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Impact evaluation of the Menabe and Melaky development programme in Madagascar

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About this report

3ie accepted the final version of the report, *Impact evaluation of the Menabe and Melaky development programme in Madagascar,* as partial fulfilment of requirements under grant TW4.2.02 awarded through the Agricultural Innovation Thematic Window. Despite best efforts in working with the authors, some figures could not be improved. We have copy-edited the content to the extent possible.

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We also gratefully acknowledge the patience exercised by the Malagasy households, community leaders and community members during interviews. It is our hope that the insights from the information they provided will translate into valuable support for their communities.

Plain-language summary

Background

Farmers in western Madagascar live in an arid region that makes it difficult to survive on their own production. As in many other regions in less developed countries, there is a big initiative to improve agricultural production. Agricultural development is particularly important for a country like Madagascar, with 77.8 per cent of the population living in rural settings (Rasambainarivo and Ranaivoarivelo 2003). In such a dry region, it is important to understand whether large-scale investments in irrigation infrastructure can improve outcomes for smallholder farmers. To do so, we focused on crop yields, cropping in multiple seasons and improved agricultural practices. We identified these outcomes as key indicators of improved agricultural livelihoods.

Appui au Développement du Menabe et du Melaky (AD2M) farmers had the opportunity to change the way they grow crops. The programme created new irrigation infrastructure in areas that had not been irrigated and rehabilitated existing irrigation infrastructure when possible. The irrigation allowed farmers to use better agricultural techniques. For example, they potentially could manage water flow to crops better during the primary growing season and could support a second growing season with the more efficient water supply. We would expect crop yields to increase if farmers followed these techniques.

Evaluation findings

We found meaningful improvements in the AD2M programme beneficiaries' agricultural productivity. Annualised rice yields were estimated to be about 25 per cent greater for treated versus control households, and annualised total value of crop production per hectare was estimated to be about 16 per cent higher for treated versus control households. Focus group discussions with farmers revealed that they attribute the increased rice production to improved irrigation and adoption of the row-cropping method. Evidence also suggested that most of the gains in the treated communities came from the ability to crop in the second season; treated households were much more likely to crop in more than one season. AD2M also improved access to extension services and trainings, as well as the use of purchased inputs. Finally, treated households also worried less about finding food than untreated households did.

AD2M was effective in improving the delivery of water. Farmers in AD2M communities were 15 percentage points more likely to report receiving their water on time. The timing is important because crops can fail if water is unavailable at key points in the growing cycle. Farmers were also 26 percentage points more likely to report that their irrigated water was of good quality. Access to irrigation can only improve farming outcomes if it is of sufficient quality.

Results suggest that household welfare increased due to the intervention. The value of crop production per capita increased by 13.6 per cent for AD2M beneficiaries. Agricultural production is a primary source of income for rural farmers; thus, we expect the increased crop value to contribute to greater income. Non-monetary measures of household welfare also improved. Beneficiary households reported worrying about food

over the prior week 10.3 per cent less often than control households. Households benefiting from AD2M owned 1.04 more durable consumer items than control households. Qualitatively, respondents reported that individual incomes indeed increased as a result of increased rice yields. Respondents indicated that purchasing power had increased and that more people had become able to live in stone or brick houses.

Qualitative data confirmed that AD2M introduced, and encouraged farmers to grow, new crops, with the most frequently mentioned being onions, beans, peanuts and tomatoes. Farmers in focus group discussions shared their belief that multi-cropping improved soil quality, and many reported continuing to grow these new crops today. Curiously, the farmers reported little crop expansion during the quantitative survey. Rice, cassava and beans/pulses were common crops in the area for all farmers. Other crops were far less common.

On the negative side, some respondents reported increased tension as a result of AD2M. There appears to have been a division between farmers that cooperated with AD2M and those that did not, as well as a general mistrust of Water User Association members among non-member farmers. Despite the tensions between AD2M, farmers in intervention areas were 10 per cent more likely to engage with extension workers, meaning that farmers still felt it worthwhile to engage with extension workers.

Recommendations

As with other ex-post evaluations, one must consider the limitations of the study. The Appui au Développement du Menabe et du Melaky programme was implemented in areas that were more agriculturally and hydrologically promising. Therefore, we cannot rule out that there were underlying differences between treatment areas and control areas, despite our efforts to avoid this.

One recommendation to keep in mind when planning activities for future irrigation programming is to be mindful of the seasons. Farmers expressed frustration that some AD2M activities were poorly timed, such as dam repairs in Mahabo during the rainy season. A second recommendation is to place more emphasis on initial sensitisation to the programme and community engagement; some farmers felt that they were not consulted about programme activities and were left out of key decisions. Community surveys suggest that AD2M Water User Associations may have even simply replaced existing, functioning farmers' associations. A third recommendation is to invest in higher-quality irrigation materials. Qualitatively, farmers reported that infrastructure was not durable once AD2M left. Quantitatively, only 40 per cent of treated farmers felt that the irrigated water was of good quality. Although higher than in control areas, this rate remains low. Finally, the findings from our evaluation underscore the importance of maintaining clear communication with community members throughout programme implementation (especially when taking an important action such as a water cut) and including modes of communication appropriate for illiterate community members.

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Abbreviations and acronyms

AD2M	Appui au Développement du Menabe et du Melaky (Support for the Development of Menabe and Melaky)
AIR	American Institutes for Research
ATET	Average treatment effect on the treated
ATW	Around The World
CEPs	Champs écoles paysans (farmer field schools)
GIS	Geographic information system
IFAD	International Fund for Agricultural Development
IPWRA	Inverse-probability-weighted regression adjustment
NDVI	Normalised difference vegetation index
SRA	Système de riziculture améliorée (improved rice system)
SRI	System of rice intensification
WUA	Water User Association

1. Introduction

We evaluated the impact of access to newly constructed or rehabilitated irrigation in western Madagascar. Access to irrigation is an important way to increase food security for farmers otherwise dependent on much riskier, rain-fed agriculture. Climate change increases the need to protect farmers from weather shocks that negatively impact agricultural yields. This is particularly true for farmers in the Appui au Développement du Menabe et du Melaky (AD2M) target regions of Menabe and Melaky in central-western Madagascar, where farm households currently face very high levels of poverty and malnutrition.

Research has frequently shown that many projects that aim to increase the area under irrigation have not led to the hoped-for gains (Branca et al. 2013). There are a number of reasons cited in the literature, including the quality of initial feasibility studies, the quality and appropriate location of irrigation infrastructure, and the efficacy of governance put in place to regulate water uses and users and to ensure maintenance of irrigation infrastructure.

The research questions addressed in this report, covering the impact of irrigation on crop production and stability of crop income, provide much-needed evidence on the likely gains to farmers from future irrigation interventions in Madagascar. The descriptive analysis of information on infrastructure construction, management and maintenance will shed light on the relative importance of these components in generating gains at the farm level. The potential implications of the research are threefold: (1) results will provide evidence on the gains from irrigation that policymakers can compare with other potential investments to increase food security; (2) results will inform the importance of construction, particularly management and maintenance, in ensuring sustainable gains; and (3) results will highlight how future irrigation projects could use impact assessments to gain further valuable evidence on the importance of beneficiary targeting, irrigation management mechanisms and maintenance activities.

Most of the empirical evidence regarding yield and household income gains from irrigation indicates large increases, at least when infrastructure is well built and governance of the irrigated areas functions well (Hussain and Hanjra 2004). In the case of Madagascar, Jacoby and Minten (2005) documented a large, statistically significant increase in yields and net revenue per hectare on irrigated lands compared with non-irrigated lands – an increase of approximately 30 per cent for both. This study also found a 30 per cent increase in rice yields (we considered only the main-season rice yields and net revenues, so annual increases in net revenue could well be higher if the off-season were taken into account). Thus, the empirical literature supports the hypothesis that having access to irrigated land should lead to increases in yield, net crop revenues and marketed surpluses. Oddly, even though irrigation is often seen as a way to reduce the risks associated with rain-fed agriculture, the empirical literature for developing countries, particularly outside of South East Asia, is less thorough in quantifying the benefits of a more stable crop income, although Nakano and colleagues (2013) present some evidence on yield and income stability in six Sub-Saharan African countries. We add to the body of literature with this study, finding that irrigation caused an increase of roughly US$45 in crop income over the previous year.

The purpose of this evaluation is to provide evidence on the effectiveness of irrigation in promoting more stable crop production and improved farmer livelihoods. This goal is particularly relevant for AD2M because a second phase of AD2M is to be implemented in new areas. Key AD2M staff have expressed great interest in using the results of this evaluation to better understand how they can improve their upcoming work.

We use quasi-experimental matching techniques to quantify the impacts of AD2M irrigation on beneficiaries. We compare AD2M beneficiaries with control farmer households identified using inter-temporal geographic information system (GIS) analysis. We find that the total value of production increased by 25–30 per cent, and the value of the rice harvest increased by approximately the same amount. At the same time, our findings raise concerns about the longevity of these impacts after the AD2M programme is completed.

Section 2 discusses the theory underlying the AD2M intervention and the focus of the evaluation. Section 3 outlines the evaluation methodology. Section 4 gives the key findings of the study. Section 5 discusses the validity of the findings. Section 6 discusses policy implications and concludes the report.

2. Research focus

2.1 Context

Agriculture is the most common livelihood for residents of Madagascar, employing 75.3 per cent of the rural population and accounting for 28.2 per cent of the gross domestic product (World Bank 2012). The AD2M programme implemented irrigation, land titling, training and related rural development projects in 19 communes (groupings of villages) throughout 5 districts in western Madagascar: Belo sur Tsiribihina, Mahabo and Miandrivazo in the Menabe region, and Antsalova and Maintirano in the Melaky region. Agricultural terrain in these areas is typically either flat coastal delta valleys or terraced hillsides. The valleys are well suited for agricultural exploitation, whereas the hillsides are subject to erosion. The months of November to March bring warm temperatures and increased rainfall, and the months of April to October are drier and cooler. The west of Madagascar is generally considered a dry area because storms from the Indian Ocean deposit their rain on the eastern slopes of Madagascar's highlands. The regions of Menabe and Melaky are similar to the rest of the country, which has an overall poverty rate of 76.5 per cent, with 50 per cent of the population affected by climate-related shocks and environmental degradation. However, the two regions differ from the rest of the country in that they receive far less rainfall.

Agriculture in Menabe and Melaky resembles agriculture in much of the rest of the country. The typical farmer grows primarily for subsistence and exploits a small area of land. Many of the techniques the farmers use are suboptimal either in terms of yields or in terms of environmental impact. For example, farmers rarely employ SRI (system of rice intensification), a method of transplanting and spacing seedlings, despite its improved output. Farmers also employ slash-and-burn methods for increasing the land available to them for crops – a practice that is counterproductive in both the short and long term. AD2M promoted improved agricultural practices and provided irrigation to 5,508 hectares: 3,313 hectares of new irrigation and 2,195 hectares of rehabilitated irrigation.

The AD2M programme arrived at a time of political turmoil in Madagascar. A sudden change in the presidency in 2009 led to turmoil that effectively halted government development activities. Furthermore, a number of donors withdrew funding for programmes in Madagascar until democratic rule was re-established. This led to a paucity of other interventions during the period from 2008 to 2014. However, even though foreign aid increased after the presidential elections, economic growth has remained low, at a rate of 3.3 per cent in 2014 and 3.4 per cent in 2015. To summarise, AD2M began when there was a great need for interventions that would spur improved livelihoods.

In the mid-2000s, the Government of Madagascar began adopting laws and implementing policies aimed at empowering the poor and decentralising administration and public services. Land reforms and decentralisation of land offices were a strong focus of this process, beginning in 2005. Programme activities began in 2007. The political crisis in 2009 delayed activities significantly, but the land reform and other decentralisation plans were continued under the new government. At the same time, despite relatively generous rainfall and water resources within the country, many farm households remained mired in poverty and vulnerable to the vagaries of the weather. This situation was particularly intense in the two regions of Menabe and Melaky, where farmers focus heavily on rice production but many also undertake a range of other income-generating activities, including agricultural wage labour, raising livestock and the production of some cash crops (for example, groundnuts and sugarcane). The programme's goals were to support the government's land decentralisation and certification process and to increase the ability of poor farm families to increase agricultural production sustainably and to market their produce. Irrigation was seen as a key activity, particularly as it leads to not only higher production but also more stable production.

2.2 Intervention

The AD2M programme is organised around three components (and eight subcomponents): component I, support for local governance and land tenure security; component 2, support for sustainable development of the productive base; and component 3, project management and monitoring and evaluation. Its implementation was planned to take place over a period of eight years beginning in 2007.

The intervention itself focused on tenure security and more productive, stable and sustainable agricultural incomes. The first component included activities directly related to local land governance and tenure security. With respect to land governance, activities included land use diagnostics, the development of local land use plans, and the establishment of 14 land offices, as well as numerous training sessions on land administration and legal rights related to land for land office staff, local leaders and community members. With respect to tenure security, through support to the land offices, 8,840 land certificates were issued. The second component focused on promotion of technologies and practices to increase agricultural production, including increasing access to irrigation, introduction of new seed varieties, promotion of additional cash crops (e.g. onions), increasing access to agricultural equipment, and increasing access to markets through road construction, waterway infrastructure and micro-finance kiosks. With respect to irrigation specifically, the programme hired consultants to perform detailed irrigation feasibility studies to identify irrigated areas in need of rehabilitation and

sites for new irrigation infrastructure. The feasibility studies included detailed information on hydrological and topographical features, rainfall, the size of the irrigable area and cost estimates for irrigation infrastructure, and basic information about socioeconomic characteristics of potential beneficiaries. Of 62 sites considered, 36 were deemed to be feasible; of these 36, 18 sites received new or rehabilitated infrastructure.

The programme targeted 57,000 households in five groups, including, in order of priority: (a) landless agricultural wage earners with no productive assets and no cattle; (b) households with small, non-irrigated landholdings (less than two hectares) and no cattle; (c) households primarily dependent on fishing the regions' watersheds; (d) households with small irrigated landholdings (less than two hectares) and fewer than 10 cattle; and (e) households primarily dependent on raising cattle. AD2M anticipated that this programme would affect 40 per cent of the rural population of the Menabe and Melaky regions. The number of beneficiaries was estimated at 342,000, out of a total estimated population of 586,000 in the intervention area (i.e. 58%).

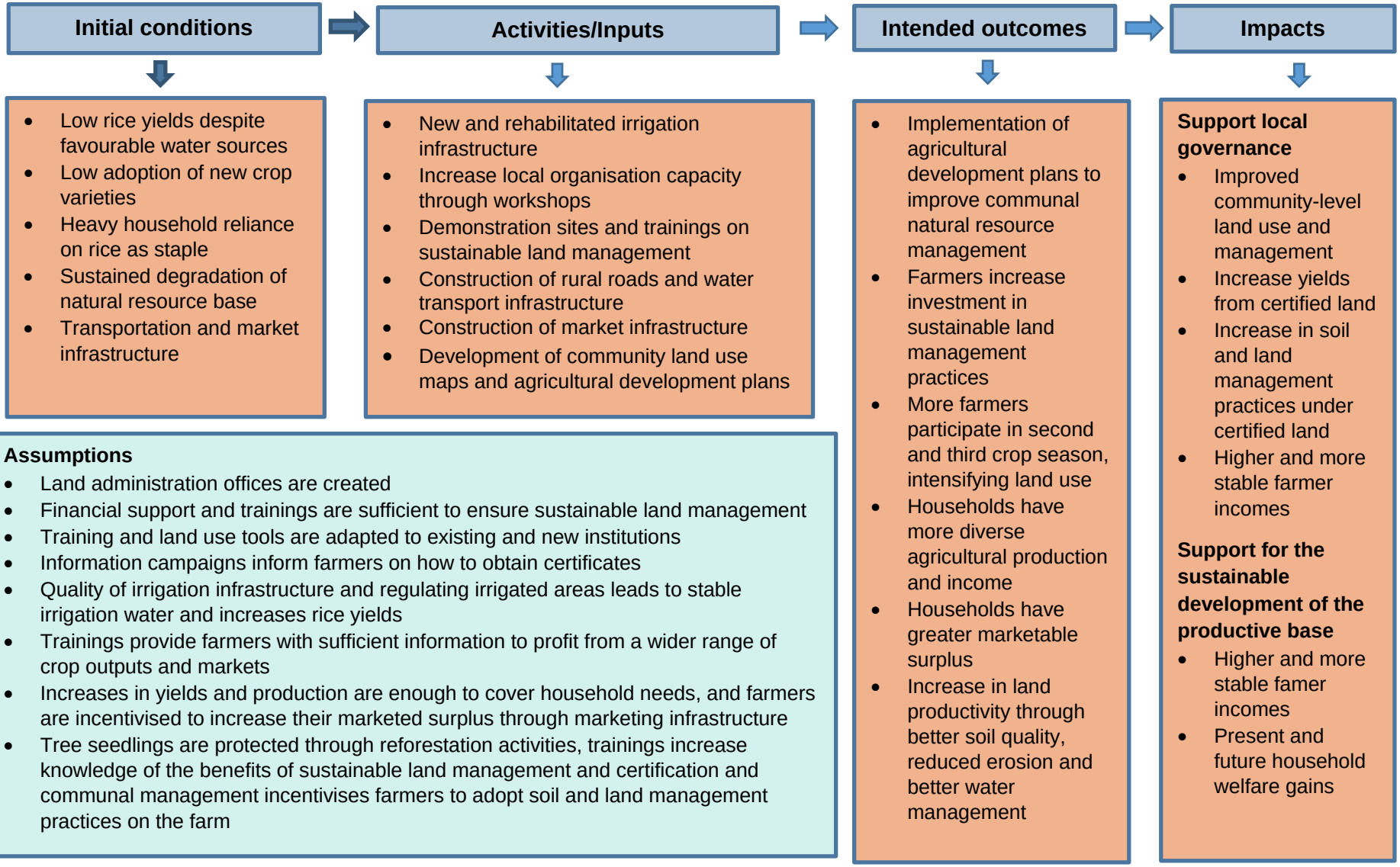
The programme involved co-financing and strategic partnerships (technical and financial) with the Millennium Challenge Account, the European Union supported *Appui aux communes et organisations rurales pour le développement du sud* (ACORDS) programme and the SAHA programme of the Swiss Agency for Development and Cooperation. Implementation of these activities was entrusted to partner organisations or specialised service providers (such as NGOs, consulting firms, private companies, de-concentrated technical service providers) from the Menabe and Melaky regions.

2.3 Theory of change

The evaluation focused on the household-level outcomes and impacts from access to certificated irrigation land. We used information collected on other programme activities as control variables to account for regional variation in other AD2M interventions. Although the evaluation focused on irrigated land, below we present the theory of change for the entire programme, including both the certification and irrigation activities that were the focus of this evaluation, as well as all other programme inputs for which we collected data (and which we controlled for in the analysis).

The figure reads from left to right, in order of events. First, we identify the initial conditions that made the AD2M intervention necessary. Then, we briefly describe the activities that would initiate change. Next, we identify the immediate outcomes that follow from the programme's activities. Finally, we show the ultimate impacts of the AD2M interventions.

Figure 1: Theory of change



2.4 Research questions

Given that AD2M is a complex programme with many activities, we could not separately evaluate the impact of individual activities. Because many of the activities were related to increasing crop production and land productivity, we focused on these variables as key measures of programme impact. Because there is pre-existing irrigation infrastructure throughout this area of Madagascar – meaning that compairson households were likely to have access to irrigation as well – we precisely selected controls for our analyses to ensure similar levels of access to irrigation at the beginning of the AD2M programme. The distinguishing impacts of AD2M on crop production were hypothesised to occur through three main channels: (1) expanded irrigation plots with certificated rights; (2) higher-quality irrigation infrastructure; and (3) other programme activities, such as training, aimed at increasing crop productivity and overall farm incomes.

The key crop production research questions were as follows:

1. Did treatment lead to increases in: (1) rice yields; (2) quantity of rice produced per capita; (3) total value of irrigated crop production; and (4) value of crop production per capita? Our analyses assessed the extent to which crop income increased. These outcomes are closely associated with higher average yields and crop income.
2. Did treatment enable farmers to increase the number of cropping seasons within the year and to have a more diversified crop portfolio? These outcomes are closely related to stability in income, both within the year (greater production throughout) and across years (more diversified crop portfolio).

Answering the above research questions enabled us to draw conclusions about the extent to which farmers obtained higher and more stable incomes. We could also assess whether AD2M households were more likely to adopt crop productivity-enhancing practices and inputs, which helped us to understand how higher and more stable crop production was generated. This led to the following key research question:

3. Did treatment lead to an increase in sustainable land management practices or adoption of cash inputs?

Additionally, for the subset of households with access to plots in an irrigation scheme, we could evaluate the extent to which treatment induced better performance of Water User Associations (WUAs) in maintaining and governing the irrigation system, as follows:

4. Given the importance of well-functioning WUAs in maintaining irrigation infrastructure and regulating water use, did treatment lead to better WUA performance?

Finally, although the data set is not powered to evaluate whether different subgroups exhibit heterogeneous impacts, we could use estimated coefficients and standard errors from our estimations to determine whether estimated treatment effects are different for certain control variables. We performed this type of heterogeneity-of-impact analysis on three variables: (1) whether any plot managers in the household were women; (2) whether any plot managers had any schooling; and (3) the proportion of households within a village that accessed any source of credit. Interpreting these results must be done with care, as they are only suggestive, given the power of the sample.

2.5 AD2M programme activities and timeline

Table 1 illustrates the timeline of AD2M programme implementation by the International Fund for Agricultural Development (IFAD).

Table 1: IFAD Madagascar AD2M programme timeline

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016/17
Administrative activities											
Approval of the programme by the IFAD Executive Board											
Signature of loan agreement											
Establishment of the regional and national steering and follow-up committees											
Start-up workshop											
Entry into force of IFAD Loan No. 689-MG and Grant 849-MG											
Technical activities											
Component I: Support for local governance and land tenure security											
I.A Support to producers' organisations and strengthening local actors											
a. Mobilising producers and supporting their organisations											
b. Support to rural communities and regions											
c. Functional literacy											
d. Boosting projects for the most vulnerable											
I.B Support for land security											
a. Construction and rehabilitation of buildings											
b. Delivering land certificates											
c. Micro-projects for the most vulnerable											
Component II: Support for the sustainable development of the productive base											
II.A Rural development											
a. Hydro-agricultural development											
b. Rural road track development											
II.B Agricultural development and preservation of natural resources											

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016/17
a. Agro-ecological sites and reforestation											
b. Agricultural intensification and diversification											
II.C Commercialisation and rural financing											
a. Providing and installing farming tools workshops											
b. Commercialisation activities											
c. Rural financing activities											
Component III: Monitoring, evaluation and learning											
III.A Internal programme monitoring and evaluation											
III.B Independent external evaluation											

2.5.1 Rice cultivation/multi-cropping/row cropping training

In order to dispense this training, the programme put in place farmer field schools (champs écoles paysans or CEPs). This was the programme's main tool regarding agricultural intensification and diversification activities. The CEPs consisted of workshops/classes designed to train participants on farming techniques for various types of crops (rice, beans, lentils, onions, peanuts and apiculture). By the end of 2014, the programme had held 863 CEPs (compared with an original target of 590), affecting 18,007 beneficiary farmers (122% of the targeted 14,750). Farmers put the CEP techniques in place on 6,135 hectares of land (104% of the target of 5,900 hectares) (Rapport de supervision, 2014).

2.5.2 WUA trainings

As of December 2014, 992 members in 161 WUAs had received training. Participants were trained on irrigation management and systems for recovering maintenance fees for WUAs. Participants also received training on group governance.

3. Evaluation: Design, methods and implementation

This evaluation uses matching techniques to study the impact of the AD2M programme using surveys with 1,454 households. Qualitative research used 18 key informant interviews and 16 focus group discussions. Data were collected in Mahabo and Belo sur Tsiribihina during November and December 2016.

3.1 Sample selection

In collaboration with IFAD and AD2M local officers, and through the observation-based and criteria-based targeting approach, we identified potential treatment and control areas for inclusion in the study. Including control areas helped to address concerns about not capturing the true impacts because of spill-over effects into neighbouring areas. One of the key criteria for control areas was that they be potentially irrigable sites that were nonetheless not selected to receive irrigation infrastructure under the programme's first phase. AD2M provided the detailed feasibility studies that it had performed for every site; of the sites studied, 36 were considered feasible, and the programme undertook activities in 24 irrigated areas (perimeters) at 18 sites. The feasibility studies also included basic information on predominant crop practices and other characteristics that further aided us in selecting control areas.

The evaluation aimed to survey 1,950 households, split between 650 treated households and 1,300 controls (see calculation in section 3.1 below). The AD2M programme also provided data from household questionnaires that it had administered in 2007 and 2015; the 2007 questionnaires had also been augmented with further information in 2009. The 2007 and 2015 data sets were not longitudinal. In both cases, some information was collected from non-treated villages, although the number of potential control households was very small (245 of 1,450 households in 2015). Nonetheless, the data sets enabled us to triangulate evidence from the extant literature on rice crop yields and annual crop incomes, enabled us to calculate village-level intra-cluster correlation coefficients (household-level outcomes on rice yields, value of rice production and value of total crop production, clustered at the village level), and allowed us to explore the extent to which household covariates explained rice yields.

Analysis at project inception also enabled us to design a better filter questionnaire. The filter questionnaire ensured that only those potential control group farmers who were most similar to the treated farmers remained in the final sample. By including a filter questionnaire that eliminated dissimilar farmers, we ensured that project resources spent on the full household survey were allocated to those farmers most relevant to the study and reduced the overall time burden associated with the survey (because we administered the survey only to the relevant farmers).

The evaluation study's sample was designed to provide enough statistical power to identify impacts above a reasonable threshold. Using the data collected for this study, we conducted power calculations to determine what size of impact we could expect to detect; the study is sufficiently powered to detect a 0.348 standardised-mean-difference impact. Online Appendix D further explains the details of the power underlying the evaluation's analysis.

The research team maintained careful processes to ensure accurate data. ATW implemented data collection activities under the supervision of the American Institutes of Research (AIR) and Lead Analytics. Quantitative surveys were administered on pre-programmed tablets. Prior to data collection, ATW provided the research team templates for data collection. There were extensive discussions to revise survey instruments to minimise the challenges that would arise in the field. Dr Morey, the research team's quantitative researcher, travelled to Madagascar to assist in data collector training. During data collection, ATW communicated regularly about successes and challenges encountered in the field. Throughout the roughly six-week data collection, ATW sent the research team batches of completed surveys. AIR and Lead Analytics conducted rigorous and systematic data checks to verify data quality.

Qualitative data collection followed similar quality assurance processes. Ms Ring, the co-principal investigator, travelled to Madagascar to assist with data collection training. She also travelled with the data collection team to Mahabo to participate in the first week of focus group discussions and key informant interviews. ATW used digital voice recorders to enable professional transcription and translation of all interviews and focus groups. As ATW completed and processed qualitative transcripts, they sent them to the research team in batches. Two researchers then reviewed the transcripts and coded them on the basis of the established analytical framework. In addition to the triangulation between researchers that occurred during the data coding and analysis phase, responses from individual participants in the AD2M evaluation were also triangulated with those of other respondents. Protocols were designed in such a way as to document the experience and perspectives of those on whom the programme had an impact (e.g. programme implementers, government stakeholders, local leaders, and groups of WUA members and non-WUA farmers across two districts) on shared topics, events and issues related to the AD2M programme. By asking similar questions about common themes and issues across these groups, researchers were able to identify areas of convergence and divergence among participants.

3.2 Quantitative estimation strategy

Given the complexity of the programme, we focused on the parts promoting irrigation in Menabe. Households in Menabe all received ownership certificates for their irrigated plots, whereas those in Melaky did not; resources prevented us from evaluating two different treatments. Although we controlled for the benefits of other programme activities in the analyses, we were not able to evaluate these activities separately, as different activities were undertaken in different areas (e.g. transportation infrastructure projects). Our impact estimates, therefore, measure the impact of irrigation only for those whose land was titled.

All of the analysis results reported here and in the Online Appendices use a double-robust estimator specification. Specifically, we use Wooldridge's inverse-probability-weighted regression adjustment (IPWRA) estimator (Wooldridge 2010), implemented with the IPWRA command in STATA. This estimator models both the treatment probability and the outcome, and is considered double robust because consistent estimates of the treatment effects are obtained even if one of the two models is mis-specified (Bang and Robins 2005; Scharfstein, Rotnitzky and Robins 1999). Given limited data on household characteristics for the period preceding programme

implementation, we might expect that our treatment specification would be more noisy than a longitudinal sample, and, indeed, our estimated propensity scores exhibited a fair amount of variability. As pointed out by Sloczynski and Wooldridge (2016), the Wooldridge (2010) weighted estimator is less sensitive to relatively high variation in the propensity score, which led to the choice of IPWRA over other double-robust estimators (such as the augmented inverse-probability-weighted estimator). Although double-robust estimators do have advantages, there remains the possibility that relevant variables omitted from both of the model equations can cause biased estimates.

For continuous outcome variables, we specify a linear regression for the outcome equations and specify probits for dichotomous outcome variables. To model the average treatment effect on the treated (ATET) within the context of the IPWRA model, we followed Hirano and Imbens (2001). The weighted least squares regression capturing ATETs and allowing for additional covariates can be written as follows:

$$Y_i = \alpha_0 + \tau T_i + \alpha_1 Z_i + \alpha_2 (Z_i - \bar{Z}) T_i + \varepsilon_i, \quad [1]$$

where Y_i is our outcome variable of interest, T_i is our indicator for treatment, Z_i is a vector of covariates in the outcome equation, $\bar{Z}$ is the sample average of Z for the subsample of treated households, ε_i is the error term, and τ, α_1 and α_2 are parameters to be estimated. Our weights are given by:

$$\omega(t, x) = t + (1 - t) \frac{\hat{p}(x)}{1 - \hat{p}(x)}, \quad [2]$$

where $\omega(t, x)$ is the weight applied, t represents $T_i = 1$, $\hat{p}(x)$ is the estimated propensity score and x is a vector of covariates.

Finally, the ATET is estimated using the comparison of average predicted outcome values ($\hat{Y}$) for treatment households to average predicted values for control households:

$$ATET = E\left[\hat{Y} \middle| T_i = 1\right] - E[\hat{Y} | T_i = 0], \quad [3]$$

3.3 Qualitative estimation strategy

After transcription, all qualitative data collected during the AD2M evaluation were imported into the NVivo qualitative software programme. Then two qualitative researchers from AIR followed a series of steps to sort, code, analyse and interpret the data. The analysis team created a preliminary coding scheme on the basis of the original research questions, interview protocols and field notes regarding themes that emerged during data collection. This thematic coding outline served as the tool to initially index, sort and organise the data gathered from interviews and focus group discussions.

Once the data were organised in this way, the analysts reviewed the data extracts to identify and compare patterns and emerging findings within and among themes and cases, examining differences in perspectives among groups, contradictions, and any key findings and themes related to the research questions. At the beginning of the coding process, the two analysts selected a sample of interviews for them both to code, so that they could then compare and discuss their findings, ensuring inter-coder reliability.

During the process of coding and analysis, researchers met to discuss new themes that had emerged and any other necessary revisions to the coding scheme (e.g. deletions, recategorisations, clarifications), and to compare similarities and differences in thematic analysis.

Both qualitative researchers separately coded the first two full focus group discussion transcripts and then performed a coding comparison query through NVivo to determine their level of agreement. The comparison query revealed an overall agreement percentage of 98.1 per cent, indicating a high level of consistency between the two researchers in the interpretation of data and showing the clarity of the coding scheme.

3.4 Evaluation timeline

Table 2 illustrates the timeline of the AD2M impact evaluation.

Table 2: Evaluation study timeline

Activity	Year (August 2016 – August 2017)												
	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Inception		X											
Finalising research design		X	X										
Developing survey instruments and interview protocols		X	X										
Quantitative evaluation													
Selection of treatment and control areas			X										
Piloting instruments			X	X									
Data collection			X	X	X								
Data entry and cleaning				X	X	X	X	X	X				
GIS analysis				X				X					
Quantitative analysis						X	X	X	X	X			
Qualitative evaluation							X	X	X	X	X		
Key informant interview, national level				X	X				X				
Key informant interview, regional level				X	X								
Key informant interview, commune level				X	X								
Focus group discussions, commune level				X	X								
Analysis of qualitative data						X	X	X	X				
Reporting									X	X	X	X	
Presentation													X

The above schedule was at times disrupted or deviated from because of unanticipated events. Our data collection team was unable to access one of the irrigated perimeters in the town of Belinta because of a mix of security issues, poor roads and inclement weather. Our timeline also had to be modified to allow for a GIS analysis that had not been planned for during the evaluation's inception phase.

4. Impact analysis and results

All findings are based on data collected in late 2016. We collected quantitative data on tablets using Open Data Kit technology to provide safeguards against errors in recording survey responses. The programme would provide real-time error messages if households answered questions in a way inconsistent with their prior responses. The data collection firm's staff provided data to the research team as they collected it to allow AIR and Lead Analytics to conduct data checks. We received qualitative data from 34 sources in total, coded by two qualitative researchers using NVivo software. We drafted coding nodes with input from both qualitative analysts on the basis of knowledge of the project and the questions being asked of individuals and focus groups. Both researchers coded the data from the first two focus groups. Once a high level of agreement (98.1%, discussed above) was confirmed, the analysts individually coded the remaining 32 data sources. The analysts met frequently to discuss their findings to make sure consistent themes were being uncovered and asked questions related to coding as they arose.

4.1 Outcome variables

Our primary outcome variables included the annual value of production per hectare cultivated, the annual value of production per capita, annual rice yields and annual quantity of rice harvested per capita. In addition, we evaluated programme impacts on crop input and crop management variables, measures of household welfare outcomes and measures of the performance of the irrigation system. With respect to crop input and management variables, we considered whether the household received any agricultural extension advice, whether they attended a training on any agricultural topic, whether they invested in any mechanical soil and water conservation measures, whether they invested in any biological soil and water conservation measures, the number of cattle held and the number of oxen held, the proportion of plots on which they applied inorganic fertiliser, whether they used pesticides on any plot, whether they used herbicides on any plot, and whether they cultivated any plot in the second or third seasons.

With respect to household welfare measures, we included whether the household reported having worried about adequate food during the prior 7 days, whether the household had faced a situation of too little food in the past 12 months, the number of consumer durables owned, education expenditures, and whether any member of the household had been ill in the past 2 weeks.

For irrigation performance, we were able to run the statistical tests only for respondents who had access to plots in a gravity-based system, which reduced the sample to 995, comprising 418 treated households and 577 control households. Households in this subset were more likely to be located in areas where it was relatively less costly to construct and maintain gravity-based systems (i.e. areas with topographical, hydrological and other environmental characteristics that lower the cost of constructing and operating such systems). However, despite this shortcoming, these tests allowed us to explore the impact of the programme on irrigation performance, going beyond the mere existence of irrigation construction/rehabilitation. Irrigation performance outcomes included whether the household generally received water on time, whether they received their full allocation and whether water quality was deemed good (as opposed to brackish or somewhat brackish).

4.2 Control variables

We included a set of controls covering biophysical characteristics, plot management characteristics, and household characteristics and a set of spatial dummies. For the treatment model, we included only control variables that we expected not to have been impacted by the AD2M programme.

The main measure of the land's fertility that we included is the normalised difference vegetation index (NDVI) from August 2011 satellite imagery. The degree of greenness captured by the NDVI is a useful measure of fertility that we expected to increase as a result of irrigation, although the measure is too coarse to capture irrigation at the level of a farmer's plot. We used the August 2011 NDVI because this should capture greenness in the second season, when irrigation may be more useful than during the primary rainy season. We used data from 2011 primarily because that year is the earliest available observation for the month of August, and because few, if any, irrigation perimeters were fully up and running by that time.

To account for differences in each household's plots and thus in their production potential, we included variables capturing the proportion of households' plot area where the primary soil type was sand and where the primary soil type was loam, with the excluded category being soil that was primarily clay. We also controlled for the proportions of plot area that were flat, slightly sloped and moderately sloped, with the excluded category being steeply sloped plots.

To account for production decisions that might affect household output, we controlled for whether the household had any plots managed by a female family member, whether there were any plots managed by a family member with any education, and the proportion of the household's plots that were owned by the household. We used 'any education at all' as a variable because of the low education levels across our sample. Female managers were considered because they might use different decision-making priorities than male managers. The correlation between having any plot managed by a female manager and having a female head of household was high, at 82 per cent, so this variable may also capture other information about the household. Plots were considered owned by the household if the household did not rent, borrow or squat without permission.

We included the natural logarithm of total hectares cultivated in any season, or the natural logarithm of hectares of cultivated rice in any season, for the dependent variables that were specific to rice production. We also captured whether the household used organic and inorganic fertiliser.

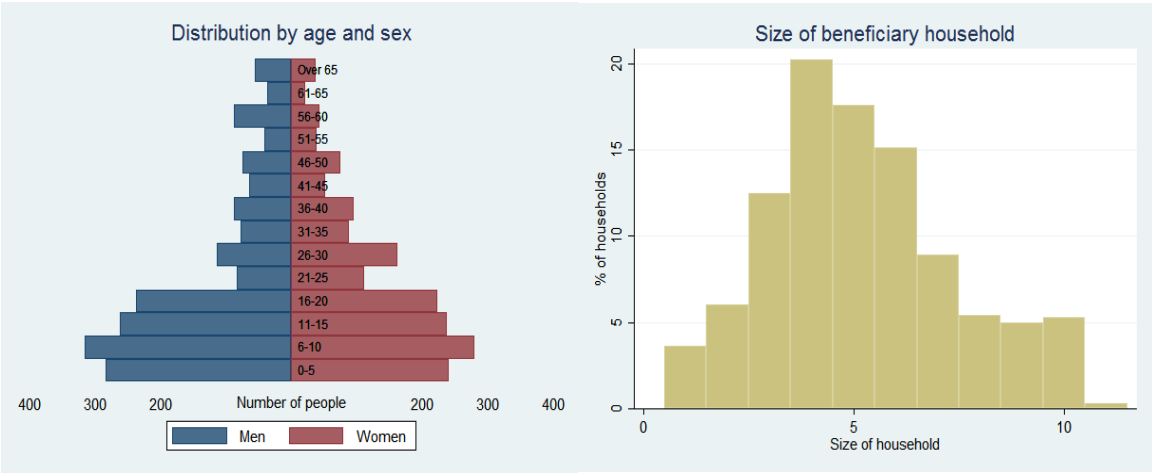
In the outcome equations, we included two specifications in the results reported in section 4.5 and onwards. One specification included a dummy for whether the household irrigated any of their plots, irrespective of the type of irrigation (e.g. pumped groundwater and stream diversion, as well as gravity-based irrigation systems), and a second specification did not include this dummy. On the one hand, having irrigated plots will have a positive impact on crop production, irrespective of the type of irrigation. On the other hand, having access to any type of irrigation is clearly correlated with being treated. Specifically, for the sample used in our main results, the simple correlation

coefficient was 0.14; nearly 73 per cent of treatment households had at least one plot with irrigation, but nearly 60 per cent of control households also had at least one plot with irrigation. These households gained water access outside the context of AD2M. Because there is no simple way to address this statistically, we present results from both specifications.

The irrigation that exists in control areas means that we are presenting conservative estimates of the impacts of irrigating a farm. With such a high rate of irrigation among control households, the effect of irrigation we estimate is relative to a mix of no irrigation and partial irrigation. However, the irrigation in control areas formed organically and is not a case of contamination. Less than 3 per cent of control households reported participating in AD2M trainings and they did not receive interventions from other projects either. The Projet Bas Mangoky is irrigating part of the Atsimo Andrefana region in the south, a consortium of donors is irrigating the Boeny region of the northwest, and a small World Bank project is irrigating an area of Mahabo that was not part of our study. Therefore, there is little concern that the control area has been contaminated by any exogenous irrigation.

Household characteristics related to productive capacity were the number of adult equivalents in the household and the ratio of adults to dependents. We included the natural logarithm of the household head's age and dummy variables for whether the household head was literate in French and in Malagasy. We captured household wealth by including the number of rooms in the household's dwelling and a dummy for whether the household had an improved toilet in the dwelling. Income diversification was proxied by dummies for whether the household had any members receiving regular wages and whether any members were engaged in casual employment. We also included the number of children of the household head and spouse who were living elsewhere. These children living elsewhere may represent an important risk-coping mechanism; they may be far enough away to be unaffected by shocks that threaten the household's well-being. Figure 2 shows the gender distribution of AD2M beneficiaries in our study as well as the distribution of household size. The left panel in the figure shows that there is relative gender parity; the right panel shows the distribution of household size, reflecting an average of 5.2 members per household.

Figure 2: Beneficiary demographics



Finally, we were not able to collect data at the village level to control for location-specific characteristics. Instead, we used the proportion of households in the village that had accessed any source of credit and the average time to collect drinking water. Both of these variables help to control for more favourable local conditions (in this case, access to greater financial resources and easier access to drinking water). We also included a district dummy, noting here that households were in one of two districts.

4.3 Observations used in analysis

Table 3 below summarises the observations used for analysis. We collected data from 1,743 households – 1,126 control and 617 treated. We first restricted our analysis to the 1,713 households that reported having any crop cultivation, since these are the subset where an irrigation programme might directly affect household outcomes. There were 259 control households in areas that had higher NDVI values in August 2011 than any treatment areas. August is a month in the secondary rainy season in which the presence of irrigation can have tangible effects on the NDVI. We believe the observations in 2011 would be prior to the AD2M programme having an effect on greenness, as most perimeters were still being constructed or rehabilitated. Since the 259 control households started with higher NDVI than any of our treated households, they represented a problem for our counterfactual, and we omitted them from our analysis. The balance plot and test results suggested that matching on the subsample significantly improved the balance. In online appendix F.A, we provide the balance plot and the balance test for the full sample; results showed that we rejected the null hypothesis that covariates were balanced. Thus, in sections 4.5 and onwards we present results for this subsample of 1,454 households rather than the full sample; full results are in online appendix F.B. In a third specification, we also dropped the 98 treatment households that did not have any plots in the irrigation perimeter and therefore definitely did not receive the full treatment. This increased the potential for biased estimates but provided a cleaner comparison between treatment and control households. For the third specification, we report results only for our four crop production variables; full results are in online appendix F.C. Finally, we note that the number of observations households analysed differs when we consider rice production, since not all of the included households produced rice.

Table 3: Numbers of households in analyses

	Total	Treatment	Control
Full sample			
*Household*s	1,743	617	1,126
Restricting to households that cultivated any crop			
Households	1,713	614	1,099
Rice producers	1,582	597	985
Restricting to areas where August 2011 NDVI < 0.46			
Households	1,454	614	840
Rice producers	1,401	597	804
Removing treatment households without access to irrigation			
Households	1,356	516	840
Rice producers	1,318	514	804

4.4 Quality of counterfactual

In this section, we present the balance test results for the subsample of 1,454 households. The balance plot in Figure 3 shows that the two distributions skew towards relatively high propensity scores for the treatment households, which supported use of IPWRA. Although the densities are rather different just above 0.5, the balance test, where the null hypothesis is that covariates are balanced, gives a chi-square value of 29.6 and a *p*-value of .160, so we failed to reject the null hypothesis. Furthermore, the weights do a good job in balancing on the August 2011 NDVI values, which is a particularly important variable on which to achieve balance, as shown in Table 4. Table 4 presents the values of key outcomes for treatment, control, and a test of equivalence between the two. The ratio of the difference and the standard error of the difference provides a test of equivalence. The results show good balance, with none of the outcomes statistically significantly different.

Figure 3: Balance summary

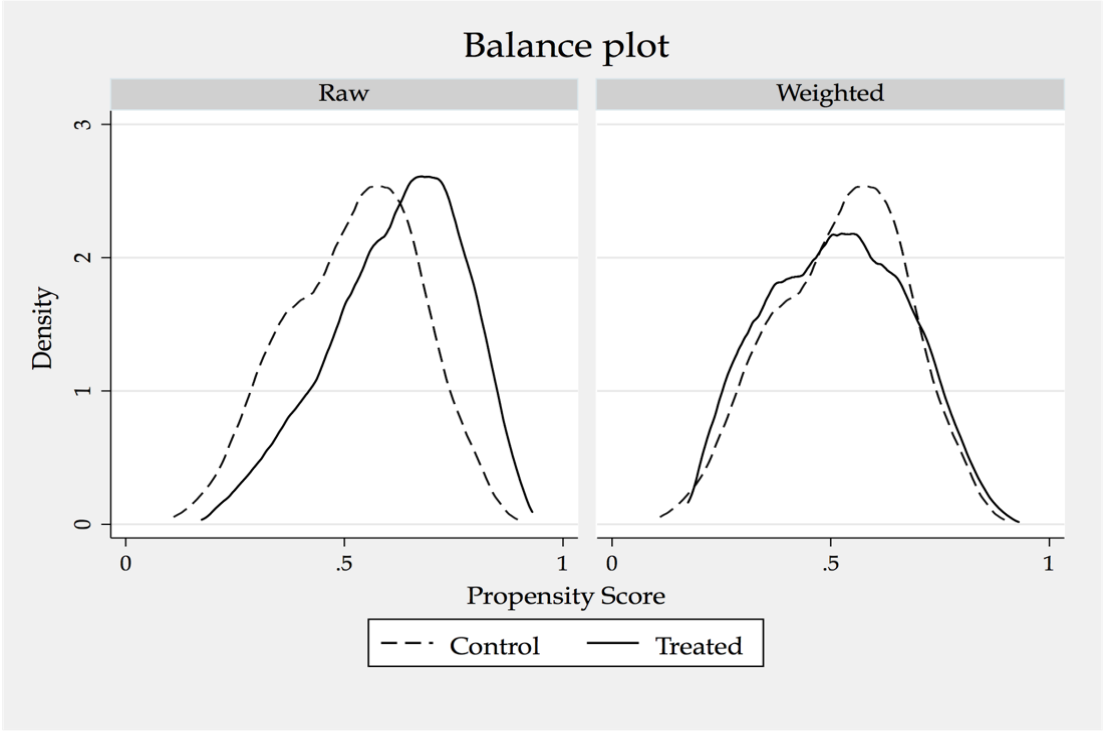


Table 4: Test of covariate balance

Variable	Control mean	Treated mean	Difference	Std err of difference
NDVI (August 2011)	0.370	0.370	0.000	0.003
ln (hectares cultivated)	0.060	0.062	0.002	0.060
Plot manager is female	0.188	0.168	-0.020	0.024
Plot manager has any education	0.524	0.515	-0.009	0.029
Plot is held on a permanent or semi-permanent basis	0.855	0.863	0.008	0.020
Plot primary soil type is sand	0.199	0.193	-0.007	0.021
Plot primary soil type is loam	0.337	0.314	-0.023	0.026
Plot slope is flat	0.708	0.723	0.015	0.025
Plot slope is slight	0.243	0.226	-0.016	0.024
Plot slope is moderate	0.027	0.027	0.000	0.008
Plot is marsh/wetland	0.485	0.490	0.006	0.027
Organic fertiliser used on any plot	0.106	0.101	-0.005	0.019
Household adult equivalents	4.604	4.624	0.021	0.121
Dependency ratio (age < 15 | > 60):(15 ≤ age ≤ 60)	1.071	1.080	0.009	0.053
ln (household head age)	3.792	3.788	-0.003	0.018
Household has a member with wage employment	0.570	0.547	-0.023	0.029
Household has a member with part-time employment	0.594	0.565	-0.028	0.029
Household head can read and write French	0.187	0.182	-0.005	0.026
Household head can read and write Malagasy	0.425	0.419	-0.007	0.030
Separate rooms of dwelling	1.532	1.471	-0.061	0.122
Household dwelling has improved toilet	0.119	0.124	0.004	0.022
N of children of head or spouse greater than 15 living elsewhere	0.457	0.461	0.004	0.057

Note: Total observations = 1,454; treatment N = 614; control N = 840.

4.5 AD2M impacts on crop production

Tables 5 to 8 give results for four sets of outcome variables. For the three sets of outcome variables (Tables 5, 6 and 8), we give results for two different specifications: with and without a dummy for any type of irrigation on any plot in the outcome equation. The tables give estimates of the ATET, the corresponding *t*-statistic and *p*-value, the estimated control mean, the estimated treated mean and the number of observations. Given the fact that we are using a cross-sectional data set with only NDVI values that predate programme activities, it is likely that the more restrictive assumptions on conditional independence and overlap may not be met (Wooldridge 2010). Therefore, we present ATET estimates instead of average treatment effects. We have highlighted results that are statistically significant at 10 per cent or lower in bold.

Looking first at our annualised crop production variables for the subsample of 1,454 (all crops) or 1,401 (rice) in Table 5, the estimated impacts are positive and significant for all four production variables when there is no irrigation dummy in the outcome equation. When we control for any type of irrigation in the outcome equation, the impacts disappear for value of production per hectare and per capita. However, impacts remain positive and significant for rice production per hectare and per capita. In the final column of the table, we present the percentage difference between treatment and control means, by transforming the natural logarithm values reported in the previous two columns. When we do not control for irrigation, the value of crop production per hectare is 13 per cent higher for treatment households than for control households, and the value per capita is 15 per cent higher. Rice yields are estimated to be 25 per cent higher when we control for irrigation and 30 per cent higher when we do not control for irrigation. The difference in rice production per capita is statistically significant, with and without controlling for irrigation; production is 19 per cent higher for treatment households than for control households when not controlling for irrigation, and 25 per cent higher with the irrigation control.

Table 5: Annualised crop production outcomes

Variable	Irrigation dummy	ATET	t-stat	p-value	Control mean	Treated mean	*% Diff.*
Value, crop production per hectare	Yes	0.034	0.58	(.564)	13.78	13.81	3%
	No	**0.124**	2.04	(.041)	13.69	13.81	13%
Value, crop production per capita	Yes	0.050	0.85	(.394)	12.27	12.32	5%
	No	**0.142**	2.33	(.020)	12.18	12.32	15%
Rice yields	Yes	**0.157**	2.74	(.006)	7.51	7.67	25%
	No	**0.203**	3.51	(.000)	7.47	7.67	30%
Kgs of rice per capita	Yes	**0.187**	3.21	(.001)	5.86	6.05	19%
	No	**0.235**	3.98	(.000)	5.81	6.05	25%

Note: N = 1,454 for value of crop production per hectare and per capita; all variables in natural logarithms; N = 1,401 for rice yields and kgs of rice produced per capita. ATET values in bold are statistically significant at the 10 per cent level or lower.

Table 6 shows the same production outcomes, using the sample that excludes the 98 (93 for rice) treatment households without access to irrigation. The results in the two tables are similar, though the estimated impacts are higher for Table 5's more inclusive sample, as we would expect.[1] Excluding households that were only partially treated reduces possible biases that may arise when only a fraction of treated households actually receive full treatment (impacts would be expected to be biased downwards, given that these households did not have irrigated plots). However, treated households with access to irrigated plots appear to have been relatively better off at programme inception, so dropping treated households with no irrigated plots is likely to lead to an upward bias. Taken together, we believe that the estimated impacts from these two specifications provide reasonable lower and upper bounds for overall programme impacts on these variables.

[1] When we drop these 98 households, our balance test and summary statistics indicate this smaller subsample is well balanced; results are in online appendix F.D.

Table 6: Annualised crop production outcomes

Variable	Irrigation dummy	ATET	t-stat	p-value	Control mean	Treated mean	*% Diff.*
Value, crop production per hectare	Yes	0.068	1.07	(.285)	13.82	13.88	6%
	No	**0.181**	2.79	(.005)	13.70	13.88	20%
Value, crop production per capita	Yes	0.078	1.21	(.228)	12.30	12.38	8%
	No	**0.194**	2.96	(.003)	12.18	12.38	22%
Rice yields	Yes	**0.192**	3.07	(.002)	7.54	7.74	26%
	No	**0.250**	4.01	(.000)	7.48	7.74	30%
Kgs of rice per capita	Yes	**0.216**	3.36	(.001)	5.86	6.08	25%
	No	**0.276**	4.31	(.000)	5.80	6.08	32%

Note: N = 1,356 for value of crop production per hectare and per capita; all variables in natural logarithms; N = 1,318 for rice yields and kgs of rice produced per capita. ATET values in bold are statistically significant at the 10 per cent level or lower.

These results align with the data from the qualitative focus group discussions. A number of respondents of all types (farmers, community leaders, AD2M implementers and WUA members) from Mahabo commented that rice production increased significantly as a result of AD2M. One Mahabo farmer attributed the greater yields to better land maintenance: 'Since [AD2M] came, we learned about land maintenance, which we did not do before, and so we took better care of our rice croppings. And our harvests increased as a result'. This corresponds with the survey, in which AD2M farmers reported a higher rate of erosion control than control farmers (35.7 per cent versus 26.6 per cent, $t = 2.39$). In a Mahabo focus group, one farmer attributed greater rice yields to the row-cropping method introduced by AD2M: 'This is what really convinced us to adopt the row-cropping method, because it was easier to plant the seeds and we could harvest a higher amount'. Other farmers added that once the new techniques were adopted, fewer seeds were required to yield greater harvests. A key informant from Ankilizato (Mahabo) corroborated the farmer's focus group comments, saying that improved farming techniques led to better harvests: 'Since the programme's existence, the rice production has increased for each family. The cultivated surface of the land has not changed…. It was due to the introduction of the improved agricultural techniques'. Several community leaders also commented that rice was grown more frequently (two or more times per year), which also resulted in greater production.

Qualitative respondents from Belo also maintained that rice production increased, although according to one farmer the increase in rice harvests was 'not so huge.' Interestingly, farmers from Belo were more likely to attribute the increase in rice yields to irrigation, as opposed to the 'land maintenance' or row cropping mentioned by Mahabo farmers. One Belo farmer commented, 'The harvests improved mostly thanks to the improved water supply'. Also of note, one farmer from Belo commented that higher rice yields had not been sustained since the AD2M programme had ended: 'Crop production decreased since AD2M left the town. Some farmers went back to traditional agricultural practices'.

4.6 Heterogeneity of impacts on crop production outcomes

We examine heterogeneity in the treatment effects by using the coefficients and standard errors generated in the two outcome equations, provided in Table 7. It is worth noting that the sample framework was not designed to separately analyse the impact of various subgroups by treatment and control. That is, we cannot separately run the treatment effects analysis on households with a female manager and without a female manager and compare the difference in difference between the two.

Instead, we can examine the coefficients from the treatment and control outcome equations resulting from the inverse-probability-weighted regressions. We used the following assumptions: (1) that the coefficient on the covariate of interest is the same across treatment and control households; (2) that the distribution of covariates across treatment and control households are independent and normally distributed; and (3) that the regression equations are correctly specified. Using those assumptions, the estimated impact of treatment by the covariate of interest is given by the difference of the coefficient on the covariate in the treatment equation minus the coefficient in the control equation. Then, using the standard errors, one can easily compute the t-test and corresponding p-values, where the null is that there is no heterogeneity of treatment effects.

We consider three covariates in our heterogeneity analysis. The first is a dummy for whether any plots are managed by a woman, the second is whether any adult in the household has had any education, and the third is whether there are any sources of financing within the village. We present results for two of our four main outcomes: (1) value of production per capita in logs; and (2) rice production per capita in logs. (The analyses by hectare yielded similar results.)

Starting with the value of crop production per capita, Table 7 shows that households with female plot managers have worse outcomes in both control and treatment households, and that the difference between genders is negative and significant. It also shows that the treatment effects on the value of production per capita are greater for households with any educated adults, and for households located in villages with financial services; these two results suggest that better-off households were better able to capitalise on the programme’s activities.

Impacts look a bit different when we instead consider rice production per capita. Here, treatment effects on households with female plot managers are positive. Combined with the negative impact on value of crop production per capita discussed above, these results suggest that these households reduced land allocated to non-rice crops, and/or that yields of non-rice crops were lower. Treatment effects on rice production per capita were higher for households with any education, similar to the total value of crop production per capita. However, there is no heterogeneous treatment effect from having access to a financial source in the village; this suggests that having access to financial services enables households in treatment villages to increase profitability from non-rice crops.

Table 7: Heterogeneous impacts on production per capita

	Production value (MGA) per capita			Rice production (kgs) per capita		
	Female plot manager	**Any education**	**Finance source in village**	**Female plot manager**	**Any education**	**Finance source in village**
Control mean	-0.038	-0.105	-0.104	-0.209	-0.042	0.747
Control std error	0.111	0.107	0.479	0.109	0.096	0.463
Treated mean	-0.153	0.187	0.779	-0.086	0.161	0.728
Treated std error	0.096	0.088	0.405	0.086	0.082	0.395
Treated mean - controlled mean	-0.114	0.292	0.883	0.123	0.203	-0.019
Sum std errors	0.206	0.195	0.884	0.194	0.178	0.859
t-statistic	21.100	57.100	38.090	24.180	43.490	0.850
Difference p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.399

Note: Outcomes are measured in log.

There are three key points from the analysis of heterogeneity of impacts:

1. Households with female plot managers in treatment areas may be shifting too much focus to rice crops, to the detriment of non-rice-crop profits.
2. Those with greater education are more able to leverage the benefits from treatment, indicating that there is a greater need to continue focusing efforts on households where no adult has been to school.
3. Access to finance – which was seen as critical in the first phase of AD2M – does indeed enable households to gain more from the treatment.

4.7 Crop input and management outcomes

In terms of our crop input and management variables, we see a number of significant and positive impacts, and the difference between the ATET impacts when including or not including an irrigation dummy in the outcome equation is far less pronounced than for the crop production variables. In particular, treatment households were more likely to receive extension guidance from any source and were also more likely to have attended training activities. In terms of inputs, there were limited impacts on land conservation efforts, livestock and fertiliser, but treatment households were more likely to have applied pesticides and herbicides.

Table 8: Crop input and management outcomes

Variable	Irrigation dummy	ATET	t-stat	p-value	Control mean	Treated mean	*% Diff.*
Extension from any source	Yes	**0.076**	2.02	(.044)	0.289	0.365	8%
	No	**0.090**	2.52	(.012)	0.275	0.365	9%
Whether attended any trainings	Yes	**0.076**	2.02	(.044)	0.289	0.365	8%
	No	**0.090**	2.52	(.012)	0.275	0.365	9%
Mechanical soil and water conservation	Yes	0.028	0.99	(.320)	0.249	0.277	3%
	No	**0.047**	1.77	(.077)	0.230	0.277	5%
Biological soil and water conservation	Yes	**-0.019**	-1.02	(.308)	0.099	0.080	-2%
	No	-0.012	-0.71	(.479)	0.093	0.080	-1%
Number of cattle held	Yes	0.614	0.97	(.332)	4.340	4.950	14%
	No	0.011	0.02	(.987)	4.940	4.950	0%
Number of oxen held	Yes	**0.406**	1.84	(.066)	1.800	2.200	0%
	No	**0.381**	1.66	(.096)	1.820	2.200	0%
Proportion of plots with inorganic fertiliser	Yes	-0.008	-0.82	(.409)	0.027	0.019	-1%
	No	-0.005	-0.60	(.551)	0.024	0.019	-1%
Used pesticide or herbicide on any plot	Yes	**0.097**	4.65	(.000)	0.151	0.248	10%
	No	**0.100**	4.82	(.000)	0.148	0.248	10%
Cropped more than one season	Yes	**0.138**	4.23	(.000)	0.470	0.608	14%
	No	**0.179**	5.91	(.000)	0.428	0.607	18%

Note: N = 1,454. ATET values in bold are statistically significant at the 10 per cent level or lower.

Perhaps most importantly, treatment households are much more likely to crop more than one season (61% versus 43%). This provides a partial explanation for why annualised crop production figures were higher for treatment versus control households. As shown in online appendix F.E, if we look at the value of crop production and rice yields only in the primary season, we see that for most specifications, there are no statistically significant impacts; in two specifications, estimated impacts are actually negative. This provides further evidence of the importance of access to improved irrigation infrastructure, particularly in the second season.

4.8 New crops

From the quantitative data, there is extremely limited evidence of expansion into new crops in treatment areas. Just one household reported growing tomatoes, and that household was located in a control area. Similarly, in treatment areas, just 5 households reported cultivating onions or beans, versus 12 households in control areas. Finally, 45 households in treated areas cultivated peanuts, versus 167 households in control areas. Given these low adoption figures, we did not perform further quantitative analyses.

Both in surveys and in qualitative interviews and focus group discussions with beneficiaries, many respondents indicated that AD2M encouraged farmers to cultivate new crops (other than rice) such as onions, beans, peanuts and tomatoes, and that farmers in Mahabo and Belo continue to harvest these crops today. The average AD2M household grew 0.05 more types of crops on his or her main plot during the main growing season (1.00 versus 0.95, t = 2.36), so AD2M impacts extended not only to the

number of seasons cultivated but also to the number of crops cultivated. According to a community leader from Ankilizato Nord (Mahabo), ‘Onions and beans are the main alternative crops that AD2M has introduced here. Now, they have a warehouse where the onions are stored here’. A community leader from Antrobiky corroborated this, and indicated that these new crops were still being harvested today: ‘We continued growing peanuts and onions. We have truly continued’!

In addition to the direct benefit of harvesting new crops, several respondents also commented that multi-cropping improved the quality of their soil and ultimately the quality of their rice. A Mahabo WUA member said:

> In the Menabe area, we were only used to our rice cropping on the rice fields. We had never heard about the multi-cropping. Then AD2M brought technical training to show us that we could also grow beans, tomatoes, onions and other crops on our rice fields. In fact, because we only grew rice, the soil was left to rot. With the multi-cropping, we even saw improvements in the quality of our rice, after the harvesting of the beans, because the soil had actually improved thanks to the fertilisers.

A respondent from the Ministry of Agriculture in Ankilizato echoed this sentiment, saying that the introduction of other non-rice crops such as onions and beans served to fertilise the soil better.

Experiences harvesting new crops in Belo were slightly less positive, and both farmers and WUA members here seemed more reluctant to focus on cultivating crops other than rice. One WUA member commented, ‘Our experience with the peanuts was that we had insects, so we could not save much. We didn’t get the insecticides on time, so we … could only save a little’. Similarly, a Belo farmer also said that he tried to grow onions on his field but was unsuccessful. Another Belo WUA member maintained that the primary focus remains on rice cultivation: ‘All of us do the same thing; we all cultivate rice. That’s our principal activity. Rice is the basis of our alimentation; that’s why we focus on this’. This message was corroborated by other WUA members as well, who said, ‘People here prefer rice instead of onions and beans,’ and ‘We were focused on growing rice, [not] on growing onions nor peanuts’.

4.9 Changes in household welfare

Farmers and programme implementers from both districts reported that incomes increased as a result of farming practices and irrigation schemes introduced or improved by AD2M. For the most part, respondents indicated that increases in income resulted from bigger rice harvests. One farmer from Mahabo said that because of the increase in volume of rice production as a result of the row-cropping method introduced by AD2M, farmers were able to produce sufficient amounts of rice to begin selling outside of Mahabo: ‘Yes, we are able to produce in excess and have [rice] to sell outside our region’. A key informant from Mahabo commented, ‘If looking at Ankilizato, it was obvious that there were some very important changes, especially in terms of the farmers’ income’. This point was echoed by a respondent from the Ministry of Agriculture in Morondava, who said that ‘people who did not have money before had money afterwards, and they could grow things; their livelihoods had improved.’ When discussing

changes in income that they believed had resulted from AD2M, respondents primarily referenced increased rice production leading to greater profits as opposed to sales of other crops. One WUA member from Mahabo shared that he had tried to sell onions, but that the profit margin was such that it was not worthwhile given the amount of onions he had harvested. A fellow Mahabo WUA member agreed, saying that he had suffered a financial loss when he tried to sell onions.

Table 9 presents quantitative findings on household welfare outcomes that echo the qualitative findings. Treatment households were less likely to report that they had worried about securing enough food in the past 7 days, but there were no differences between treatment and control households in the proportion of households who indicated that they had experienced a lack of food in the past 12 months. It is worth noting that about 75 per cent of both treated and control households had faced food shortages in the past 12 months, indicating high levels of intra-annual food insecurity, even for those with access to irrigation. Treatment households were also more likely to own more consumer durables. The largest differences are in the impacts of treatment on educational expenditures. The values are in natural logs; transforming these to dollars gives a percentage difference for control and treated households of 68 per cent and 80 per cent.

Table 9: Household welfare outcomes

Variable	Irrigation dummy	ATET	t-stat	p-value	Control mean	Treated mean	*% Diff.*
Food worries, past 7 days	Yes	**-0.109**	-3.33	(.001)	0.556	0.447	-11%
	No	**-0.098**	-3.02	(.003)	0.546	0.447	-10%
Lacked food, past year	Yes	-0.021	-0.94	(.350)	0.767	0.747	-2%
	No	-0.021	-0.91	(.363)	0.767	0.747	-2%
N of consumer durables	Yes	**1.080**	3.89	(.000)	4.950	6.030	11%
	No	0.925	3.42	(.001)	5.100	6.030	11%
Any household member ill	Yes	-0.015	-0.43	(.695)	0.308	0.293	-1%
	No	-0.008	-0.23	(.850)	0.300	0.293	-1%
Educational expenditures	Yes	**0.583**	1.89	(.059)	2.510	3.100	80%
	No	**0.520**	1.69	(.091)	2.580	3.100	68%

Note: N = 1,454. ATET values in bold are statistically significant at the 10 per cent level or lower.

4.10 Community-level effects

Similar to qualitative respondents' beliefs about whether AD2M was helpful or harmful, there were mixed opinions about whether AD2M had a positive, unifying effect on the local community, had increased tensions, or had no tangible effects at the community level.

According to one WUA member from Belo, AD2M unified the community: 'AD2M here unified us because all [activities] were well planned and there [was] sensitisation of farmers. It had boosted our cohesion and our unity. We were living peacefully and calmly because there were fewer disputes.' Farmers from Mahabo agreed, attributing the positive change in the community dynamic to more regular meetings. One said, 'During AD2M's tenure, regular meetings were held in each sector. The fact that people gathered

around often created some closer ties and brought more harmony.' Similarly, in Belo, one farmer shared his belief that the WUA played a role in bringing people together and enhanced communication between neighbourhoods. Farmers from Mahabo also said that AD2M's irrigation support (in particular the repair of the channels) lessened disputes over water supply. This appears to be confirmed by the quantitative survey as well; only one of 10 AD2M WUAs reported there being disputes over the past 12 months.

Other positive community-level effects were associated with changes in rice yields and increased incomes. According to one Mahabo farmer, 'The community is also more peaceful; we eat well, our harvests are successful, and even the unemployed get work.' A key informant from Mahabo maintained that rice revenues resulting from AD2M increased purchasing power and changed the village economy in Ankilizato:

> They sold the rice and dare then to buy a TV set, they also dare to buy a zebu. In the past, a farmer, one family did not own a zebu working the fields, but now after they harvest the rice, they bought two zebus; … this transformed the economy in general in the Ankilizato village.

A respondent from the Country Programme Coordination Team echoed this sentiment, saying that 'the landscape in general has changed', with more farmers living in houses made of stone or brick and houses with iron roofs, which were previously only inhabited by foreigners and civil servants. A former AD2M social facilitator said the installation of a dam in Levaheloka led to its transformation from a small village with only four houses to one with more than 50 houses and 'a protestant church, a Catholic church, a Catholic school, [and] a rice machine.' Additionally, the social facilitator maintained that members of the Levaheloka community were now able to go to the hospital when they were ill.

On the negative side, a farmer from Ankilizato maintained that AD2M increased tensions within the community: 'We were more divided because some would collaborate with AD2M and some would not. Some people were angry with the farmers who collaborated with AD2M'. A fellow Mahabo farmer said that it was the changes in water regulation as a result of AD2M that led to community conflicts: 'Regarding the water, they imposed themselves on us. This is how conflicts came up in the community'. Farmers from Belo also felt that community life had deteriorated as a result of AD2M, referencing disputes over water use and declining harvests.

4.11 Key challenges and potential moderating factors

This section explores key challenges faced by the programme (both environmental and social) that may have served as moderating factors to AD2M's impact on the treatment communities. These key challenges primarily emerged through qualitative data collection; wherever we have relevant quantitative data we include that as well. We group these findings in six categories: reluctance to adopt new farming approaches; irrigation infrastructure challenges; local market constraints; safety concerns; communication and lack of trust; and timing, seasonality and weather shocks.

4.11.1 Reluctance to adopt new farming approaches

A number of WUA members and farmers commented during interviews and focus groups that Malagasy farmers are 'set in their ways' and often reluctant to change practices, including those introduced through AD2M. One Mahabo WUA member commented,

‘People’s habits are hard to change’. A few respondents added that farmers have reverted to old ways since AD2M has left – according to one Mahabo farmer, ‘Today the community is divided between those who still use the row technique and those of us who continue to stick to our ancestors’ ways.’ Another Mahabo farmer mentioned that initially some farmers were hesitant to use fertilisers because of rumours that they were harmful to the land: ‘There are rumours that artificial fertilisers damage your land. … That would mess up people’s minds and they reject the use of fertilisers just based on these wrong beliefs’. The AD2M Monitoring and Evaluation Officer indicated that, while farmers were initially reluctant to adopt new techniques, over time more and more farmers had begun adopting them.

4.11.2 Irrigation infrastructure challenges

On the basis of the quantitative survey, we found that households generally reported receiving better-quality irrigation. For the smaller subset of households with plots located in a gravity-based irrigation system, Table 10 demonstrates that treated households were more likely to receive water on time and to receive good-quality, non-brackish water. However, they were not more likely to receive their full allocation of water. It is worth noting that even though a higher proportion of treated households reported having received good-quality water, the estimated proportion was still only 40 per cent (the definition of ‘good water’ was left to the farmer’s individual interpretation).

Table 10: Irrigation performance outcomes

Variable	ATET	t-stat	p-value	Control mean	Treated mean	*% Diff.*
Received water on time	**0.150**	2.49	(.013)	0.583	0.733	15%
Received full allocation	**-0.054**	-1.87	(.062)	0.712	0.659	-5%
Water quality good	**0.269**	6.14	(.000)	0.129	0.398	27%

Note: N = 893. ATET values in bold are statistically significant at the 10 per cent level or lower.

Although AD2M farmers reported higher-quality irrigation, qualitative findings suggest potential areas for improvement in future irrigation programming. According to the qualitative data, the primary issues surrounding irrigation infrastructure related to quality, sustainability and the challenge of meeting the demands of farmers who follow different harvesting schedules and have varying water needs based on the elevation of their land. On the issue of quality, channels reinforced with cement appeared to be functioning far better than channels lined with mud. A farmer from Mahabo explained the difference between mud and cement channels:

> They informed us that they would repair the channel all the way from the dam to the channel down here and put cement on these structures. And indeed, they brought in tons of cement. Initially, the work was due to reach until down here but in fact, they barely covered 1 km and now the water is filled with mud … That’s why the irrigation system down south is not able to reach the fields because it is filled with mud as it wasn’t properly fixed with cement. But the part which has been cemented works well and the water is clean.

Qualitative data suggest that maintaining the infrastructure developed or rehabilitated by AD2M is a challenge in both districts. According to a Mahabo WUA member, 'There is no one to properly manage it. So the taps are wide open at the top and the water is overflowing down here'. In Belo, farmers mentioned that they were not able to manually clear the debris (garbage and pieces of wood) that fell in the canal, which led to blockages. In Mahabo, some farmers blamed the WUA for failing to maintain channels properly. One said, 'If the funds were properly used, the channel would be in a much better state right now and we would have twice [as many] fields benefiting from the irrigation system'.

Finally, several qualitative respondents reported that AD2M's irrigation schemes affected higher- and lower-level plots differently. According to a key informant from Andranovory, AD2M's irrigation schemes created problems at times for farmers with lower-level plots: 'Those in high lands are well irrigated, while those that are in low lands are flooded, and they don't dry by themselves'.

4.11.3 Local market constraints

Qualitative data suggest that local market constraints limited AD2M's positive effect on farmers' income. Specifically, farmers discussed struggling to find sufficient buyers for new crops introduced by AD2M. According to one farmer from Mahabo, 'On onions I can truly say we got real results, but the issue was more around where to sell them. There weren't many buyers. Unlike rice – you don't need to go too far to sell all your stock [of rice]'. A WUA member from Mahabo agreed, pointing to other difficulties associated with selling onions:

> When we produce rice, collectors buy it rapidly. It was not the same thing with onions because when onions are stored in a warehouse about 15 days, they lose a lot of [their] weight before collectors are coming. [As a result], farmers faced financial loss.

4.11.4 Safety concerns

During interviews and focus groups, respondents from both districts referenced safety concerns that inhibited their ability to maintain irrigation structures and cultivate their fields, as well as safety concerns emanating from disputes over water. The issue of security was particularly pronounced in Mahabo, where a number of respondents referred to thieves (*Dahalo*). One Mahabo farmer commented, 'We should be able to maintain [the channels] but the issue is around the safety. The water is running well and we should be able to also grow onions but we can't because of the thieves'. WUA members also referenced safety concerns when maintaining the channels in Ankilizato (Mahabo): 'We took risks and worked anyway. There have been fist fights and even threats with knives but we continued anyhow because we have chosen to lead this'. Despite these concerns, only 1.2 per cent of households reported violence as one of the top three shocks they faced over the prior year during the survey. This disparity could be due to violence being common but not one of the three most important shocks.

Also, during interviews and focus groups, many individuals and WUA members reported various safety issues that occurred when they went out into the area to try to fix or perform maintenance on a water structure or regulate water usage. One individual from Ankilizato (Mahabo) said, 'This has not been effective yet, as we have also faced safety

issues. Previously, you could be shot even by just walking around with a bag because they would think you are carrying money'. Others felt unsafe when going out to regulate the water supply in different areas because farmers and land owners did not understand their function and did not want their water supply managed by other people. Even other governing authorities did not always recognise the authority of the WUA to control and manage water supply, so members did not feel supported in their decisions.

Individuals tampering with the water plugs without the knowledge of the WUAs or diverting water towards or away from their own fields was another issue captured in the qualitative analysis. It seemed that disputes over water and the management of the irrigation infrastructure had the potential to escalate quickly to violence because access to water is so imperative to these farmers' livelihoods.

4.11.5 Communication and lack of trust

A number of concerns emerged from the qualitative data related to communication and decision-making under AD2M. Some respondents felt that AD2M made unilateral decisions. Most notably, a number of respondents did not understand why water was shut off for periods of time, and indicated that they did not receive proper warning from AD2M before the water supply was cut. One Mahabo farmer commented:

> We were not notified that it would be cut, yet we were all users of the water. It was just cut without any warning. That made people angry. They should have properly communicated that they would cut the channel, or send a paper announcement to our village chief so that he could inform us in turn. If we were aware, it would have made a clear difference.

Similarly, another Mahabo farmer said that poor communication from AD2M extended beyond the issue of the water cuts: 'AD2M did not seek to consult the community and went on to take decisions on their own with regard to the work that they needed to implement.… They never involved us in any decisions regarding irrigation'. A fellow Mahabo farmer added that AD2M misled them as to how long irrigation system repairs would take: 'They told us it would only take a month for their work, but then it took three whole months, so we stopped trusting them. They fooled us'.

During a focus group, one Mahabo farmer maintained that AD2M's positive impact was tempered by a lack of proper communication given the high rate of illiteracy locally:

> It is due to lack of awareness and motivation. They just place signs to communicate meeting dates but not everyone can read. Only the people who can read do attend the meetings. That's why you need megaphones. If people can't read, at least they can hear. There was not enough awareness building.

It is important to note, however, that despite criticisms from some farmers, AD2M staff did report conducting what they referred to as a 'social study' prior to programme implementation, during which they engaged the local community and solicited their input on, and agreement with, the proposed approach.

4.11.6 Timing, seasonality and weather shocks

Timing and seasonality

One item that emerged during focus group discussions and is potentially relevant for future irrigation programming is farmers' feelings of frustration that AD2M interventions (specifically repairs) were not well timed in terms of Madagascar's seasons. According to one Mahabo farmer, '[AD2M] hired people to work on the dam during the month of December, when it should have been in May. That makes no sense. They brought employees during the rainy season to repair the channels'. Similarly, another Mahabo farmer complained that AD2M did not respect the established harvest calendar and interfered with channel irrigation during the cultivation period:

> In fact, their work was not aligned with the farmers. I am [one] of the people who lost my harvests during that time. Usually, when we plant the seeds in January, then we harvest in April, plant seeds again in May, and so on and so forth. But then AD2M did not comply with that and focused directly on the channels while we were busy with our rice fields.

WUA members from Belo made similar statements during focus groups, maintaining that water cuts were poorly timed: 'The issue we faced with AD2M [was] with the water shortages. Sometimes, we would plough our land, but then they would interrupt the water for three days, so the land goes dry'. A key informant from Ankilizato (Mahabo) also noted that there were repeated delays in AD2M's implementation, specifically when it came to construction. According to the rural infrastructure head, construction delays were caused by delays in funding disbursement and difficulty in identifying a contractor to undertake the construction work in Ankilizato:

> The technicians of the programme had tried to explain that it was not because of them but [because] of the funding, as the funds came from Rome and it took months before the money arrived here. It is only disbursed then, and that's the reason [for] the delay. Added to that was the selection of the contractor, because they had twice changed the contractor until the project completion.

This key informant also added that the 'water digging cut' lasted for one full year, which severely disrupted the livelihoods of farmers in Mahabo. Farmers frequently reported receiving water at the wrong time for their crops; 31.1 per cent said that the timing of irrigation did not coincide with their needs. However, based on the survey we cannot say whether the timing mismatch was due to water cuts or not.

Weather and other shocks

The primary shocks mentioned by respondents during interviews and focus groups were cyclones, flooding (which particularly affected lower-level plots), locusts, insects and rats. A key informant from Ankilizato (Mahabo) maintained that cyclones were particularly disruptive to AD2M activities:

> The cyclonic damages hindered the implementation of this programme because of the flood that damaged the dam. The entire infrastructure – the dam and the irrigation channels – were blocked by the sand. This fact had somehow caused the delay in the cultivation period. The water decreased which resulted in the crops' decline.

Farmers from Mahabo also added during focus groups that channels were blocked during cyclones, and multiple respondents referenced sand pileups resulting from cyclones. Quantitative results support these findings: 75.6 per cent of survey respondents reported suffering from too little, too much, or too variable rainfall, and 60.9 per cent reported that their crops suffered from pests.

4.12 AD2M training activities and changes in farming practices

4.12.1 Farming: SRI, row cropping, crop diversification, off-season planting

According to qualitative respondents, SRI seemed to be the main focus of training activities, and reportedly worked well, especially while trainers remained in the field working with the farmers. The new system of planting, watering and harvesting seemed to work better in some areas than in others, with some individuals commenting on their vulnerability to water fluctuations and reporting that they were hesitant to change their entire planting and harvesting system. To this end, a WUA member in Belo reported:

> In the training, we learn about seeding that requires water, yet our normal practice does not require much water, which is not the same. Then some people might complain that we just cut the water. But if all farmers are properly trained to do their seeding together using the standardised method then it can work. The main issue is that people are not all trained.

Those who followed the instructions of trainers and implemented the SRI system reported increased crop yields and income after planting fewer seeds than they had previously used. To this end, a farmer from Ankilizato (Mahabo) said:

> We did change our way of working. We were taught new techniques, which we applied. We put fertilisers in the fields which we never did before. We learned how to produce those fertilisers. Then we grew rice seeds following the standardised eight-day seed planting programme.

Similarly, another farmer from Ankilizato attested to the increased profitability associated with the adoption of SRI:

> We saw that the 8-day method was much more profitable than our usual random cropping. Five kilograms of seeds would be sufficient to cover 1 hectare using this method, whereas we would require at least 5 gallons if we stuck with our old method. So the 8-day method brought real improvement for us. We were able to waste less by using just 5 kilograms of seeds to produce 1 hectare. The SRI was truly beneficial.

AD2M also provided training on the benefits of crop diversification and provided new seeds for farmers to grow additional crops alongside their rice. Beans and onions were the two main crops introduced that served to supplement rice cultivation in many regions of AD2M outreach. In Ankilizato (Mahabo), one respondent reported:

> With AD2M, they brought techniques around peanuts cropping, and today, some people have fully moved to growing peanuts. That is the case for some people. So it brings some diversity. Even people opened up their mind to other crops … not only rice. In Ankilizato, now we also grow beans.

Additional crops discussed in focus groups and interviews included fruit trees, tomatoes, corn, cassava, sweet potatoes, peanuts, greens and lentils. The addition of multi-cropping not only increased production from the farmers' fields and their income but also served to fertilise the land better and increase harvests of the rice that farmers were already growing. Crop diversification also allowed for additional off-season planting of additional fruits and vegetables. This increased income for some farmers and allowed for steadier crop production periods rather than fluctuating periods of production and income generation.

4.12.2 Irrigation: water system management, flooding and drying fields

Many farmers indicated during focus groups that they wished AD2M trainers had stayed and helped with the SRI planting techniques for longer periods; they noted that the technique fell out of favour with some farmers once the trainers left: 'We are still very keen on getting further training regarding farming, as there are still many things we don't know. What we have learned is insufficient; there is more to add. So yes, we are very interested' (Ankilizato Sud). Others felt that the SRI system did not work well on their farm because of the levels of water they received from the irrigation systems put in place. Although some received appropriate amounts of water for the technique to be effective, others saw their fields routinely flooded or dried out, and felt that they had little control over the water levels.

4.12.3 Irrigation

Along with building new irrigation structures, such as canals and dams, AD2M also provided various training sessions for farmers and members of WUAs. Training included how to regulate water access for farmers, how plugs could be used to flood and dry fields to promote crop growth, and how to manage and maintain the structures once they had been built to ensure their use and function after AD2M left:

> Some training was given to the Water Users' Associations, especially the WUA president of the base and the board members; they were trained by the AD2M by a consultant. They hired a consultant to train all the board members – training on leadership. A women's association [Femme Leader] was also trained; they were also given training for women. About the water ditch, the training was done gradually. … It was a kind of training that was given gradually by the AD2M. (AD2M Rural Infrastructure Head in Ankilizato)

Although irrigation support was widespread, it seems that training activities put in place on the management of the infrastructure varied in different areas. Although information about access, use and water schedules seemed to be well communicated in some areas, in others people were very confused and angry about water management and did not understand why some areas received more or less water at certain times. Maintenance and upkeep of the infrastructure that AD2M built also varied widely by level of community buy-in and by degree of assistance and functioning of different WUAs. Training seemed to take hold and become more effective in well-established WUAs that focused on communication and sensitisation of their communities but did not see the same levels of success in other communities.

4.12.4 Reactions to training

Farmers in focus groups tended to have very positive responses to all of the AD2M training provided, but the general consensus was that they still wanted the AD2M programme facilitators to stay longer and provide additional support and even increase the area to which they provided aid. Individuals interviewed talked most about the benefits of the agricultural training sessions and practices for their communities, noting that farmers' livelihoods were improved in areas where training occurred. Increased training may spread AD2M benefits to more households; only 38.7 per cent of AD2M beneficiaries reported attending a training. However, it seems that the farmers felt that they benefited most when they were receiving the combination of hands-on training from AD2M staff and the continued stream of supplies such as seeds, tools and fertilisers. Some farmers noted that to continue the practices that AD2M had introduced for their training they needed basic supplies that were not there before, such as special seeds and pesticides and tools such as ploughs. Some of the practices introduced, such as SRI and row cropping, fell out of favour when the AD2M trainers left in certain areas. This could be because farmers either did not feel they were receiving the support they needed or fell back into old routines.

4.13 WUAs

4.13.1 Changes in structure of WUAs during and after AD2M

Where WUAs did not previously exist, they provided a working structure for maintenance and upkeep of dams and canals and water regulation. WUAs already existed in some areas informally but needed a formalised leadership structure, rules and chain of command. In order for WUAs to continue to function and maintain the structures AD2M built, there needs to be a system in place to ensure that they keep functioning properly. WUAs need a point of contact if a larger issue arises after AD2M leaves, and leaders need to be trained adequately to ensure that training continues after AD2M leaves the area. Once AD2M leaves, WUAs need to learn to take more responsibility for the structure of their association and maintenance of irrigation structures. There were some reports of groups falling apart or becoming corrupt after AD2M trainers and facilitators left, whereas in other groups, leaders stepped up and took more responsibility. Trusted and well-respected individuals should be voted into WUA leadership positions and trained to sensitise their community members to the fact that the WUA is an organisation run by the community. The WUAs that took this approach seemed to have more community buy-in and verbalised trust for the WUA and its leadership. Areas that saw increased WUA participation from community members should be used as an example of how to build community trust and respect for the programme.

4.13.2 Sensitisation (and lack thereof) to WUAs

Although all qualitative respondents reported that AD2M members undertook some level of outreach and sensitisation, there was a general overall feeling of lack of communication about the functions of the WUAs and what they were doing to benefit the community. Many respondents found the WUAs and their leadership and presidents to be dictatorial or corrupt. There seemed to be a community feeling that the individuals who lived and worked in the area were not consulted and asked about their interest in the programme and its benefits but rather had the WUA forced on them. Many did not understand the goal of the WUA, its function in the region, how the leadership structure

worked and how its actions would have a direct impact on them. Indeed, one key informant expressed his belief that many AD2M communities struggled (at least initially) to accept the WUA structure.

During interviews and focus groups, some board members reported receiving leadership training from AD2M staff, which seems to have fostered more effective communication; however, many farmers felt that there still needed to be some level of oversight and assistance from an AD2M member rather than just establishing the WUA and leaving it to function independently.

The greatest concern among WUA members was that the leadership was receiving additional money from AD2M or was keeping the money from fees and dues for themselves rather than putting it back into the irrigation structure and infrastructure maintenance. People were concerned that they did not know where their money was going and that that was never communicated to them. This seemed to stem from a lack of trust in the leadership of a given WUA and believing that the WUA did not have the best interests of the community at heart. For others, lack of trust stemmed from lack of communication about how water would be regulated and when water cuts would occur.

Farmers reported water cuts occurring without warning and resultant crop loss, and even those who understood how the schedule worked urged much more communication before implementation, so that all farmers in the community could agree on planning the planting and harvesting of their crops based on the water schedule. They said that better communication with everyone in the area needed to occur before the WUA started enforcing stricter water usage schedules so crops and profits would not be lost by farmers who did not know water cuts were coming. Farmers also wanted input into the schedule because they have knowledge of their land and when things grow best. Many felt that the water regulation schedules coming from the WUAs did not take their crop rotations and schedules into account and harmed their production and profits. To avoid this conflict and feeling of imposition, respondents recommended additional training and consultation with those farmers on whom WUA decisions in each region would have an impact. They noted that posting signs about meetings and information about the WUAs is not enough outreach because a lot of people cannot read.

Because of the terrain and population of different regions in Madagascar, a lot of areas rely on the same irrigation system, but the people are very spread out. Information still needs to reach all of them so that nobody is caught off guard when water regulation begins.

People did not seem motivated to spend their time maintaining the structures and work without being paid when they could not perceive the positive impact that the upkeep would have on them. The WUAs needed community input and buy-in to be successful, and that comes from trusted leadership within the community and trusted individuals elected by everyone. Some areas had trusted leadership in place, and the WUAs in those regions seemed to report more positive impacts and a system that worked smoothly in maintaining dams and canals and enforcing water regulation. Most of these were in areas that had some sort of association or organised structure in place before AD2M.

The purpose of the WUA is to be an association to provide water to farmers and maintain irrigation structures so that all farms in the area can be irrigated, and this is a good aim if it is clearly explained. When farmers and community members using the water are adequately informed of the benefits, it seems that they are much more willing to pitch in and actively participate in WUA activities. For this to happen, AD2M needs to explain adequately the benefit to the people, including how water regulation will occur and why there is a need for flow and maintenance support. The WUA should clearly show that the money being contributed through fee and dues payment is ultimately benefiting the members of the WUA and their community.

4.13.3 Fee collection

All individuals using the irrigation structures built by AD2M were automatically made members of the WUA and were supposed to pay fees. This was not always communicated well, and some farmers could not afford or did not want to pay fees but still needed to use the water. Many of those interviewed felt that the fees were fair and trusted that they were going to the maintenance and upkeep of the dams that they all used for farming. However, some felt that the fees were imposed on them without discussion and were decided on by AD2M rather than the people living in the areas and participating in the WUAs. ‘We previously did some calculation and it was found to be expensive; we first went to collect it and people refused to pay’ (AD2M Rural Infrstructure Head in Ankilizato). There were also reports from different groups about various levels of corruption within some WUAs. Although some groups had leaders who were trusted by the community and functioned well with them, others felt that the leaders of the WUA were taking advantage of them. Some felt that the president and other board members of the WUAs were collecting fees and keeping the money for themselves, and noted that fee collection was never well documented and it was not clear where the money went.

4.13.4 Reasons for joining or not joining WUAs

The majority of individuals who spoke about the WUAs felt that their attendance and participation in the organisation was mandatory if they were receiving water from the dams and canals that were built by AD2M:

> The sensitisation was a bit forced, it is like something compulsory, i.e. when you are a water user, then you become automatically a member of the association because you use the water managed by the association. So, whether you like it or not, you must be a member. And if you say ‘I don’t want to join it’, then you don’t get water; you should not fetch water there. (AD2M Rural Infrastructure Head in Ankilizato)

The majority of the members realised that the organisation was tasked with the upkeep and maintenance of the dams, canals and regulation of water access to farmers. Farmers joined the WUA because they recognised that the water was the source of their livelihood and that they all needed to pitch in with its maintenance in order to continue receiving benefits. Any farmer working within the perimeter and using the irrigation structure was integrated because they were called upon to contribute whenever the channel needed repair, for example. Reports from different WUAs drove home the same message: If everyone is informed about the function of the WUA and pitches in, it is successful; if not, there is animosity between members and non-members because of non-members’ lack of participation and help.

> Everyone uses the water, so we think a minimum contribution is needed to anticipate any future necessary repairs. Unfortunately, many think they don't owe anything despite our explanations. And this kind of situation makes me really sad. This means the association is doomed to fail if people do not want to contribute. (A WUA member from Mahabo, Ankilizato)

Those who did not participate in the WUAs seemed very sceptical about what the organisation was trying to accomplish, what they were doing with the fees that were collected, and how joining the WUA would benefit them. Again, the issue of how things were communicated from WUAs to the farmers was critical in their success or failure in different regions, and installing a trusted community member to head the local WUA played a large role in others joining and buying into the system.

5. Discussion

5.1 Internal validity

To conduct a valid assessment of the impact of AD2M on smallholder farmers, it is necessary to establish a clear counterfactual. This requires using a rigorous methodology that enables us to address the question of what would have happened to programme participants had they not received the intervention. In the absence of an experimental design, comparison groups can be constructed using quasi-experimental identification strategies. However, estimating programme impacts by comparing a treatment group with a non-experimental comparison group may be biased because participants self-select into the programme or implementing partners specifically target beneficiaries who are more likely to experience the largest programme impacts. In this section, we describe in detail how AD2M targeted programme beneficiaries, and, on the basis of this information, we discuss our strategy for constructing a credible control group for AD2M beneficiaries to estimate the causal effects of interest. Although we discuss some of the key data sources that we used in the evaluation, the full instruments are in Online Appendix C.

5.1.1 Programme targeting

The irrigation component of the AD2M programme targeted areas that were well suited to agricultural activity and would benefit from improved water access. Individuals were targeted based on their degree of agricultural vulnerability. In order of the degree of vulnerability, the programme targeted the landless, farmers with unirrigated land, poor fishermen, farmers with irrigated land, and those raising livestock. The programme aimed to affect 16,000 households.

We planned to sample randomly from beneficiary households but only in the 14 irrigated communes out of the total of 16 communes of Menabe targeted by the larger AD2M intervention. AD2M selected these communes on the basis of their suitability for irrigation. These communes were selected from a larger set of candidates, some of which were also suitable for irrigation and will benefit from a future AD2M programme. In consultation with local AD2M staff, we selected control communes and villages to provide us with our counterfactual observations. We considered the communes that were eligible but not selected for AD2M programmes as control group candidates. However, we intended a systemised and rigorous study of feasibility reports. Only non-selected

communes similar to the treatment communes would qualify for the control group. AD2M officials helped us to select additional control communes if the non-selected group did not provide enough for statistical power. We improved the quality of the control group by using the matching techniques described in the following sub-section.

5.1.2 Dealing with key sources of bias

An obvious concern in this evaluation was that respondents in the treatment group might offer answers that they believed the research team sought as a way of thanking the programme (i.e. the Hawthorne effect). Although it is difficult to rule this out entirely, enumerators were trained to introduce the goal of the survey in such a way that beneficiary households would not be aware of the AD2M evaluation. In addition, comparison farmers did not know much about the AD2M programme because they were drawn from similar geographical areas that did not share irrigation infrastructure. We therefore do not believe this evaluation exhibits John Henry effects (i.e. non-treated farmers reacting to overcome the disadvantage of being in the control group). Our procedures for selecting control areas also allowed us to reduce concerns regarding programme externalities and spill-over effects.

5.2 External validity

The results of the evaluation of the AD2M programme will inform the design and implementation of similar irrigation policies, both elsewhere in Madagascar and in other developing counties. First, AD2M is entering a second phase; the results of this study can be used to inform and improve the upcoming implementation. AD2M has expressed to us in preliminary discussions that one of the most important uses of this evaluation will be to inform AD2M-2, so the results of this study will inform that intervention at a minimum. Second, many of the features and challenges in accessing water faced by rural farmers in Madagascar are shared by farmers throughout Sub-Saharan Africa. In the face of climate change, many farmers must cope with insufficient rainfall. The results of an AD2M study will provide timely and policy-relevant evidence for other irrigation projects.

The AD2M sample largely reflects the larger population of Madagascar. The average household in the AD2M population had 5.2 people in it. The average household in Madagascar has 4.5 members.[2] Both the national population and AD2M sample have near gender parity. The percentage of households in the AD2M sample reporting lacking food over the previous week was 75 per cent, which is similar to nationwide food security: 76 per cent of people do not meet their minimum daily caloric intake. AD2M study households were quite likely to be involved in agriculture (92%), which is primarily a result of the targeting scheme that focused on agricultural regions. Nationwide, households have 1.7 hectares of cultivated land, while AD2M farmers have an average farm of 1.6 hectares. These similar sizes suggest that the average Malagasy farmer and the average AD2M farmer are both smallholders. A minority of households hold livestock: 22 per cent of AD2M households had any form of ruminant livestock, and 19 per cent of households hold cattle nationwide.

[2] All statistics for the nationally representative sample come from the Enquête Nationale sur le Suivi des indicateurs des Objectifs du Millénaire pour le Développement survey. All statistics are means and do not provide statistical comparisons with our sample; they are provided simply as context.

6. Specific findings for policy and practice

Increasing access to irrigation is already a policy priority for the Government of Madagascar, but climate change coupled with the high level of food insecurity in this region of Madagascar adds impetus to the need to expand irrigation infrastructure.

The canals and dams that were built by AD2M and the additional irrigation infrastructure that was introduced allowed much greater water access for communities that previously lacked it. Regulation of use allowed most communities to increase their crop yields, and, when properly maintained, the irrigation infrastructure worked well and made their lives easier.

Our results are directly relevant to practice for irrigation interventions. Specifically, for projects implementing small-scale gravity-based irrigation systems in Madagascar, such as the next phase of AD2M, the primary lessons from this impact assessment are as follows:

6.1 Continue to promote second-season cropping

Value of crop production and rice yields in the primary season were similar between treatment and control households, so annual differences are primarily due to cultivating a second season. The programme's focus should be on training and practices to improve second-season cropping. However, there should still be training activities and information dissemination to achieve higher crop production in the primary season. This is backed by the qualitative research findings that many farmers stopped practising SRI or SRA (système de riziculture améliorée or improved rice system) techniques after AD2M programme staff left the area, for instance.

6.2 Sustainability of irrigation infrastructure

Individuals and groups interviewed also emphasised the need for sustainable structures that will last and can be maintained once AD2M leaves the region and staff engineers are no longer available. They wanted permanent structures built with cement rather than mud and sand to allow proper functionality and to decrease the amount of maintenance and upkeep required by the communities in which they are located. Because the success of the AD2M programme depends on how farmers and communities that received assistance function once trainers, technicians and engineers are gone, a system needs to be put in place to allow the management of the irrigation structures built, including groups such as the WUA that are established in part to maintain them. Multiple individuals need training to be able to continue the upkeep required and to maintain the organisation of the group, to ensure that none of the structures fall into disrepair and that the management methods do not fall out of favour or use.

Benefits depend on maintenance and management of irrigation infrastructure, especially in the medium to long term. Maintaining resulting increases in crop production throughout the year requires a well-functioning WUA. Both quantitative and qualitative results suggest that the ability to generate significant crop production benefits are already compromised by the inability of at least some treatment WUAs to manage and maintain the irrigation infrastructure.

There is ample opportunity to learn from WUA functioning and performance in both treatment and control areas, in order to strengthen WUA activities in the second phase of AD2M. Collecting information on WUAs, as well as beneficiaries, should be explicitly incorporated into AD2M phase 2 monitoring and evaluation strategies if they are not yet planned for.

6.3 Increased communication

Along with the reported benefits of the irrigation arm of the AD2M programme, there were additional requests and recommendations for improving irrigation support in the future. As has been mentioned elsewhere in this report, communication with farmers is key. Many farmers interviewed were wary of the flooding schedules implemented by AD2M and did not understand why some fields were flooded but others were dried out. Equality among farmers and the perception of fairness were very important to these individuals and communities. Getting information out about how the irrigation infrastructure will benefit each home, sensitising farmers to how water regulation will increase their crop yield, and constantly communicating with and listening to those who will be affected by changes to the irrigation structure are key to the success of any programme in this area.

6.4 Teach about climate change

Beneficiaries may be more willing to embrace changes if they learn about the potential risks of climate change. In rural areas, many farmers have a mentality of minimising risks rather than maximising profit. If households are warned about the risks posed by climate change, they may better appreciate the challenges they will likely face in upcoming years. This knowledge of future climate risk may lead households to adopt better practices, especially regarding irrigation, line cultivation, fertilisers and crop rotation.

6.5 Sustained financing

Future programming must incorporate lasting financial support to help farmers access the improved but more expensive methods AD2M promoted. Acquiring higher-quality seeds, fertilisers and tools, as well as marketing non-rice products, requires farmers to commit significant funds over a long period of time. The programme should therefore include a reliable micro-finance system. Eventually, the government could implement an insurance system to protect farmers from large-scale crop losses due to natural disasters, plagues of pests or other widespread shocks. Without these financial supports, many farmers will return to their traditional methods of farming.

Online appendices

Note to the reader: These online appendices are published as they have been received from the authors. They have not been copy-edited or formatted by 3ie.

Appendix A: Field notes and other information from formative work
This appendix is only available online and can be accessed from http://www.3ieimpact.org/sites/default/files/2019-01/tw40202-madagascar-ad2m-appendix-a.pdf

Appendix B: Sample design
This appendix is only available online and can be accessed from http://www.3ieimpact.org/sites/default/files/2019-01/tw40202-madagascar-ad2m-appendix-b.pdf

Appendix C: Survey instruments
This appendix is only available online and can be accessed from http://www.3ieimpact.org/sites/default/files/2019-01/tw40202-madagascar-ad2m-appendix-c.pdf

Appendix D: Sample size and power calculations
This appendix is only available online and can be accessed from http://www.3ieimpact.org/sites/default/files/2019-01/tw40202-madagascar-ad2m-appendix-d.pdf

Appendix E: Descriptive statistics
This appendix is only available online and can be accessed from http://www.3ieimpact.org/sites/default/files/2019-01/tw40202-madagascar-ad2m-appendix-e.pdf

Appendix F: Results
This appendix is only available online and can be accessed from http://www.3ieimpact.org/sites/default/files/2019-01/tw40202-madagascar-ad2m-appendix-f.pdf

Appendix G: Cost data for programme implementation
This appendix is only available online and can be accessed from http://www.3ieimpact.org/sites/default/files/2019-01/tw40202-madagascar-ad2m-appendix-g.pdf

Appendix H: .do files
This appendix is only available online and can be accessed from http://www.3ieimpact.org/sites/default/files/2019-01/tw40202-madagascar-ad2m-appendix-h.pdf

Appendix I: GIS analysis report
This appendix is only available online and can be accessed from http://www.3ieimpact.org//sites/default/files/2019-01/tw40202-madagascar-ad2m-appendix-i.pdf

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