)	-36.36%	DID
Percentage of households that implement at least one practice at endline n=3088	0.92 [0.27]	-0.02 (0.05)	-2.17%	DID

Number of conservation agricultural practices adopted at endline n=3088	3.55	-0.29	-8.17%	DID
	[2.08]	(0.30)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

Sampling weights are included and standard errors (indicated in parentheses) are clustered at the local level. Reference mean refers to baseline mean for the treatment group for DID and the potential outcome mean for IPWRA.

6.3 Agricultural productivity gains

Our results indicate that participation in the SLEM programme led to significant improvements in agricultural production (Table 5). Notably, we observe large gains in ground nut and Bambara pea production, with increases of over 560 per cent and 190 per cent, respectively. As corroborated by FGDs, the promotion of these crops has provided participants with additional short-term livelihood opportunities, supporting both increased income and greater dietary diversity. In parallel, the programme also supported the cultivation of longer-cycle cash crops, whose yields are not yet observable at endline due to their extended maturation periods. This suggests that the full impact of the programme may be even greater in the longer term, as these investments begin to mature and generate returns.

We also find an increase in the share of crops sold, pointing to a possible shift toward more market-oriented farming practices, though not robust to our alternative estimations. Complementary analyses show an overall rise in the total value of crop production, reflecting broader gains in farm performance. Additionally, bean productivity improved for participating farmers. These findings suggest that the project has effectively enhanced both production and income potential for participating households.

Table 5: Endline impacts on agricultural production

Agricultural production	**Reference mean** **[std dev] / (std error)**	**ATT**	**%change**	**Method**
Rice production at endline (in kg, inverse hyperbolic sine transformation) n=3206	195.75	0.06	6.18%	DID
	[4.50]	(0.25)		
Bean production at endline (in kg, inverse hyperbolic sine transformation) n=3206	0.78	0.09	15.01%	DID
	[2.62]	(0.24)		
Groundnut production at endline (in kg, inverse hyperbolic sine transformation) n=3206	0.08	0.43 **	564.79%	DID
	[0.68]	(0.19)		
	0.16	0.30 **	196.48%	IPWRA

Bambara peas production at endline (in kg, inverse hyperbolic sine transformation) n=1602	(0.06)	(0.15)		
Ginger production at endline (in kg, inverse hyperbolic sine transformation) n=3206	0.15	-0.03	-20.11%	DID
	[1.19]	(0.08)		
Total value of crop production (in MGA, inverse hyperbolic sine transformation) n=1600	477,755	0.91	148.43%	IPWRA
	(0.70)	(0.63)		
Total value of livestock production at endline (in MGA, inverse hyperbolic sine transformation) n=1601	33,418	1.31	270.62%	IPWRA
	(0.82)	(0.80)		
Total value of forest production at endline (in MGA, inverse hyperbolic sine transformation) n=1590	241.49	-0.12	-11.31%	IPWRA
	(1.32)	(1.36)		
Share of crop production that was sold at endline n=3132	4.28	3.55 *	82.94%	DID
	[5.22]	(2.06)		
Share of livestock production that was sold at endline n=2376	10.06	-1.11	-11.03%	DID
	[13.84]	(2.43)		
Share of forest product harvest that was sold at endline n=924	6.33	1.92	30.33%	DID
	[14.41]	(3.19)		
Rice yield (in kg/are) n=1537	24.5	-2.31	-9.43%	IPWRA
	(1.65)	(1.95)		
Bean yield (in kg/are) n=621	4.7	2.97 ***	63.19%	IPWRA
	(0.84)	(1.00)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

Sampling weights are included and standard errors (indicated in parentheses) are clustered at the local level. Reference mean refers to baseline mean for the treatment group for DID and the potential outcome mean for IPWRA.

6.4 Income gains

Improvements in agricultural production translated into higher crop income for participating households (Table 6). We find statistically significant income gains from rice and most of the crops promoted by the project, with the exception of ginger, providing additional evidence of increased market participation among SLEM households.

Some estimated percentage effects appear large; however, these should be interpreted with caution. The large percentage changes reflect the high prevalence of zero sales at baseline, which results in very small reference means. For example, because 82 per cent of households do not sell rice, the baseline mean rice income is only 13 MGA. In this context, an estimated increase of 1,993 per cent corresponds to an absolute gain of just 259 MGA (approximately USD 0.05). Alternative specifications also suggest a positive effect on total household income, although these estimates are not statistically robust.

Table 6: Endline impacts on income and expenditures

Income and expenditures	Reference mean [std dev] / (std error)	ATT	%change	Method
Income from rice selling at endline (in MGA, inverse hyperbolic sine transformation) n=1602	13.01 (0.40)	3.04 *** (0.64)	1993.54%	IPWRA
Income from bean selling at endline (in MGA, inverse hyperbolic sine transformation) n=1602	1.51 (0.27)	1.39 *** (0.49)	339.06%	IPWRA
Income from groundnut selling at endline (in MGA, inverse hyperbolic sine transformation) n=1602	0.61 (0.25)	0.84 ** (0.40)	217.70%	IPWRA
Income from Bambara peas selling at endline (in MGA, inverse hyperbolic sine transformation) n=1602	0.14 (0.06)	0.55 ** (0.26)	431.17%	IPWRA
Income from ginger selling at endline (in MGA, inverse hyperbolic sine transformation) n=1602	0.29 (0.18)	0.02 (0.19)	7.11%	IPWRA
Total annual household income at endline (in MGA, inverse hyperbolic sine transformation) n=1599	383,407 (0.52)	0.68 (0.49)	97.39%	IPWRA
Household expenditures at endline (in MGA, inverse hyperbolic sine transformation) N=3204	1,634,509 (0.89)	-0.04 (0.14)	-3.92%	DID

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

Sampling weights are included and standard errors (indicated in parentheses) are clustered at the local level. Reference mean refers to baseline mean for the treatment group for DID and the potential outcome mean for IPWRA.

6.5 Food security

We find limited but suggestive evidence of impact on food security outcomes. Despite gains in agricultural production and income, the CARI index shows no statistically significant changes (Table 7).[33] In fact, average food security levels declined slightly for both treatment and comparison groups since the baseline (with the CARI index increasing from 2.3 to 2.6), potentially reflecting broader external shocks during the evaluation period. We also observe an increase in the number of days without food since baseline, though the rise was smaller for project participants (13 days vs. 20 days in the comparison group).

At the same time, several secondary indicators suggest positive behavioural shifts in food access and consumption. The value of food consumed from own production increased by 30 per cent relative to the comparison group, a difference that is statistically significant at the 5 per cent level based on DID estimates. Additionally, the likelihood of households resorting to food begging, a coping strategy reported by one-third of households at baseline, declined by 51.5 per cent relative to the comparison group, based on DID estimates statistically significant at the 5 per cent level. These patterns point to improved food self-sufficiency and reduced reliance on negative coping mechanisms.

While Household Dietary Diversity Scores (HDDS) do not show statistically significant differences between the two groups, complementary analyses using alternative matching methods suggest a modest improvement of 3 per cent to 4 per cent for programme participants. These findings align with focus group discussions, where households reported perceived improvements in dietary diversity.

Together, these results suggest that while the programme contributed to production gains and some positive changes in household behaviour, these alone were insufficient to shift overall food security outcomes. This highlights the importance of complementary interventions, such as nutrition-sensitive agriculture, seasonal safety nets, or targeted support during lean periods, to translate income gains into sustained improvements in food access and dietary quality. At the same time, household spending patterns suggest a strategic shift toward long-term well-being. Rather than increasing food expenditures, project participants, particularly female-headed households, invested more in education, while male-headed households prioritized durable assets such as housing and tools. **These choices point to a form of resilience that emphasizes human and physical capital accumulation, rather than short-term food consumption.**

[33] Household food security was assessed using the WFP's Consolidated Approach for Reporting Indicators of Food Security (CARI) which combines: (i) Food consumption score (dietary consumption, considering both the quantity and quality of food intake); (ii) Food expenditure share (proportion of household budget spent on food); and (iii) Livelihood coping strategies (extent to which households adopt strategies to meet basic food needs in response to shocks).

Table 7: Endline impacts on food security

Food security	Reference mean [std dev] / (std error)	ATT	%change	Method
CARI at endline (units) n=3206	2.31	-0.02	-0.87%	DID
	[0.73]	(0.11)		
Number of days without food in the last 12 months at endline n=3192	14.36	-6.65	-46.31%	DID
	[30.27]	(6.39)		
Household Dietary Diversity Score n=1603	8.67	-0.01	-0.12%	IPWRA
	(0.12)	(0.22)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

Sampling weights are included and standard errors (indicated in parentheses) are clustered at the local level. Reference mean refers to baseline mean for the treatment group for DID and the potential outcome mean for IPWRA.

6.6 Impact of climate hazards

We find limited evidence that the programme reduced households' sensitivity to climate shocks affecting agriculture and forest products. As shown in Table 8, we do not observe statistically significant reductions in the impact of shocks, as measured by reported losses in harvest, livestock, or forest products, among programme participants compared to the comparison group. These results may imply that the activities promoted by the programme are not yet sufficient to buffer against more severe shocks, such as cyclones or prolonged droughts that might have increased in intensity from the baseline. This is consistent with qualitative findings from FGDs, where participants noted that extreme weather events, such as prolonged drought and cyclones, often disrupted agricultural activities and limited the effectiveness of interventions. Importantly, protecting households from increasingly intense extreme climate events may exceed the programme's benefits, and likely require complementary external support and broader systemic interventions.

Table 8: Endline impacts on the impact of climate hazards

Impact of climate hazards	Reference mean [std dev] / (std error)	ATT	%change	Method
Percentage harvest loss due to any shock at endline n=2740	55.21	10.42	18.87%	DID
	[34.13]	(6.56)		
Percentage of livestock that perished due to any shock at endline n=2074	4.69	-3.65	-77.83%	DID
	[17.34]	(2.25)		
Percentage decrease in forest products due to any shock at endline n=810	12.78	-1.47	-11.50%	DID
	[25.51]	(4.81)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

Sampling weights are included and standard errors (indicated in parentheses) are clustered at the local level. Reference mean refers to baseline mean for the treatment group for DID and the potential outcome mean for IPWRA.

6.7 Vulnerability to climate shocks

To assess household vulnerability to climate shocks, we use a composite climate change vulnerability index developed by CI, which combines three dimensions: exposure, sensitivity, and adaptive capacity. Exposure captures the degree to which households experience climate hazards; sensitivity reflects how strongly these hazards affect livelihoods; and adaptive capacity measures households' ability to cope and adjust with these shocks.

We do not detect statistically significant impacts of the programme on overall vulnerability or on any of the three subcomponents (Table 9). While the estimated average treatment effects are not statistically significant, the direction of the changes is consistent with early signs of improved resilience: the vulnerability, exposure, and sensitivity indices show small declines, while the adaptive capacity index shows a modest increase. These patterns align with earlier findings of gradual improvements in agricultural production and reduced climate-related losses.

While these changes cannot be interpreted as definitive programme impacts at this stage, they may signal reduced vulnerability and improved resilience. If observed gains in agricultural production are sustained and expanded, they have the potential to strengthen household livelihoods and enhance resilience to future climate shocks over time.

Table 9: Endline impacts on vulnerability to climate shocks

Vulnerability	Reference mean	ATT	%change	Method
Vulnerability index n=2800	2.21 [0.51]	-0.03 (0.08)	-1.36%	DID
Exposure index n=3206	2.11 [1.10]	-0.15 (0.16)	-7.11%	DID
Sensitivity index n=2898	2.29 [0.79]	-0.07 (0.12)	-3.06%	DID
Adaptation capacity n=2806	2.24 [0.46]	0.08 (0.09)	3.57%	DID

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

Sampling weights are included and standard errors (indicated in parentheses) are clustered at the local level. Reference mean refers to baseline mean for the treatment group for DID and the potential outcome mean for IPWRA.

6.8 Mitigation and reduction in unsustainable resource use

Our findings suggest that the programme contributed to reducing household reliance on environmentally unsustainable activities, during both the wet and dry seasons (Table 10). While overall engagement in such activities has increased since baseline, likely due to external pressures such as population growth and rising demand for wood and fuel, the increase was significantly smaller among programme participants. This suggests that the programme has helped slow the pace of environmentally harmful livelihood strategies.

Table 10: Endline impacts on mitigation

Mitigation	Reference mean [std dev] / (std error)	ATT	%change	Method
Deriving income from non-environmentally sustainable activities in the wet season n=3206	0.03 [0.17]	-0.09 ** (0.04)	-300%	DID
Deriving income from non-environmentally sustainable activities in the dry season n=3206	0.03 [0.18]	-0.08 * (0.04)	-266.67%	DID

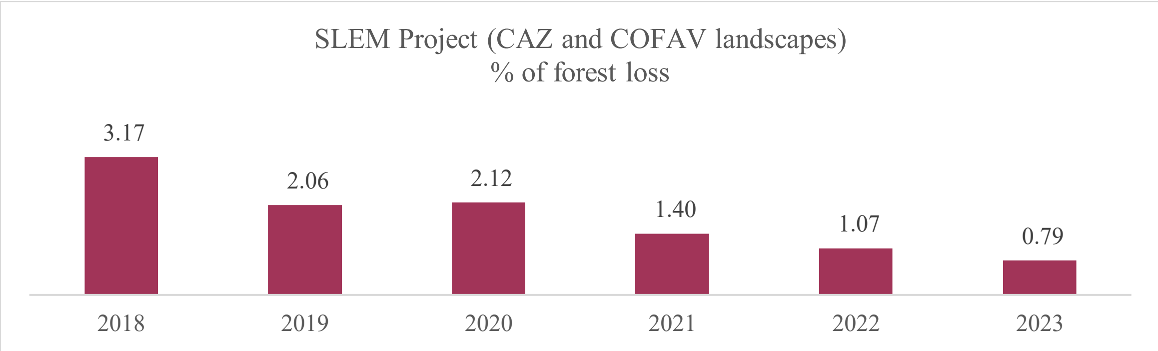
Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

Sampling weights are included and standard errors (indicated in parentheses) are clustered at the local level. Reference mean refers to baseline mean for the treatment group for DID and the potential outcome mean for IPWRA.

These behavioural changes are consistent with broader environmental outcomes observed in programme areas. A complementary Geographic Information System (GIS) analysis conducted by the SLEM team shows a decline in the rate of forest loss within intervention zones since 2018 (Figure 3). This reduction likely reflects a combination of both behavioural shifts, such as reduced reliance on unsustainable income sources, and strengthened enforcement mechanisms, including patrolling activities and reforestation measures.

Figure 3: Change in the rate of deforestation in SLEM intervention areas



Source: CI's calculation.

Note: Deforestation trends were calculated using the national satellite monitoring method recommended by BNCCREDD. This involved downloading satellite images by monitoring date, creating mosaics, applying supervised classification using the Random Forest algorithm, and calculating annual deforestation rates.

VII. Differential impacts

This section examines how programme impacts varied across key population groups and explores possible factors that may have shaped these outcomes. We focus on two dimensions: gender and exposure to recent cyclones. Although the analyses presented here do not test causal mechanisms, they offer insight into the differentiated experiences of project participants and the potential pathways through which the programme may have supported resilience.

7.1 Gendered impact

Female-headed households were unable to sustain their adoption of conservation agriculture practices over time. Despite initial progress at midline, female-headed households were significantly less likely to adopt or maintain labour- and input-intensive conservation practices by the endline, a result which was not found among male-headed households (see Table 11). This pattern aligns with evidence from across East and Southern Africa showing that women's adoption of conservation agriculture is hindered by limited access to labour, land, credit, equipment, and extension services, alongside heavy time burdens and competing uses for crop residues.[34] These constraints are particularly acute for female-headed households, who often face severe labour shortages and limited support. Indeed, while qualitative findings indicate positive outcomes for women, these reflect experiences in male-headed households where men's engagement enhanced the programme's impacts.[35, 36] In Zimbabwe, for instance, women dis-adopted conservation agriculture within the first year when labour demands outweighed perceived benefits, practising conservation agriculture on smaller plots or abandoning key principles to save time.[37]

Table 11: Conservation agriculture practices by gender

EQ2: Conservation agriculture practices	ATT for female headed households	ATT for male headed households	Diff. test
Used soil conservation at endline N of female headed-households= 458	-0.36 **	-0.00	0.02**
	(0.16)	(0.06)	
Percentage of households that implement at least one practice at endline N of female headed-households= 458	-0.17 **	0.01	0.02**
	(0.09)	(0.05)	
Number of conservation agricultural practices adopted at endline N of female headed-households= 458	-1.00 **	-0.11	0.02**
	(0.41)	(0.32)	

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

[34] Farnworth and others, 2015; Wekesah and others, 2019; Huyer and others, 2020.
[35] CI Madagascar, 2025.
[36] As yields and incomes improved, men became more supportive of their spouses' participation and adoption of new practices, strengthening intra-household collaboration.
[37] Hove and Gweme, 2018.

Sampling weights are included and standard errors (indicated in parentheses) are clustered at the local level. Difference test displays the p-value of the t-test on the interaction term, indicating whether the effect differs significantly between groups.

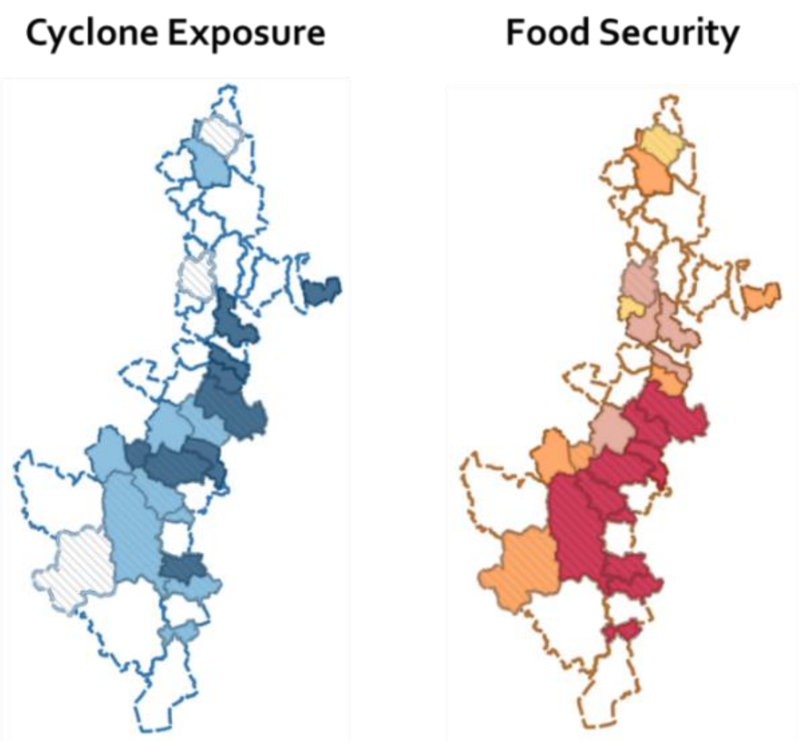
These disparities appear to reflect structural constraints, such as time, labour shortages and vulnerability to shocks, rather than lack of interest or awareness. This leads to reduced adaptive capacity among female-headed households, posing a risk to their long-term resilience. These findings underscore the importance of designing adaptation interventions that account for differentiated constraints across household types. The qualitative study conducted by CI Madagascar provides illustrative examples of how women in women's associations supported each other in adopting climate-smart agricultural practices. The findings suggest that shared labour, pooled inputs, and informal collaboration may have helped some women sustain these practices beyond the project period.[38]

7.2 Resilience for cyclone-affected households

In 2022, a major cyclone struck the project region, causing widespread losses to agricultural production and household assets. This event provides a real-world context to examine whether the SLEM programme helped strengthen households' capacity to cope with large-scale climate shocks.

Geospatial analysis shows that areas most severely affected by the cyclone, indicated by darker blue shading on exposure maps, also exhibited higher levels of food insecurity at endline (Figure 4). This spatial overlap underscores the heightened vulnerability of cyclone-affected regions and highlights the importance of assessing whether the SLEM programme contributed to increased household resilience in the face of large-scale climate shocks.

Figure 4: Cyclone exposure and food insecurity

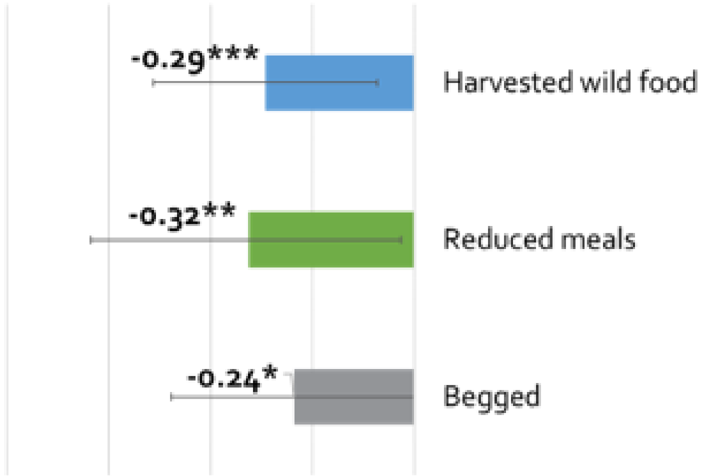


Source: LORTA team analysis using data from the Madagascar endline household survey (2025). Darker shades indicating higher levels of cyclone exposure (on the left) and of food insecurity (on the right).

[38] CI Madagascar, 2025.

Our findings suggest that project participation was associated with greater resilience among cyclone-affected households. Specifically, treated households were significantly less likely to resort to negative short-term coping strategies, such as reducing meals, begging for food, or harvesting wild foods. There was also a lower incidence of harmful long-term strategies, such as withdrawing children from school, though this difference was not statistically significant.

Figure 5: Impact of cyclone exposure on negative coping behaviours



Source: LORTA team analysis using data from the Madagascar endline household survey (2025).

These patterns point to potential gains in adaptive capacity. The programme's support for diversified livelihoods, increased own-production, and behavioural shifts away from environmentally unsustainable activities may have contributed to households' abilities to absorb and adapt to the cyclone's impacts. While these findings are based on subgroup comparisons and should be interpreted with caution, they provide suggestive evidence of improved resilience in the face of climate shocks.

VIII. Discussion

The SLEM programme demonstrated that forest conservation and livelihood improvement can be mutually reinforcing. Over five years, the programme contributed to a significant shift in agricultural production and income among participating households, while simultaneously reducing pressure on forest resources. These findings are supported by a DID analysis using data from two rounds of surveys and matched comparison groups, allowing us to attribute observed changes to the programme with confidence.

Overall, the SLEM programme led to improved profitability in the agricultural production of VOI members five years after their participation in the programme, both in terms of increased output and higher income from crop sales. The agricultural practices promoted by the programme were designed to reduce household vulnerability to climate hazards, such as more frequent and prolonged droughts. These practices included crop diversification, with some crops delivering short-term benefits (e.g. Bambara peas and white beans), while others, particularly cash crops, are expected to generate longer-term impacts. The programme also supported stronger market linkages, notably by encouraging farmers to join cooperatives. At endline, 7 per cent of programme participants were members of a farmer association, compared to only 3 per cent in the comparison group.

The programme's impact on reducing deforestation was also notable. Annual deforestation rates in project areas dropped from 3.2 per cent to 0.8 per cent, supported by community-led patrolling and reduced reliance on income from environmentally harmful activities. Households in project areas were significantly less likely to engage in unsustainable practices such as tree cutting and charcoal production, by 8 percentage points in the wet season and 7 points in the dry season, relative to the comparison group.

Long-term resilience gains remain fragile. Despite increased agricultural income, improvements in resilience and food security were more limited. While average measures of food security did not improve and, in fact, declined across both treatment and comparison areas, there is some evidence that project participation partially mitigated this trend. Households shifted their spending toward long-term investments – education in female-headed households and assets in male-headed ones – rather than immediate consumption, suggesting a prioritization of future wellbeing. These decisions, while strategic, may explain why food consumption indicators lagged behind income growth.

At the same time, the programme appears to have strengthened households' ability to cope with extreme climate shocks. Among cyclone-affected households, project participants were significantly less likely to adopt negative coping strategies, particularly skipping meals and resorting to begging, compared to non-project households. These findings point to gains in short-term resilience, reflecting better preparedness and the ability to smooth consumption during extreme weather events. The effects are consistent with the programme's emphasis on livelihood diversification and preparedness, which may help households absorb shocks even in the absence of large income gains.

Sustaining gains without continued support remains a key challenge. Despite promising results, the evaluation reveals that adoption of conservation agriculture practices declined after project support ended. Simple, low-cost techniques like mulching and composting were more likely to persist, while labour- and input-intensive practices, such as irrigation, off-season rice, and terracing, saw sharp declines in use. This trend highlights the importance of sustained support and enabling environments beyond the programme's two-year implementation period. Expanding irrigation infrastructure and encouraging more efficient water management could significantly enhance climate resilience and agricultural productivity. Equally important is addressing road infrastructure constraints, which continue to limit farmers' access to markets. Nearly half of programme participants (46 per cent) reported market inaccessibility as one of the shocks experienced in the year preceding the endline survey. Improved market connectivity is essential for farmers to fully benefit from increased production, especially as cash crops with longer maturation periods begin to generate returns.

Gender disparities and structural barriers. Female-headed households faced distinct challenges that hindered their continued adoption of resource-intensive practices. Time constraints, reduced access to inputs, and weaker links to extension services disproportionately affected women. A separate qualitative study suggests that women's associations may play a critical role in overcoming gender-related barriers, suggesting that peer support structures can help improve long-term adoption of climate-smart practices when tailored to women's specific constraints.

The lessons learned from the impact evaluation are summarized in the table below. They are organized into lessons relevant for GCF's institutional learning and those specifically applicable to climate project design and implementation.

Table 12: Learnings for the GCF and for project design

For the GCF (institution-level learning)	For project design and implementation
Integrating adaptation and mitigation can deliver measurable co-benefits.	**Resilience requires more than income gains.**
The SLEM programme demonstrates that integrated adaptation-mitigation approaches can simultaneously support livelihood improvement and reduce deforestation, provided that promoted livelihood activities are viable within local community contexts. GCF can prioritize programmes that explicitly link income-generating activities with ecosystem conservation outcomes, supported by clear theories of change.	Increased agricultural income did not automatically translate into improved food security or long-term resilience. Project designs should complement income-focused interventions with measures that directly support food security and resilience, such as nutrition-sensitive agriculture or seasonal consumption support.
Short-term resilience gains are achievable, but long-term resilience remains fragile.	**Design for both shock absorption and longer-term resilience.**
Evidence from cyclone-affected households suggests that projects can strengthen households' capacity to cope with climate shocks. In this impact evaluation, short-term resilience refers to households' ability to absorb and recover from shocks without resorting to immediate negative coping strategies, such as reducing food consumption. While these findings point to gains in short-term resilience, longer-term resilience, captured through structural dimensions of adaptive capacity, was not clearly observed within the available timeframe. This highlights the importance of clearly defining and consistently measuring different dimensions of climate resilience.	Livelihood diversification and preparedness measures helped households avoid negative coping strategies following climate shocks. However, maintaining resilience over time may depend on continued enabling conditions, including the ability to retain productive inputs and access markets.
Sustained engagement and enabling conditions matter for impact durability.	**Plan explicitly for sustainability beyond project closure.**
Poor roads and limited irrigation reduced the potential for scaling productivity gains. While not always part of a project's scope, funding	Declines in adoption of conservation agriculture practices after project closure underline the importance of phased support or structured exit

proposals can identify critical infrastructure gaps and explore co-financing, partnerships, or integration into broader programmes.	strategies to maintain gains. This may include planning for what happens after the project ends, including linkages to extension systems, cooperatives, or market actors.
Community institutions and gender-responsive approaches strengthen outcomes.	**Tailor interventions to gender-specific constraints.**
Community structures, including VOIs and women's groups, played an important role in supporting adoption and sustained gains. Investing in local institutional capacity can enhance sustainability and inclusion.	Female-headed households faced disproportionate barriers to sustaining resource-intensive practices. Gender-responsive design, such as targeted extension, labour-saving technologies, and support to women's associations, should be embedded from the design stage to ensure equitable and lasting impacts.

Appendix

Baseline balance

The need to identify a control group outside the project area with no similar association resulted in observable differences between project participants and the comparison group at baseline (Table A - 1). The comparison group included more female-headed, Betsileo and Bestimisaraka households, lower education levels and fewer adults (though the adult difference was minimal). While this might suggest that comparison households were initially more vulnerable, they had higher baseline food security, were closer to the village centre, and, as expected, located further from the forest.

Table A - 1: Baseline balance

		(1)		(2)	(1)-(2)
		Control		Phase 1	Pairwise t-test
Variables	**N**	**Mean/(SE)**	**N**	**Mean/(SE)**	**Mean difference**
Female household head	908	0.200	912	0.111	0.090***
		(0.013)		(0.010)	
Ethnicity: Other	908	0.044	912	0.372	-0.328***
		(0.007)		(0.016)	
Ethnicity: Betsileo	908	0.372	912	0.175	0.197***
		(0.016)		(0.013)	
Ethnicity: Bestimisaraka	908	0.389	912	0.211	0.178***
		(0.016)		(0.014)	
Ethnicity: Tanala	908	0.195	912	0.240	-0.045**
		(0.013)		(0.014)	
Age of the household head	908	44.954	912	44.748	0.206
		(0.493)		(0.451)	
Never went to school	908	0.176	912	0.161	0.015
		(0.013)		(0.012)	
Primary school	908	0.694	912	0.622	0.072***
		(0.015)		(0.016)	
Above primary	908	0.130	912	0.217	-0.087***
		(0.011)		(0.014)	
Nb. of adults at baseline	908	2.622	912	2.843	-0.221***
		(0.044)		(0.050)	
Nb. of children at baseline	908	3.324	912	3.386	-0.062
		(0.077)		(0.077)	
Food secure	908	0.116	912	0.133	-0.017
		(0.011)		(0.011)	
Marginally food secure	908	0.503	912	0.409	0.094***
		(0.017)		(0.016)	
Moderately insecure	908	0.357	912	0.409	-0.052**
		(0.016)		(0.016)	
Severely insecure	908	0.024	912	0.049	-0.025***
		(0.005)		(0.007)	
Total expenditures at baseline (in log)	907	12.126	912	12.233	-0.106**
		(0.037)		(0.036)	

Residence in CAZ	908	0.398	912	0.407	-0.009
		(0.016)		(0.016)	
Distance to Fokontany centre (in log)	908	2.167	910	3.026	-0.859***
		(0.049)		(0.055)	
Distance to closest forest (in log)	907	4.192	910	3.764	0.428***
		(0.031)		(0.036)	

Source: Baseline data.

Note: Standard errors clustered at the locality level. Sampling weights are used. *** p<0.01, ** p<0.05, * p<0.1

Attrition analyses

Of the 1,820 households interviewed at baseline, 1,623 were successfully reinterviewed at endline, with little difference between project participants and the comparison group. The overall attrition rate (under 11 per cent) is only slightly above the 10 per cent buffer anticipated in the study design.

The main reasons for attrition were migration (31 per cent), death (23 per cent), and temporary unavailability (19 per cent), with migration and death more frequent among project participants.

To explore potential attrition bias, we regress a binary indicator for being missing at endline on baseline characteristics, including household head demographics, household composition, and livelihood indicators. Results are shown in Table 11.[39]

Table A - 2: Attrition analysis at endline

	(1)	**(2)**	**(3)**
Variables	**Attrition in the whole sample**	**Attrition within Phase 1**	**Attrition within Control**
Female household head	0.35**	0.33*	0.40
	(0.17)	(0.19)	(0.25)
Ethnicity = 1, Betsileo	-0.76***	-0.84***	-0.93***
	(0.19)	(0.30)	(0.20)
Ethnicity = 2, Bestimisaraka	0.01	0.12	-0.63
	(0.16)	(0.18)	(0.60)
Ethnicity = 3, Tanala	-0.30*	-0.22	-0.54***
	(0.16)	(0.21)	(0.19)
Age of the household head	-0.01	-0.00	-0.01**
	(0.00)	(0.01)	(0.00)
Highest education level in the household = 2, primary school	-0.12	-0.30*	0.10
	(0.12)	(0.17)	(0.16)
Highest education level in the household = 3, above primary	-0.28*	-0.18	-0.54**
	(0.15)	(0.20)	(0.26)
Nb. of adults at baseline	0.05	0.03	0.09
	(0.04)	(0.04)	(0.06)
Nb. of children at baseline	-0.05**	-0.05	-0.07**
	(0.02)	(0.03)	(0.04)
Food security index = 2, marginally food secure	-0.26	-0.22	-0.30
	(0.17)	(0.19)	(0.32)
Food security index = 3, moderately insecure	-0.13	-0.11	-0.18
	(0.18)	(0.22)	(0.34)

[39] The regression includes 1,814 households due to missing values on some covariates.

Food security index = 4, severely insecure	-0.27	-0.53	0.21
	(0.29)	(0.35)	(0.49)
Total expenditures at baseline (in log)	-0.08*	-0.05	-0.11**
	(0.05)	(0.08)	(0.05)
Residence in CAZ	0.00	-0.05	0.44
	(0.20)	(0.22)	(0.69)
Distance to Fokontany centre (in log)	0.04	0.01	0.09*
	(0.03)	(0.04)	(0.05)
Distance to closest forest (in log)	-0.03	-0.10*	0.04
	(0.05)	(0.05)	(0.10)
Observations	1,814	908	906

Source: Baseline and endline data.

Note: Marginal effects from probit regressions. Attrition refers to not having participated to the endline survey. All independent variables are obtained from the baseline survey. Standard errors clustered at the locality level. Sampling weights are used. *** p<0.01, ** p<0.05, * p<0.1.

Female-headed households were more likely to be missing at endline. Betsileo households – and, within the comparison group, Tanala households – were less likely to attrit. Among project participants, differences between reinterviewed and missing households are otherwise minimal, supporting the representativeness of the sample. However, attrition limits extrapolation to the missing non-Betsileo and female-headed households. The implications for gendered impacts are unclear: missing female-headed households may reflect time constraints unrelated to the project, increased economic activity due to the project (leading to underestimation), or migration to other opportunities (potentially leading to overestimation).

Attrition in the comparison group is more selective, with household head age, education, number of children, and wealth affecting the likelihood of reinterview. This pattern actually reduces some of the imbalances observed at baseline, while the study's evaluation design accounts for remaining differences, preserving internal validity.

Robustness check

For each of our estimation strategies, we conduct two main robustness checks. Our DID estimation relies on the parallel trends assumption, which we cannot directly test with the available data. This assumption is more plausible when the treatment and comparison groups are similar at baseline. By combining matching with DID, we reduce the reliance on the parallel trends assumption. Specifically, we implement the Sant'Anna and Zhao (2020) estimator of the Average Treatment Effect on the Treated (ATT) in DID setups where the parallel trend assumption is assumed to hold after conditioning on a set of pre-treatment covariates. These variables include baseline values of remoteness (distance from the fokontany centre and from forest) and involvement in herding. We compare results both using the improved doubly robust DID estimator based on inverse probability of tilting (robustness test 1) and using the doubly robust DID estimator based on stabilized inverse probability weighting (robustness test 2). We further test the robustness of our matching estimates by examining their sensitivity to the choice of matching method. Specifically, we alternatively apply five nearest-neighbours matching (robustness test 1) and kernel matching (robustness test 2).

Robustness test 1: Nearest-neighbours matching

Table A - 3: Livelihood strategies

EQ1: Livelihood strategies	Reference mean [std dev] / (std error)	ATT	% change	Method
Participation in farm livelihoods in the wet season at endline	0.99	0.03	3.03%	DRDID
n=3206	[0.11]	(0.02)		
Participation in off-farm livelihoods in the wet season at endline	0.09	-0.03	-33.33%	DRDID
n=3206	[0.28]	(0.04)		
Participation in non-farm livelihoods in the wet season at endline	0.35	-0.15 **	-42.86%	DRDID
n=3206	[0.48]	(0.07)		
Participation in farm livelihoods in the dry season at endline	0.98	0.04 **	4.08%	DRDID
n=3206	[0.13]	(0.02)		
Participation in off-farm livelihoods in the dry season at endline	0.08	-0.04	-50.00%	DRDID
n=3206	[0.28]	(0.04)		
Participation in non-farm livelihoods in the dry season at endline	0.34	-0.07	-20.59%	DRDID
n=3206	[0.47]	(0.07)		
Number of crops cultivated by the household at endline	5.17	0.25 *	4.84%	5-NNM
n=1603	[2.05]	(0.14)		
TLU at endline	0.81	0.52	64.20%	5-NNM
n=1603	[1.38]	(0.47)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, a doubly robust DID estimator based on stabilized inverse probability weighting and ordinary least squares is used,[40] with sampling weights included and standard errors (indicated in parentheses) clustered at the local level.

5-NNM = Five nearest-neighbour matching. DRDID = Doubly robust difference-in-differences. For cross-section regressions, 5-NMM is used with robust standard errors. Reference mean refers to baseline mean for the treatment group under DRDID and to the mean within the control group under 5-NNM.

[40] Sant'Anna and Zhao, 2020.

Table A - 4: Conservation agriculture practices

EQ2: Conservation agriculture practices	Reference mean [std dev] / (std error)	ATT	% change	Method
Used soil conservation at endline	0.45	-0.03	-6.67%	DRDID
n=3088	[0.50]	(0.08)		
Used agroforestry at endline	0.45	0.04	8.89%	DRDID
n=3088	[0.50]	(0.08)		
Used terracing at endline	0.24	0.01	4.17%	DRDID
n=3088	[0.43]	(0.06)		
Used resistant crops at endline	0.31	0.06	19.35%	DRDID
n=3088	[0.46]	(0.06)		
Used multi-cropping at endline	0.52	0.08	15.38%	DRDID
n=3088	[0.50]	(0.07)		
Used irrigation at endline	0.67	0.04	5.97%	DRDID
n=3086	[0.47]	(0.08)		
Used off-season rice at endline	0.29	0.02	6.90%	DRDID
n=3088	[0.45]	(0.06)		
Used storage at endline	0.24	-0.13 ***	-54.17%	DRDID
n=3088	[0.43]	(0.05)		
Used pest management at endline	0.28	-0.03	-10.71%	DRDID
n=3088	[0.45]	(0.09)		
Used saving groups at endline	0.11	-0.04	-36.36%	DRDID
n=3088	[0.31]	(0.05)		
Percentage of households that implement at least one practice at endline	0.92	-0.01	-1.09%	DRDID
n=3088	[0.27]	(0.05)		
Number of conservation agricultural practices adopted at endline	3.55	0.01	0.28%	DRDID
n=3088	[2.08]	(0.30)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, a doubly robust DID estimator based on stabilized inverse probability weighting and ordinary least squares is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, 5-NMM is used with robust standard errors. Reference mean refers to baseline mean for the treatment group under DRDID and to the mean within the control group under 5-NMM.

Table A - 5: Impact of climate hazards

EQ3: Impact of climate hazards	Reference mean [std dev] / (std error)	ATT	% change	Method
Percentage harvest decrease due to any shock at endline	55.21	9.73	17.62%	DRDID
n=2740	[34.13]	(6.09)		
Percentage of livestock that perished due to any shock at endline	4.69	-3.00	-63.97%	DRDID
n=2074	[17.34]	(2.23)		
Percentage decrease in forest products due to any shock at endline	12.78	-4.60	-35.99%	DRDID
n=810	[25.51]	(6.03)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, a doubly robust DID estimator based on stabilized inverse probability weighting and ordinary least squares is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, 5-NNM is used with robust standard errors. Reference mean refers to baseline mean for the treatment group under DRDID and to the mean within the control group under 5-NNM.

Table A - 6: Agricultural production

EQ4: Agricultural production	Reference mean [std dev] / (std error)	ATT	% change	Method
Rice production at endline (in kg, inverse hyperbolic sine transformation)	5.97	0.14	15.03%	DRDID
n=3206	[2.21]	(0.25)		
Bean production at endline (in kg, inverse hyperbolic sine transformation)	0.72	0.09	15.01%	DRDID
n=3206	[1.69]	(0.25)		
Groundnut production at endline (in kg, inverse hyperbolic sine transformation)	0.08	0.45 **	593.21%	DRDID
n=3206	[0.64]	(0.18)		
Bambara peas production at endline (in kg, inverse hyperbolic sine transformation)	0.22	0.21 ***	99.92%	5-NNM
n=1603	[0.93]	(0.06)		
Ginger production at endline (in kg, inverse hyperbolic sine transformation)	0.15	-0.03	-20.11%	DRDID
n=3206	[1.01]	(0.08)		
Total value of crop production (in MGA, inverse hyperbolic sine transformation)	14.38	0.28 **	32.31%	5-NNM
n=1601	[2.35]	(0.11)		

Total value of livestock production at endline (in MGA, inverse hyperbolic sine transformation)	11.61	0.66 *	93.48%	5-NNM
n=1602	[5.63]	(0.39)		
Total value of forest production at endline (in MGA, inverse hyperbolic sine transformation)	5.95	-0.64	-47.27%	5-NNM
n=1591	[5.86]	(0.41)		
Share of crop production that was sold at endline	4.28	3.11	72.66%	DRDID
n=3132	[5.22]	(1.94)		
Share of livestock production that was sold at endline	10.06	-2.41	-23.96%	DRDID
n=2376	[13.84]	(2.35)		
Share of forest product harvest that was sold at endline	6.33	0.54	8.53%	DRDID
n=924	[14.41]	(2.85)		
Rice yield (in kg/are)	20.5	-1.71	-8.34%	5-NNM
n=1537	[19.52]	(1.39)		
bean yield (in kg/are)	7.39	0.09	1.22%	5-NNM
n=621	[6.84]	(0.69)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, a doubly robust DID estimator based on stabilized inverse probability weighting and ordinary least squares is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, 5-NMM is used with robust standard errors. Reference mean refers to baseline mean for the treatment group under DRDID and to the mean within the control group under 5-NNM.

Table A - 7: Income and expenditures

EQ5: Income and expenditures	**Reference mean [std dev] / (std error)**	**ATT**	**% change**	**Method**
Income from rice selling at endline (in MGA, inverse hyperbolic sine transformation)	2.98	3.40 ***	2904.15%	5-NNM
n=1603	[5.47]	(0.43)		
Income from bean selling at endline (in MGA, inverse hyperbolic sine transformation)	1.26	1.57 ***	420.90%	5-NNM
n=1603	[3.63]	(0.32)		
Income from groundnut selling at endline (in MGA, inverse hyperbolic sine transformation)	0.43	1.04 ***	364.54%	5-NNM
n=1603	[2.21]	(0.17)		

Income from Bambara peas selling at endline (in MGA, inverse hyperbolic sine transformation)	0.21	0.40 ***	206.57%	5-NNM
n=1603	[1.55]	(0.10)		
Income from ginger selling at endline (in MGA, inverse hyperbolic sine transformation)	1.07	-0.11	-13.36%	5-NNM
n=1603	[3.61]	(0.15)		
Total annual household income at endline (in MGA, inverse hyperbolic sine transformation)	14.24	0.22	24.61%	5-NNM
n=1600	[2.46]	(0.17)		
Household expenditures at endline (in MGA, inverse hyperbolic sine transformation)	15	-0.11	-10.42%	DRDID
n=3204	[0.80]	(0.14)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, a doubly robust DID estimator based on stabilized inverse probability weighting and ordinary least squares is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, 5-NMM is used with robust standard errors. Reference mean refers to baseline mean for the treatment group under DRDID and to the mean within the control group under 5-NNM.

Table A - 8: Food security

EQ6: Food security	**Reference mean [std dev] / (std error)**	**ATT**	**% change**	**Method**
CARI at endline (units)	2.31	0.03	1.30%	DRDID
n=3206	[0.73]	(0.11)		
Number of days without food in the last 12 months at endline	14.36	-8.81	-61.35%	DRDID
n=3192	[30.27]	(6.81)		
Household Dietary Diversity Score	8.9	0.27 **	3.03%	5-NNM
n=1603	[1.51]	(0.11)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, a doubly robust DID estimator based on stabilized inverse probability weighting and ordinary least squares is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, 5-NMM is used with robust standard errors. Reference mean refers to baseline mean for the treatment group under DRDID and to the mean within the control group under 5-NNM.

Table A - 9: Vulnerability

EQ7: Vulnerability	Reference mean [std dev] / (std error)	ATT	% change	Method
Vulnerability index	2.21	-0.03	-1.36%	DRDID
n=2800	[0.51]	(0.08)		
Exposure index	2.11	-0.17	-8.06%	DRDID
n=3206	[1.10]	(0.16)		
Sensitivity index	2.29	-0.05	-2.18%	DRDID
n=2898	[0.79]	(0.13)		
Adaptation capacity	2.24	0.09	4.02%	DRDID
n=2806	[0.46]	(0.10)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, a doubly robust DID estimator based on stabilized inverse probability weighting and ordinary least squares is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, 5-NMM is used with robust standard errors. Reference mean refers to baseline mean for the treatment group under DRDID and to the mean within the control group under 5-NNM.

Table A - 10: Mitigation

EQ12: Mitigation	Reference mean [std dev] / (std error)	ATT	% change	Method
Deriving income from non-environmentally sustainable activities in the wet season	0.03	-0.08 **	-266.67%	DRDID
n=3206	[0.17]	(0.03)		
Deriving income from non-environmentally sustainable activities in the dry season	0.03	-0.07 *	-233.33%	DRDID
n=3206	[0.18]	(0.04)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, a doubly robust DID estimator based on stabilized inverse probability weighting and ordinary least squares is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, 5-NMM is used with robust standard errors. Reference mean refers to baseline mean for the treatment group under DRDID and to the mean within the control group under 5-NNM.

Robustness test 2: Kernel matching

Table A - 11: Livelihood strategies

EQ1: Livelihood strategies	Reference mean [std dev] / (std error)	ATT	% change	Method
Participation in farm livelihoods in the wet season at endline	0.99	0.03	3.03%	DRDID-IPW
n=3206	[0.11]	(0.02)		
Participation in off-farm livelihoods in the wet season at endline	0.09	-0.03	-33.33%	DRDID-IPW
n=3206	[0.28]	(0.05)		
Participation in non-farm livelihoods in the wet season at endline	0.35	-0.15 **	-42.86%	DRDID-IPW
n=3206	[0.48]	(0.08)		
Participation in farm livelihoods in the dry season at endline	0.98	0.04 **	4.08%	DRDID-IPW
n=3206	[0.13]	(0.02)		
Participation in off-farm livelihoods in the dry season at endline	0.08	-0.04	-50.00%	DRDID-IPW
n=3206	[0.28]	(0.05)		
Participation in non-farm livelihoods in the dry season at endline	0.34	-0.07	-20.59%	DRDID-IPW
n=3206	[0.47]	(0.07)		
Number of crops cultivated by the household at endline	5.17	0.58 ***	11.22%	Kernel
n=1603	[2.05]	(0.15)		
TLU at endline	0.81	0.59	72.84%	Kernel
n=1603	[1.38]	(0.50)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, simple DID is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, Kernel matching is used with bootstrapped standard errors with 100 repetitions. Reference mean refers to baseline mean for the treatment group under DID and to the mean within the control group under Kernel matching.

Table A - 12: Conservation agriculture practices

EQ2: Conservation agriculture practices	Reference mean [std dev] / (std error)	ATT	% change	Method
Used soil conservation at endline	0.45	-0.03	-6.67%	DRDID-IPW
n=3088	[0.50]	(0.08)		
Used agroforestry at endline	0.45	0.04	8.89%	DRDID-IPW
n=3088	[0.50]	(0.09)		
Used terracing at endline	0.24	0.01	4.17%	DRDID-IPW
n=3088	[0.43]	(0.06)		
Used resistant crops at endline	0.31	0.06	19.35%	DRDID-IPW
n=3088	[0.46]	(0.06)		

Used multi-cropping at endline	0.52	0.08	15.38%	DRDID-IPW
n=3088	[0.50]	(0.07)		
Used irrigation at endline	0.67	0.04	5.97%	DRDID-IPW
n=3086	[0.47]	(0.08)		
Used off-season rice at endline	0.29	0.02	6.90%	DRDID-IPW
n=3088	[0.45]	(0.06)		
Used storage at endline	0.24	-0.13 ***	-54.17%	DRDID-IPW
n=3088	[0.43]	(0.05)		
Used pest management at endline	0.28	-0.03	-10.71%	DRDID-IPW
n=3088	[0.45]	(0.09)		
Used saving groups at endline	0.11	-0.04	-36.36%	DRDID-IPW
n=3088	[0.31]	(0.05)		
Percentage of households that implement at least one practice at endline	0.92	-0.01	-1.09%	DRDID-IPW
n=3088	[0.27]	(0.05)		
Number of conservation agricultural practices adopted at endline	3.55	0.01	0.28%	DRDID-IPW
n=3088	[2.08]	(0.30)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

IPW = .Inverse probability weighting. For panel regressions, simple DID is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, Kernel matching is used with bootstrapped standard errors with 100 repetitions. Reference mean refers to baseline mean for the treatment group under DID and to the mean within the control group under Kernel matching.

Table A - 13: Impact of climate hazards

EQ3: Impact of climate hazards	Reference mean [std dev] / (std error)	ATT	% change	Method
Percentage harvest decrease due to any shock at endline	55.21	9.73	17.62%	DRDID-IPW
n=2740	[34.13]	(6.27)		
Percentage of livestock that perished due to any shock at endline	4.69	-3.00	-63.97%	DRDID-IPW
n=2074	[17.34]	(2.26)		
Percentage decrease in forest products due to any shock at endline	12.78	-4.60	-35.99%	DRDID-IPW
n=810	[25.51]	(5.90)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, simple DID is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, Kernel matching is used with bootstrapped standard errors with 100 repetitions. Reference mean refers to baseline mean for the treatment group under DID and to the mean within the control group under Kernel matching.

Table A - 14: Agricultural production

EQ4: Agricultural production	Reference mean [std dev] / (std error)	ATT	% change	Method
Rice production at endline (in kg, inverse hyperbolic sine transformation)	5.97	0.14	15.03%	DRDID-IPW
n=3206	[2.21]	(0.27)		
Bean production at endline (in kg, inverse hyperbolic sine transformation)	0.72	0.09	15.01%	DRDID-IPW
n=3206	[1.69]	(0.25)		
Groundnut production at endline (in kg, inverse hyperbolic sine transformation)	0.08	0.45 **	593.21%	DRDID-IPW
n=3206	[0.64]	(0.18)		
Bambara peas production at endline (in kg, inverse hyperbolic sine transformation)	0.22	0.31 ***	150.32%	Kernel
n=1603	[0.93]	(0.05)		
Ginger production at endline (in kg, inverse hyperbolic sine transformation)	0.15	-0.03	-20.11%	DRDID-IPW
n=3206	[1.01]	(0.08)		
Total value of crop production (in MGA, inverse hyperbolic sine transformation)	14.38	0.41 *	50.68%	Kernel
n=1601	[2.35]	(0.21)		
Total value of livestock production at endline (in MGA, inverse hyperbolic sine	11.61	0.61	84.04%	Kernel
n=1602	[5.63]	(0.52)		
Total value of forest production at endline (in MGA, inverse hyperbolic sine transformation)	5.95	0.66	93.48%	Kernel
n=1591	[5.86]	(0.48)		
Share of crop production that was sold at endline	4.28	3.12	72.90%	DRDID-IPW
n=3132	[5.22]	(2.25)		
Share of livestock production that was sold at endline	10.06	-2.41	-23.96%	DRDID-IPW
n=2376	[13.84]	(2.47)		
Share of forest product harvest that was sold at endline	6.33	0.55	8.69%	DRDID-IPW
n=924	[14.41]	(3.20)		
Rice yield (in kg/are)	20.5	-3.99 **	-19.46%	Kernel
n=1537	[19.52]	(1.59)		
Bean yield (in kg/are)	7.39	1.79 *	24.22%	Kernel
n=621	[6.84]	(0.98)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, simple DID is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, Kernel matching is used with bootstrapped standard errors with 100 repetitions. Reference mean refers to baseline mean for the treatment group under DID and to the mean within the control group under Kernel matching.

Table A - 15: Income and expenditures

EQ5: Income and expenditures	Reference mean [std dev] / (std error)	ATT	% change	Method
Income from rice selling at endline (in MGA, inverse hyperbolic sine transformation)	2.98	2.52 ***	1146.05%	Kernel
n=1603	[5.47]	(0.52)		
Income from bean selling at endline (in MGA, inverse hyperbolic sine transformation)	1.26	1.65 ***	464.58%	Kernel
n=1603	[3.63]	(0.35)		
Income from groundnut selling at endline (in MGA, inverse hyperbolic sine transformation)	0.43	0.75 ***	232.35%	Kernel
n=1603	[2.21]	(0.22)		
Income from Bambara peas selling at endline (in MGA, inverse hyperbolic sine transformation)	0.21	0.50 ***	264.54%	Kernel
n=1603	[1.55]	(0.11)		
Income from ginger selling at endline (in MGA, inverse hyperbolic sine transformation)	1.07	0.14	18.77%	Kernel
n=1603	[3.61]	(0.15)		
Total annual household income at endline (in MGA, inverse hyperbolic sine transformation)	14.24	0.56 **	75.07%	Kernel
n=1600	[2.46]	(0.23)		
Household expenditures at endline (in MGA, inverse hyperbolic sine transformation)	15	-0.11	-10.42%	DRDID-IPW
n=3204	[0.80]	(0.15)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, simple DID is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, Kernel matching is used with bootstrapped standard errors with 100 repetitions. Reference mean refers to baseline mean for the treatment group under DID and to the mean within the control group under Kernel matching.

Table A - 16: Food security

EQ6: Food security	Reference mean [std dev] / (std error)	ATT	% change	Method
CARI at endline (units)	2.31	0.03	1.30%	DRDID-IPW
n=3206	[0.73]	(0.12)		
Number of days without food in the last 12 months at endline	14.36	-8.80	-61.28%	DRDID-IPW
n=3192	[30.27]	(7.04)		
Household Dietary Diversity Score	8.9	0.40 **	4.49%	Kernel
n=1603	[1.51]	(0.16)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, simple DID is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, Kernel matching is used with bootstrapped standard errors with 100 repetitions. Reference mean refers to baseline mean for the treatment group under DID and to the mean within the control group under Kernel matching.

Table A - 17: Vulnerability

EQ7: Vulnerability	Reference mean [std dev] / (std error)	ATT	% change	Method
Vulnerability index	2.21	-0.03	-1.36%	DRDID-IPW
n=2800	[0.51]	(0.09)		
Exposure index	2.11	-0.17	-8.06%	DRDID-IPW
n=3206	[1.10]	(0.17)		
Sensitivity index	2.29	-0.05	-2.18%	DRDID-IPW
n=2898	[0.79]	(0.14)		
Adaptation capacity	2.24	0.09	4.02%	DRDID-IPW
n=2806	[0.46]	(0.10)		

Source: LORTA team

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, simple DID is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, Kernel matching is used with bootstrapped standard errors with 100 repetitions. Reference mean refers to baseline mean for the treatment group under DID and to the mean within the control group under Kernel matching.

Table A - 18: Mitigation

EQ12: Mitigation	**Reference mean [std dev] / (std error)**	**ATT**	**% change**	**Method**
Deriving income from non-environmentally sustainable activities in the wet season	0.03	-0.08 **	-266.67%	DRDID-IPW
n=3206	[0.17]	(0.03)		
Deriving income from non-environmentally sustainable activities in the dry season	0.03	-0.07 *	-233.33%	DRDID-IPW
n=3206	[0.18]	(0.04)		

Source: LORTA team.

Notes: *, **, and *** represent statistical significance at the 10 per cent, 5 per cent, and 1 per cent level respectively.

For panel regressions, simple DID is used, with sampling weights included and standard errors (indicated in parentheses) clustered at the local level. For cross-section regressions, Kernel matching is used with bootstrapped standard errors with 100 repetitions. Reference mean refers to baseline mean for the treatment group under DID and to the mean within the control group under Kernel matching.

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