Mathematica
Progress Together

MCC Burkina Faso—Agriculture Development Project

Final Report

January 15, 2021

Christopher Ksoll, Elena Moroz, Abbie Turiansky, Anthony D'Agostino, Yiriyibin Bambio, Daniel Roberge, Randall Blair

Submitted to:

Millennium Challenge Corporation
1099 14th street NW
Washington, DC 20005
Project Officer: Julian Glucroft
Contract Number: MCC-16-CON-0029 / 95332418C0214

Submitted by:

Mathematica
1100 First Street, NE, 12th Floor
Washington, DC 20002-4221
Phone: (202) 484-9220
Fax: (202) 863-1763
Project Director: Christopher Ksoll
Reference Number: 50284.01.240.032.000

This page has been left blank for double-sided copying

Contents

Tables

Figures

Acknowledgments

We greatly appreciate the contributions of the many people whose efforts influenced this report. We thank Julian Glucroft, our project monitor at the Millennium Challenge Corporation (MCC), and his predecessor Kari Nelson, for their guidance throughout the entire evaluation. The support of Jenny Lischer, Jack Molyneaux, and Sarah Lane at MCC is also greatly appreciated. Many other MCC staff provided feedback on our reports, and we thank them for that. In Burkina Faso, we are especially grateful to Julien Tougouri and Modeste Bationo of the former APD for their invaluable insights about the project, responsiveness to our copious inquiries, and help in connecting us with stakeholders, and to Ouattara Soulemane for some of the photographs included in this report. We are thankful for Mr. Ousmane Zongo, the evaluation point of contact in the Prime Minister's office, for support after the closure of APD. We are also grateful to AMVS, the Ministry of Agriculture, for its support of the evaluation. The helpful insights and generous hospitality provided by the numerous organizations and individuals who met with us during our visits to Burkina Faso were also greatly appreciated.

This report depended on contributions from a dedicated data collection team in Burkina Faso. We are particularly grateful to the staff of Centre de Recherche sur le Développement Appliqué (CRDA), led by Sondo Eloi Somtinda, for their hard work and flexibility which were key to successful data collection, despite the mounting insecurity in the field work region and the novel challenges that the COVID-19 pandemic has presented. We also thank the many farmers, water user association leaders, and AMVS staff who participated in in-depth interviews and surveys.

Several other current and former Mathematica colleagues have made important contributions to this evaluation. We thank Seth Morgan, Samuel Studnitzer, Matt Spitzer, Jeremy Page, and Zeyad El Omari for their diligent programming work for the quantitative data analysis. Chantal Toledo, Anca Dumitrescu, Kristine Bos, and Kristen Velyvis made important contributions in the design phase of the evaluation; Matt Sloan reviewed and provided thoughtful comments on the draft report. We also thank Cindy George for editorial review and Sheena Flowers for careful formatting of the report and beautiful graphics work. Many thanks are due to Brice Roads, who did an outstanding job managing the project smoothly during the drafting of the final report.

Mathematica strives to improve public well-being by bringing the highest standards of quality, objectivity, and excellence to bear when collecting information and performing analysis for our clients. The findings in this report solely reflect Mathematica's interpretation of available information. Mathematica staff involved in analyzing the information and authoring this report did not report any conflicts of interest. The evaluation was funded exclusively by MCC.

Acronyms

ADP	Agriculture Development Project
AMVS	Autorité de la Mise en Valeur de la Vallée du Sourou (Authority for the Development of the Sourou Valley)
APD	Agence de Partenariat pour le Développement (post-Compact successor to MCA-BF)
ARF	Access to Rural Finance (Activity)
CRDA	Centre de Recherche sur le Développement Appliqué
CATG	Centre d'Appui Technique et de Gestion
CBA	Cost-benefit analysis
DA	Diversified Agriculture (Activity)
ERR	Economic rate of return
FAO	Food and Agriculture Organization (United Nations)
FAPDA	The Food and Agriculture Policy Decision Analysis
FCFA	Franc of the West African *(Communauté Financière Africaine)*
FGD	Focus group discussion
GDP	Gross Domestic Product
GOBF	Government of Burkina Faso
IMT	Irrigation Management Transfer
IRIS	Center for Institutional Reform and the Informal Sector
IWRM	Integrated water resource management
M&E	Monitoring and Evaluation
MIS	Market Information System
MCA-BF	Millennium Challenge Account-Burkina Faso
MCC	Millennium Challenge Corporation
Non-PAP	Person not affected by the project
O&M	Operations and Maintenance

PAP	Personne affectée par le projet (project-affected person)
PIM	Participatory Irrigation Management
RCT	Randomized control trial
RDD	Regression discontinuity design
SONABEL	Société Nationale d'électricité du Burkina Faso
TA	Technical assistance
UAI	Unités Autonomes d'Irrigation
USAID	U.S. Agency for International Development
WMI	Water Management and Irrigation (Activity)
WUA	Water-user association

Executive Summary

A. Introduction

Burkina Faso's agriculture sector is critical to its economic health, but various challenges have kept it from being as productive as it could be. In response, the Millennium Challenge Corporation (MCC) invested in the Agriculture Development Project (ADP) as part of the US$ 482.5 million Burkina Faso Compact, which was implemented from 2009 to 2014 by the Millennium Challenge Account-Burkina Faso (MCA-BF), in partnership with the Government of Burkina Faso. The project's objectives were to improve agricultural productivity, increase the incomes of farmers and livestock producers, and support economic development through an integrated set of activities comprising investments in water management and irrigation and in the livestock and agriculture value chains. The ADP was implemented in two areas of Burkina Faso, the Sourou Valley and the Comoé Basin. Its largest investment, at a cost of $89 million, was the construction of an irrigated perimeter (known as the Di perimeter) in the Di Department of the Sourou Province. In this area, beneficiaries received land, land documentation, training in irrigated production, as well as support in managing the infrastructure through development of, and capacity building for, water user associations (WUAs).

MCC engaged Mathematica as an independent evaluator to conduct a rigorous evaluation of MCC's investments in the ADP.[1] In the evaluation design report (Ksoll et al. 2017), Mathematica developed an evaluation design that seeks to answer four overarching questions: (1) What are the project impacts or—where a counterfactual is not available—outcomes in terms of beneficiaries' land tenure, agricultural outcomes, and household incomes? (2) Are institutions developed by the project functioning and are project results sustainable? (3) What is the overall economic value of MCC's investments? (4) How were the various components of the ADP implemented?

This report presents the endline findings based on analysis of quantitative and qualitative data collected between February and August 2020, about five years after the end of the project. This final report focuses on MCC's investment in the Di perimeter and addresses longer-term outcomes, economic assessment, and sustainability-related questions (questions 1, 2, and 3 above).[2] The interim report (Ksoll et al. 2019) answered the implementation-related question (question 4 above) and assessed short- and medium-term outcomes hypothesized to lead to the project's long-term goals for the Di perimeter and several smaller project activities. The analysis in the interim report concluded that the implementation of all activities was delayed but was generally completed by the end of the compact. For the incomplete activities, the ADP coordinated the support to beneficiaries through the post-compact entity. Outputs—ranging from farmer training and land tenure assistance to training and technical assistance (TA) for WUAs—were generally considered of good quality. The interim analysis also raised some questions about the sustainability of the Di perimeter, given low water user fee payment rates and low application of organic fertilizer.

[1] Mathematica strives to improve public well-being by bringing the highest standards of quality, objectivity, and excellence to bear on the provision of information collection and analysis to our clients. Mathematica is an independent evaluator committed to the highest standards of objectivity and independence, and the findings in this report solely reflect Mathematica's interpretation of available information. Mathematica staff involved in analyzing the information and authoring this report did not report any conflicts of interest. The evaluation was funded exclusively by MCC.

[2] This final report does not investigate the long-term effects of MCC's investments in IWRM institutions, agricultural training in the Comoé Basin and the Sourou Valley (with the exception of the Di perimeter), livestock value chains, rehabilitation or construction of markets, the market information system, or the support for water management on the Niassan perimeters.

B. Evaluation questions and methodology

Table ES.1 provides a detailed set of research questions and the evaluation methodology that we employed to address the research questions, for the three evaluation components: (1) the evaluation of outcomes of beneficiaries of land on the Di perimeter that informs an economic assessment of MCC's investments into the Di perimeter, (2) an impact evaluation of the Di Lottery, and (3) an investigation into the current functioning of the perimeter, maintenance activities, and the perimeter lifespan.

Given the absence of a baseline and a comparison group, we conducted a performance evaluation to describe outcomes of Di perimeter beneficiaries and to assess the economic value of the compact's investment in the Di perimeter. We complemented this descriptive analysis with remote sensing techniques to better describe the agricultural outcomes on the Di perimeter. This performance evaluation also comprises an assessment of the economic rate of return (ERR) of the Di perimeter that we conducted by updating MCC's close-out ERR model with estimated values from our analysis.

To estimate the impacts of winning land through the Di Lottery on agricultural and land tenure outcomes of lottery winners, as well as household incomes, we conducted an impact evaluation using a randomized controlled trial (RCT). We used information on both lottery participants who were chosen as beneficiaries and those who were not chosen to estimate the difference in outcomes that can be attributed to winning the lottery. We then conducted mediation analysis to understand whether the project's outcomes worked through the mechanism of improved land tenure security. Given that not all applicants were admitted to participate in the lottery, we also implemented a second rigorous impact evaluation method, the regression discontinuity design (RDD). We conducted a methodological study that compares estimates from the RCT with that of the RDD. We used two newer approaches to RDD developed by Angrist and Rokkanen (2015) and Dong and Lewbel (2015) to investigate to what extent—in the context of an evaluation of the Di Lottery—RDD methods can provide unbiased estimates of the treatment effect away from the discontinuity.

The sustainability of the Di perimeter depends on the degree to which the infrastructure is maintained and on the ability of users to operate it. To address questions related to the operations and maintenance (O&M) of the Di perimeter, we conducted a performance evaluation using mixed-methods analysis based on thematic coding of interviews with stakeholders and financial and technical reports from the seven WUAs that are each responsible for one sector of the perimeter.

Table ES.1. Analytic approaches for the ADP evaluation

Evaluation component	Research questions	Methodology
Di perimeter	What is the total area planted, average yield/hectare, total production, and total profit by focus crop? How do these results differ by type of beneficiary?	Performance evaluation using descriptive analysis and remote sensing analysis
	How has the well-being of project-affected persons (PAPs) changed?	Performance evaluation using descriptive analysis
	What are project results in terms of land tenure security, land conflict, and land markets?	
	Have prices for focus crops changed since the completion of the perimeter?	Performance evaluation using mixed-methods analysis
	What is the ERR of the Di perimeter?	Performance evaluation using descriptive analysis

Evaluation component	Research questions	Methodology
Di Lottery	What impact does winning the Di Lottery have on agricultural practices, production, total agricultural income, and overall household income of the Di Lottery beneficiaries?	Impact evaluation using random assignment
	What are the impacts of winning the Di Lottery on land tenure security (perception, transfer rights, land documentation, conflict) and investment?	
	To what extent do these impacts operate via perceptions of increased land tenure security?	Impact evaluation using mediation analysis
	To what extent are the estimated impacts using a regression discontinuity design similar to those from the randomized controlled trial (RCT), both at the cutoff and far from the cutoff?	Impact evaluation using random assignment compared with impact evaluation using regression discontinuity
O&M	To what extent is the Di perimeter effectively and sustainably operated and maintained? What is the current state of the infrastructure (main canals, roads, pumping station) and functioning of the infrastructure?	Performance evaluation using mixed-methods analysis
	How well are the WUAs currently functioning with respect to (a) governance, (b) O&M and (c) administrative and financial management?	
	What is the expected lifespan of the perimeter given current levels of maintenance?	Performance evaluation using thematic analysis

Note: Uses MCC's categories of evaluation types (cite).

ERR = economic rate of return; O&M = operations and management; WUA = water user association.

C. Key evaluation findings

In this final report, we detail the main findings for each of the three evaluation components. The findings are summarized below.

1. Di perimeter evaluation

Background. MCC invested $89 million in the construction of the Di perimeter, a 2,246-hectare agricultural perimeter located on the east bank of the Sourou River. The perimeter featured new irrigation and drainage canal networks, seven pumping stations, guard drains, a levee, and roads and paths throughout. Project-affected persons (PAPs) displaced by the perimeter's construction received financial compensation for lost harvests and land on the perimeter with formal land titles and leasehold documents. Land and leasehold documents were also distributed to several additional groups of beneficiaries, including farmers from neighboring communities, winners of the Di Lottery, and women's and youth groups. All Di beneficiaries received training in agricultural technologies for irrigated land, and starter kits with production inputs (during the first growing seasons). The Di perimeter program logic envisioned that increased access to irrigated land, formalized land tenure, and enhanced technical capacity following training could increase cropping intensity of project beneficiaries and help them diversify crops, generate higher yields, and increase net agricultural income (Figure ES.1).

Evaluation findings. Mathematica conducted a pre-post performance evaluation of the Di perimeter sub-activity that relied on survey data collected through interviews with Di beneficiaries. Our key findings are as follows:

- **Land cultivation and agricultural outcomes.** Land on the perimeter is extensively farmed in both seasons with over 95 and 99 percent of the 2,246 hectares of land in the perimeter cultivated in the dry and rainy seasons, respectively. The area cultivated during the rainy season is more than twice as large as at baseline. The land cultivated during the dry season constitutes a 20-fold increase. Profits per hectare are lower than anticipated across all types of beneficiaries. Dry season profits per hectare were more than 10 times higher than rainy season profits, with the highest profits for onions and the lowest for maize. Profits do not meet expected profits under the ERR.
- **Well-being of project-affected persons.** PAPs are better off than at the time of the interim evaluation, and a large majority report being better off than before the construction of the perimeter. PAPs' agricultural profits and household incomes, as estimated from our surveys, increased between interim and endline. Nearly three-quarters of PAPs reported earning higher agricultural profits than before perimeter construction, while nine out of ten reported higher food security.
- **Land tenure security.** Farmers generally feel secure about their tenure on the perimeter. About three-quarters possess formal land documents—though many are confused about the precise type of documents they possess—and about 85 percent believe that its very unlikely that they would lose access to their land within the next five years. Even though perceptions of land tenure security typically differ by gender and other characteristics, in our case perceptions of land security for women's and youth groups are as strong as for other beneficiaries. As in the interim survey, not all households are fully aware of their land transfer rights. Most understand their right to bequeath or rent their land, but only about one-quarter know that they have the right to sell their land or leasehold. Very few farmers reported any land conflicts.
- **Land rentals, credit, and investment.** About seven percent of farmers rented out land in 2019. As in the interim survey, few farmers have applied for credit and used land as collateral for credit. However, rates of land investments are slightly higher than in the interim survey.
- **Onion prices are reported to have decreased due to the construction of the perimeter.** Many farmers on the perimeter struggle to plant onions early in the season or to store them until after the peak harvest season and to sell when supply is low and prices high. Poor roads and lack of market information since the market information system (MIS) became defunct hurt farmers' positions in onion price negotiations with buyers. However, recently onion prices had recovered somewhat after a low in 2017—the reference period for the interim survey—but they remain lower than they were before the perimeter construction.
- **Economic rate of return.** The estimated ERR is slightly negative and significantly below 12.5 percent, which was MCC's stated Burkina Faso-specific threshold for investments at the time of the compact, and also below the original ERR of 4.2 percent and the close-out ERR of 3.8 percent. The ERR is estimated to be -2.4 percent using baseline assumptions on perimeter lifespan, and between -4.5 and 0.4 percent when we vary the assumption on the remaining perimeter lifespan between stakeholders' minimum and maximum suggested lifespans of 10 and 30 years. The ERR is lower than expected mainly because the per-hectare profits for onions were lower than expected, and the close-out ERR estimated that onions would account for about 87 percent of the total annual profit.

2. Di Lottery RCT

Background. About 30 percent of the land in the Di perimeter was distributed to selected applicants from the Boucle du Mouhoun region via a public lottery—the Di Lottery. The ADP developed criteria for selection to the lottery that would (1) meet gender and age targeting objectives and (2) select applicants

likely to make good use of the land they received. For example, by favoring applicants with experience in irrigated agriculture, the ADP program logic envisioned that Di Lottery beneficiaries, like other Di perimeter beneficiaries, could cultivate irrigated crops with higher cropping intensity, generate higher yields, and increase net agricultural income if they had access to newly acquired irrigated land, formalized land tenure, and enhanced technical capacity as a result of training.

Evaluation findings. Mathematica used an RCT to conduct an impact evaluation of the Di Lottery on agricultural, economic, and land tenure outcomes for beneficiaries. We interviewed both lottery applicants who were chosen as beneficiaries and those who were not chosen. We conducted mediation analysis to understand the extent to which increases in land tenure security are leading to increased agricultural investments. We also assessed the degree to which the impact estimates from the RCT analysis can be replicated through an RDD. Our key findings are summarized below:

- **Land cultivation and agricultural practices.** Lottery beneficiaries cultivate 0.4 hectares more land than non-beneficiaries, but they do not cultivate all the land they received on the perimeter themselves. Treatment and control farmers who cultivated land during the dry season generally grow the same types of crops and employ mostly similar agricultural practices, with the exception of hired labor, which lottery beneficiaries hire more than non-beneficiaries. Rainy season cultivation differs more substantially between treatment and control households, given that treatment households are more likely to grow maize and rice, while a larger number of control households cultivate traditional crops such as millet, sorghum, beans and peanuts.
- **Agricultural outcomes and household income.** Di Lottery beneficiaries made significantly more agricultural sales and obtained higher agricultural profits, agricultural incomes, and household incomes. Agricultural profit increased by about 460,000 FCFA per year (about US$ 840), a nearly seventy-five percent increase over agricultural profit for non-beneficiaries.
- **Land tenure security.** Perceptions of land tenure security have increased since the interim survey, and both beneficiaries and non-beneficiaries report high levels of land tenure security. There were few differences in terms of land tenure security along most measures between farmers allocated rice and polyculture plots, but the impacts on some measures of land tenure security were larger for male farmers than for female farmers. Beneficiaries and non-beneficiaries who perceived some land insecurity identify different sources for the insecurity. Lottery beneficiaries are more concerned about losing their land to formal institutions, such as the government or the WUAs, while non-beneficiaries are more concerned about previous landowners taking over their land.
- **Land documentation.** Beneficiaries of the Di Lottery are more than four times more likely than non-recipients to have formal land documentation. Confusion about land tenure and documentation has increased since interim, with only one-third of beneficiaries understanding that they have lease documents and half incorrectly claiming to possess land titles.
- **Land rentals, credit, and investments.** Lottery beneficiaries are twice as likely as non-beneficiaries to have made physical investment in their land, mostly in the form of planting trees. The Di perimeter appears to play a larger role in formal transactions than off-perimeter land, with lottery beneficiaries more likely to let (rent out) land, apply for a loan, and use land as collateral than non-beneficiaries.
- **Drivers of land investments.** Land tenure security does not appear to be the sole driver of long-term investment in agricultural land. The impacts of the Di Lottery on long-term land investment outcomes appear to be operating through the direct components of the program, including irrigated land, land

documentation, and agricultural training, rather than through increased perceptions of land tenure security.

3. O&M of the Di perimeter

Background. MCC invested $6.6 million in capacity building and technical assistance for the institutions tasked with managing the irrigation infrastructure in the Di perimeter and the nearby Niassan perimeters. The project was designed to create and train WUAs on those perimeters. It also provided capacity building to AMVS—the Government of Burkina Faso (GOBF) agency in charge of maintaining primary canals in Sourou Valley and supervising the WUAs. The Sourou O&M program logic envisioned that creating WUAs, providing technical assistance to AMVS, and establishing two maintenance funds would lead to more sustainable and effective management of the irrigation infrastructure. While the interim report also evaluated compact investments related to the Niassan perimeter and AMVS capacity building, this final evaluation report focuses on the ability of Di perimeter WUAs to operate and maintain the Di perimeter, the sustainability of the perimeter, and an estimate of the Di perimeter lifespan.

Evaluation findings. Mathematica conducted a mixed-methods performance evaluation of the Di perimeter O&M investments that relied on qualitative interviews with implementers, interviews with WUA presidents and staff, and administrative data. Our key findings are summarized below:

- **State and functionality of infrastructure.** Pumping stations are in good condition and canals have some damage but are highly functional. However, drains and valves have significant damage, which has exacerbated flooding on the perimeter. Access routes are somewhat damaged, but mostly still functional. Overall, the perimeter received adequate levels of water, but some plots get flooded and others do not receive enough water due to errors in construction or damage.
- **Quality of the operations and maintenance (O&M) of the Di perimeter.** The WUAs have appropriate routine maintenance systems for the pumping station, but most sectors struggle to clean canals and drains due to low farmer participation and lack of appropriate tools. WUAs and AMVS lack capacity to repair the damaged portions of the access routes, cracked canals, and damaged valves. The North sector has the most challenges with maintenance, due to a higher proportion of land suitable only for rice cultivation; the sector's proximity to the river, which floods the sector and causes infrastructure damage; and a large fraction of farmers who are not from the area. The WUA union is effective in addressing and preventing some emergency breakdowns, thanks to an inventory of repair parts.
- **WUA governance.** WUAs have capacity to implement strong self-governance systems; all WUAs follow leadership protocols, practice democratic governance, and maintain financial transparency. However, they lack effective means of payment enforcement; in the rice cultivation in particular WUAs cannot lock water valves for individual plots.
- **WUAs' financial management.** The financial sustainability of the WUAs is threatened by late fee payments in most sectors, low long-term fee recovery rates in a few sectors (due to challenges related to rice plots), high electricity costs driven by unreliable electricity supply from the national grid and the need to substitute with gas-powered generators, and low farmer participation in communal work, as well as leaky canals.
- **Di perimeter lifespan.** Estimates of infrastructure longevity have decreased from a few years ago. At current levels of maintenance, stakeholders estimated the remaining lifespan of infrastructure built with earth materials (such as drains and small canals) at 10 years, and between 10 and 30 years for

pumping stations and concrete components (bigger canals). During the interim evaluation, stakeholders estimated the remaining lifespan to be at least 20 to 25 years—or 18 to 23 years from now. This compares to project assumptions of an infrastructure lifespan of 25 years, of which 18 years remain.

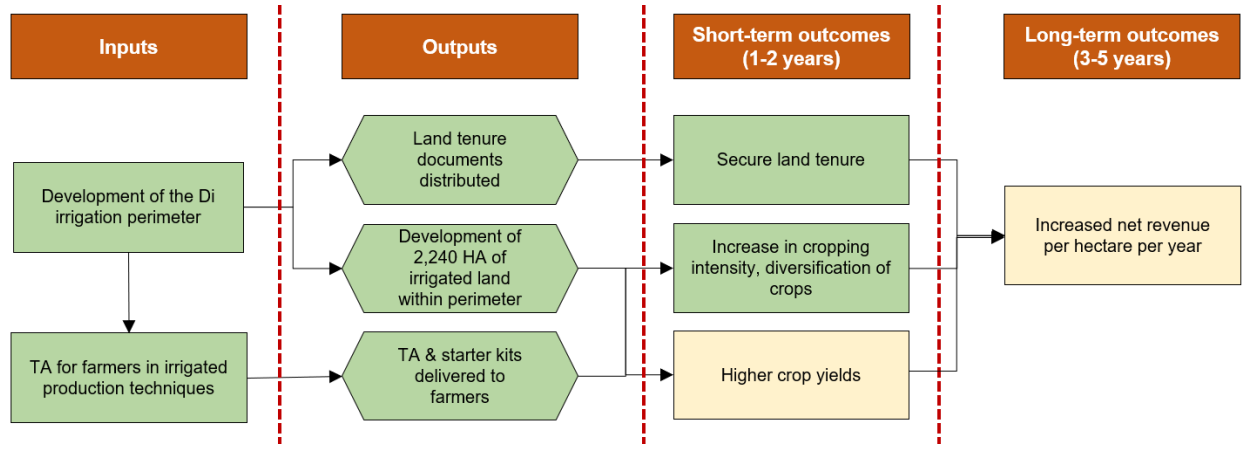
D. Lessons

In the following section, we summarize the evaluation findings relative to the project's theory of change to provide learning related to future irrigation investments. We also summarize our learning about measurement and evaluation methodology with implications for evaluations of future investments of this type.

1. Project lessons

The Agriculture Development Project's objective was to support farmers so they could earn higher incomes from increased productivity and access to irrigation. The logic model for the Di perimeter is shown in Figure ES.1. The figure shows logic model elements in solid green to indicate the steps of the Di perimeter program logic that our findings support and uses beige shading to indicate ambiguous findings.

Figure ES.1. Di perimeter program logic

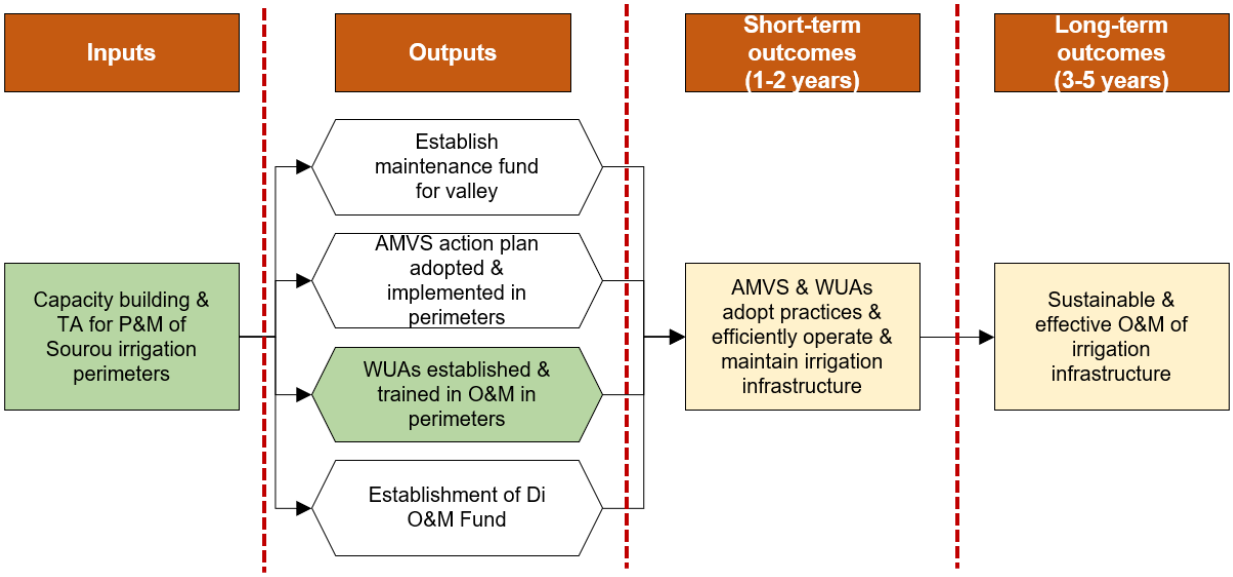


In the interim report, we documented that the project provided the intended inputs and produced the intended program outputs. The interim report concluded that implementers successfully constructed the Di perimeter, the quality of infrastructure was high, and Di beneficiaries received the expected program benefits. In the interim report and this final report, we found that the project improved many of the intended short-term and medium-term outcomes, specifically related to improved land tenure, cropping intensity and, to a large extent, the adoption of the cropping patterns anticipated by the program. Because the program did not meet project targets on profits per hectare, and survey and crop-cut data provide contradictory information on whether yields increased, we shade these components in beige. Even though the project did not meet its profit targets, most PAPs—who as original owners of the land are a primary focus of the evaluation—report being better off than before the construction of the perimeter. In the absence of baseline information on agricultural information for three other groups of beneficiaries, Di neighbors and members of the women's and youth groups, we cannot estimate the change in agricultural incomes or outcomes due to the project. We can do so for Di Lottery beneficiaries, who constitute a control group for the lottery participants who did not receive land. We found strong impacts of receiving

land on land tenure security, agricultural profits, agricultural income, and household income. Many of the increased agricultural outcomes and increased household incomes are due to farmers' ability to grow high-value cash crops, specifically onions and tomatoes, in the dry season due to the access to irrigation the perimeter provides.

The longevity of the benefits for PAPs, Di neighbors, women's groups, youth groups, and Di Lottery beneficiaries depends critically on the quality of operations and maintenance of the irrigation infrastructure. In Figure ES.2, we relate our key findings from the evaluation of O&M on the perimeter to the O&M logic model. We focus this discussion on the findings from the final evaluation with respect to WUAs and WUA operations.

Figure ES.2. Program logic for the Sourou O&M sub-activity



The capacity building and TA provided to the Di perimeters did establish and train water user associations (WUAs) in O&M. In terms of short- and medium-term outcomes, we found that the infrastructure made from concrete, such as primary canals and pumping stations, is in good shape and highly functional, but other components that were built using earthen materials such as access routes and drains have deteriorated and lost some functionality. Overall, the perimeter receives adequate levels of water, but some plots get flooded and others do not receive enough water. WUAs face challenges maintaining the infrastructure due to low farmer participation, lack of appropriate tools, and budget limitations. WUAs implement strong self-governance systems and effectively coordinate to hire specialized staff but they struggle with financial solvency; late fee payments and low long-term recovery rates, especially from farmers on rice plots, threaten their financial sustainability. As a result of the maintenance and financial challenges, the sustainability of the irrigation infrastructure on the Di perimeter is threatened and infrastructure longevity estimates have decreased to between 10 and 30 years. Combined with lower than expected profits per hectare, this leads to an estimated economic rate of return that is around zero or slightly negative. To guarantee the sustainability of the perimeter, water user fee recovery rates need to increase for WUAs to have the financial resources to improve maintenance and conduct repairs.

2. Measurement and methodological lessons

Our evaluation relied on a range of data collection and evaluation methodologies, and lessons from these different methodologies can inform future evaluations.

Different data collection methods yield substantially different results for key outcome measures in this setting. The estimates of area cultivated based on survey data are much lower than estimates from remote sensing data. Remote sensing-based approaches provide universal coverage over an area of interest. These approaches are a promising solution for monitoring agricultural outcomes when faced with challenges like compositional changes to the sample resulting from participant out-migration or the entrance of new renters, as well as survey nonresponse. Due to security concerns in the project area followed by health considerations because of the COVID-19 pandemic, we had to switch to telephone surveys in the midst of data collection which resulted in an inability to follow renters or add farmers new to the perimeter to our sample. As a result, the survey estimates under-estimated area cultivated.

Crop-cut surveys provide a physical measurement of agricultural yields based on cutting and weighing random selections of harvested crop from fields, and estimated yields from crop-cut surveys also differ from survey-based findings. For all crops, total and per-hectare yield estimates from survey data were lower than estimates based on crop-cut measurements. The differences are so large for maize and onions that estimated yields based on crop cuts exceed project targets, while those based on survey information do not meet project targets.

Remote-sensing methods offer promising solutions to some challenges of survey data, but have their own limitations. Multiple and ideally sequential years of survey and crop-cut data collection will be essential as "ground-truthed data" to test the reliability of remote sensing based on sample predictions. For example, if remote-sensing algorithms are trained on data collected in 2019, the accuracy of algorithmic predictions for 2020 would require ground truth data for 2020. Remote sensing alone will not be able to answer many of the important questions that require a survey-based data collection approach, such as total household income, employment status, and level of food security.

Switching to COVID-19 compliant phone survey data collection required significant logistical adjustments, resources and time. The COVID-19 pandemic made a call center with many interviewers unsafe. Interviewer training could also no longer be conducted in person. Instead, we conducted training remotely using pre-recorded videos to concisely convey content while reducing bandwidth requirements. To allow for interaction and assessment of understanding, we complemented the pre-recorded materials with online meeting tools and group messaging services. To be able to ensure high quality work, we recorded a random selection of interviews that the supervisors would listen to give feedback to enumerators. Adapting the in-person questionnaire with several iterations to reduce survey length while also developing these training tools and the distributed call center procedures concurrently proved challenging but was ultimately successful, albeit with a significant delay.

Best practices for addressing limits to survey length for agricultural surveys conducted over the phone are lacking. The significant cuts required to reduce survey length also posed methodological challenges. We limited data collection to two plots, split—if households owned both—between a randomly sampled plot on the Di perimeter and one randomly sampled plot outside of the perimeter. Similarly, data collection on non-agricultural income was limited to a maximum of three household members. In order to construct total agricultural income and household income, we adopted simple and multiple imputation methods to predict agricultural profits on non-surveyed plots and to predict incomes for non-surveyed household members. A lack of prior research using this approach in agricultural

evaluations mean that we could not follow established best practices. Future work should explore how best to apply simple and multiple imputation methods when designing agricultural evaluations that rely on survey data collection conducted via mobile phones.

A comparison of impact evaluation estimation methodologies shows that our randomized controlled trial (RCT) yielded larger point estimates than the regression discontinuity design (RDD), and only the point estimates from the RCT and an RDD variant were statistically significant. In this evaluation, we are able to estimate the impact of being a lottery winner by comparing agricultural and household outcomes of participants in the Di Lottery who won the lottery with outcomes of those who did not. This analysis uses the RCT toolbox. In addition, we are able to implement an RDD—a second impact evaluation methodology. In this design, we use the fact that lottery applicants were first graded on a scale of 0 to 100 according to a set of eligibility criteria. Only applicants with a score higher than 60 were admitted to the lottery. The RDD uses the threshold to compare lottery participants with scores slightly above the threshold (who won the lottery) with applicants with scores slightly below the threshold (who did not win the lottery). In many cases when an RCT is infeasible, an RDD is feasible if a program or benefit is assigned based on a cutoff in a continuous variable, such as income or test scores. In a methodological contribution of this report, we compare the RDD estimate with the RCT estimate. We find that the RDD treatment estimates at the cutoff for agricultural profit and income measures are about one-third lower than the RCT estimates and are not statistically significantly different from zero. However, an approach developed by Angrist and Rokkannen (2015) that extrapolates away from the cutoff provides robust estimates that are much closer to the RCT estimates, and is an approach that may be feasible in some contexts when an RCT is not.

I. Introduction and Overview

A. Background on the Agriculture Development Project and the Di perimeter

In Burkina Faso, as in much of Africa, the agriculture sector is a critical component of the economy. A large share of the country's population depends on farming and other agriculture-related activities for their livelihood and their own consumption. As of 2011, agriculture contributed nearly one-third of the country's annual gross domestic product (GDP), with total production estimated at just under $3 billion annually (FAPDA 2014). The sector also employs 80 percent of Burkina Faso's workforce, primarily on small subsistence farms of five hectares or less (USAID Burkina Faso 2015; FAPDA 2014). Despite its prominent role in the country's economy, the agriculture sector is characterized by low crop and livestock productivity (USAID Burkina Faso 2015). Low agricultural productivity contributes to extreme poverty in Burkina Faso, which is one of the poorest countries in the world with a GDP per capita of $634 (FAPDA 2014). Burkina Faso also is a net food importer (Chauvin et al. 2012).

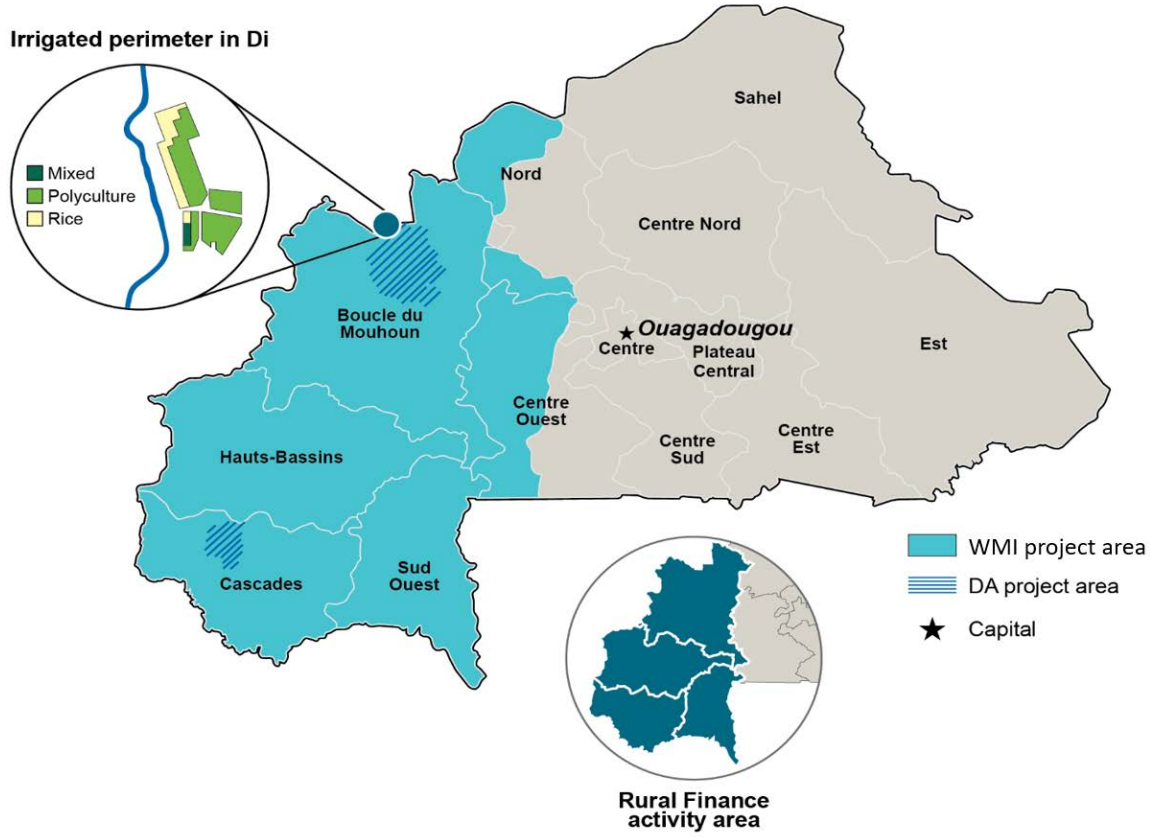
Agricultural improvements are needed for economic growth and poverty reduction in Burkina Faso. However, the sector's productivity is challenged by low and variable rainfall (USAID Burkina Faso 2015). Annual rainfall in Burkina Faso averages around 750 millimeters, with the northern Sahelian area typically receiving less than 600 millimeters while the southern Sudanian region receives up to 1,200 millimeters. The rainy season in Burkina Faso normally lasts from April or May to September or October. However, rainfall has been gradually decreasing since the severe droughts of the 1970s (Sally et al. 2011). Inadequate rainfall necessitates irrigation for successful agriculture, yet infrastructure is poor and farmers' access to irrigated water is low (FAPDA 2014). Less than 1 percent of cultivated land in Burkina Faso is equipped for irrigation (FAO 2016).

Small-scale farmers also face land security challenges (World Bank, 2020). Two-thirds of the county's population has no formal land tenure documentation and 40 percent of the rural population in Burkina Faso feels insecure about their land tenure, mainly due to a fear of government land seizures (World Bank 2020; Prindex 2020). Farmers face competition for their land from urban expansion, agroindustry, mining operations, and pastoralists. According to the World Bank, land insecurity in Burkina Faso may diminish agricultural land by 15% over the next 10 years and hurt agricultural productivity. Agricultural land and productivity have also been threatened by worsening climate conditions for decades, and this trend is expected to continue (World Bank 2020). Despite these concerns, most rural lands are still regulated by traditional law. Other challenges facing the country's agriculture sector include limited knowledge and capacity among farmers, poor roads and other transportation infrastructure, and limited access to credit. Burkina Faso's economy is also susceptible to regional trade shocks and volatile food and fuel prices (FAPDA 2014; USAID Burkina Faso 2015).

In response to the challenges facing the country's agriculture sector, the Millennium Challenge Corporation (MCC) invested in the Agriculture Development Project (ADP) as part of the Burkina Faso Compact implemented by the Millennium Challenge Account–Burkina Faso (MCA-BF). The project's objectives were to improve agricultural productivity, increase incomes among farmers and livestock producers, and support economic development primarily in the Sourou Valley and the Comoé Basin. The ADP was a five-year effort, implemented from 2009 to 2014, and it comprised three activities: (1) Water Management and Irrigation (WMI), (2) Diversified Agriculture (DA), and (3) Access to Rural Finance (ARF). The intervention areas of the three activities are shown in Figure I.1. The WMI Activity was a $103.9 million investment, representing nearly three-quarters of the ADP, while the DA Activity was a

$29.7 million investment. The largest single investment of the compact, at a cost of $89 million, was the construction of a 2,246-hectare irrigated perimeter near the town of Di in the Sourou Valley, the Di perimeter.

Figure I.1. Map of ADP intervention areas in Burkina Faso and the Di perimeter



Source: MCA (2014d).

1. Project activities

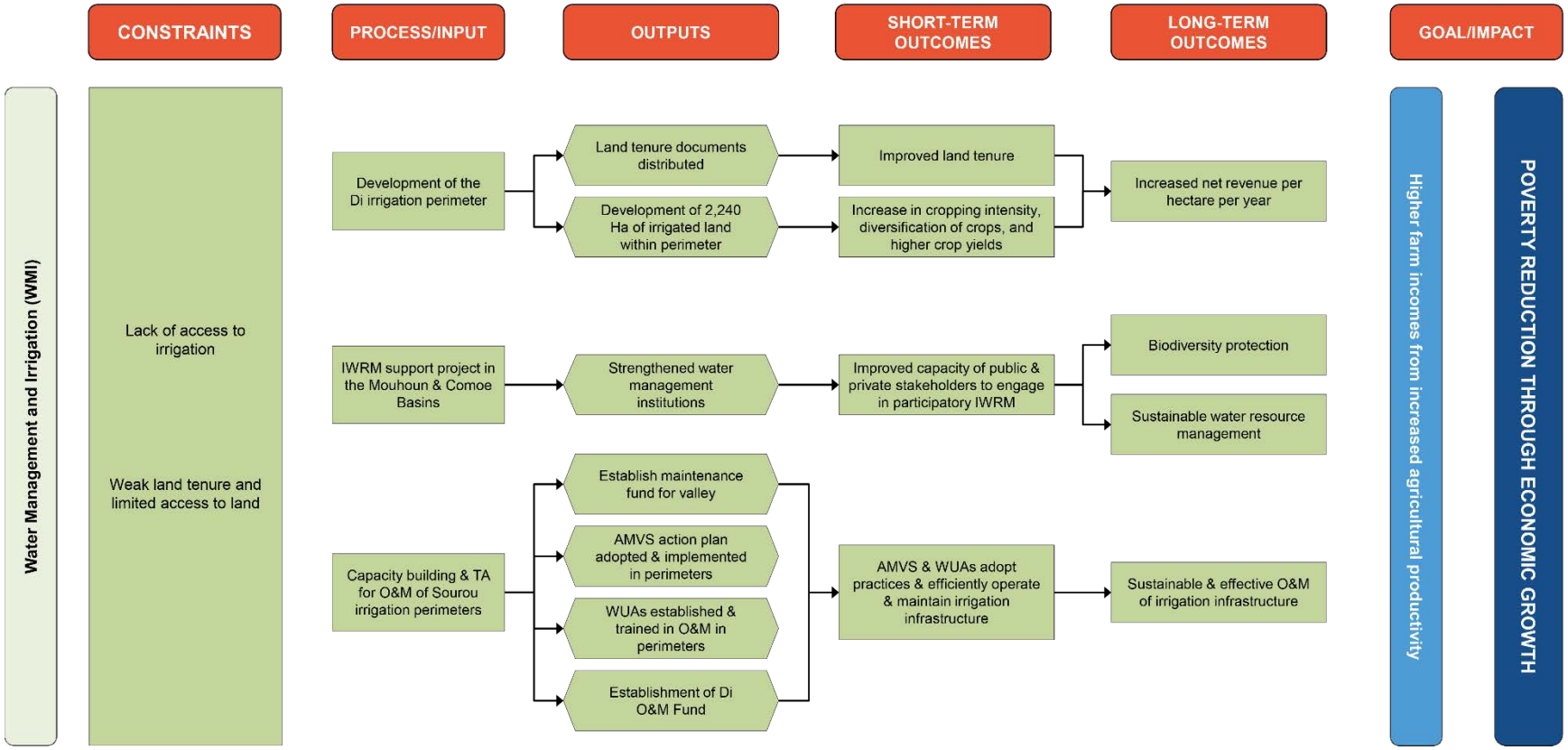
The WMI Activity was designed to improve water availability and delivery, flood control, and dam safety through several initiatives, including the construction of the Di perimeter. Also under the activity, specialists provided water authorities with capacity building and technical assistance (TA) to strengthen the operations and maintenance (O&M) of the new Di perimeter and existing irrigation perimeters—called the Niassan perimeters—in the Sourou Valley. The TA and support for capacity building provided in Sourou included (1) establishing and training water user associations (WUAs) and (2) providing TA to the Sourou Valley Development Authority (Autorité de Mise en Valeur de la Vallée du Sourou, or AMVS) on the development and implementation of its action plan. In addition, the WMI Activity aimed to improve the long-term sustainability of agricultural livelihoods by strengthening institutions devoted to integrated water resource management (IWRM) in the Mouhoun Basin of the Sourou Valley and the Comoé Basin. Finally, the WMI Activity also supported the rehabilitation of the Léry dam, an activity that does not fall under the scope of this evaluation.

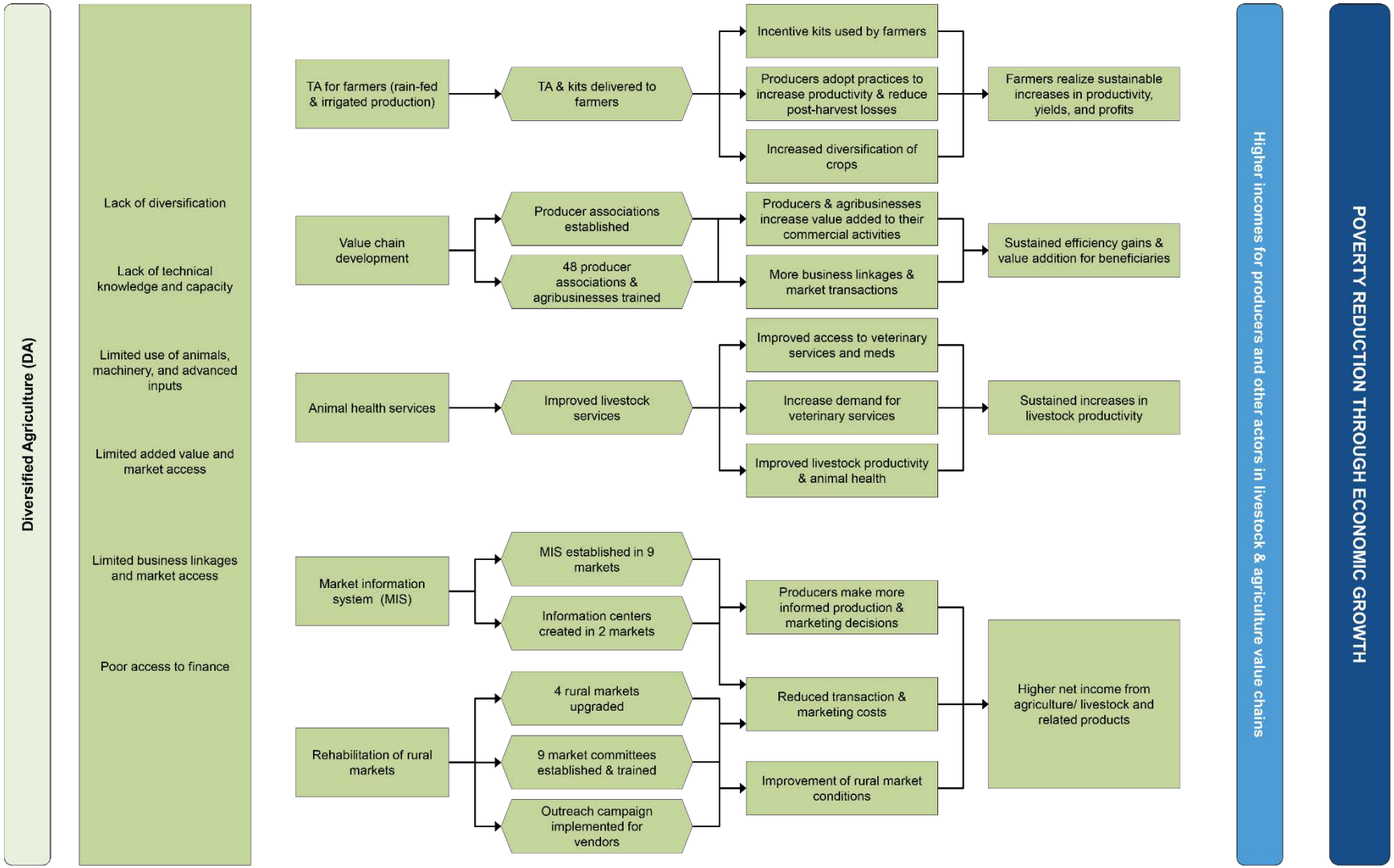
The DA Activity was designed to increase farmers' incomes by improving agricultural productivity and increasing the quantity and value of agricultural sales in the Sourou Valley and the Comoé Basin. Its components included (1) training farmers on rain-fed and irrigated production, (2) providing training to producer associations and agribusinesses, (3) improving veterinary services and providing livestock training, (4) establishing a market information system and information centers, (5) establishing and training market committees, and (6) rehabilitating rural markets.

2. Program logic

The program logic for the WMI and DA Activities is in Figure I.2. The WMI and DA Activities were designed to work in an integrated way to increase agricultural productivity and income for beneficiaries. At the activity level, the WMI Activity would guarantee reliable access to irrigation, and the DA Activity would help farmers leverage this irrigation access into year-round farming, thus diversifying into higher-value crops and obtaining higher sales and profits. Within the DA Activity, the beneficiaries in the primary project areas in the Sourou Valley and the Comoé Basin were meant to profit from multiple interlocking activities that worked together to address a variety of material, human capital, and informational constraints along the agricultural value chain. These included providing lease documents and land titles; training on animal health, irrigation-based farming, and livestock techniques; and up-to-date crop price information and market opportunities.

Figure I.2. Program logic of the DA and WMI activities




Diversified Agriculture (DA)
Lack of diversification
Lack of technical knowledge and capacity
Limited use of animals, machinery, and advanced inputs
Limited added value and market access
Limited business linkages and market access
Poor access to finance
TA for farmers (rain-fed & irrigated production)
TA & kits delivered to farmers
Incentive kits used by farmers
Producers adopt practices to increase productivity & reduce post-harvest losses
Increased diversification of crops
Farmers realize sustainable increases in productivity, yields, and profits
Value chain development
Producer associations established
48 producer associations & agribusinesses trained
Producers & agribusinesses increase value added to their commercial activities
More business linkages & market transactions
Sustained efficiency gains & value addition for beneficiaries
Animal health services
Improved livestock services
Improved access to veterinary services and meds
Increase demand for veterinary services
Improved livestock productivity & animal health
Sustained increases in livestock productivity
Market information system (MIS)
MIS established in 9 markets
Information centers created in 2 markets
Rehabilitation of rural markets
4 rural markets upgraded
9 market committees established & trained
Outreach campaign implemented for vendors
Producers make more informed production & marketing decisions
Reduced transaction & marketing costs
Improvement of rural market conditions
Higher net income from agriculture/ livestock and related products
Higher incomes for producers and other actors in livestock & agriculture value chains
POVERTY REDUCTION THROUGH ECONOMIC GROWTH

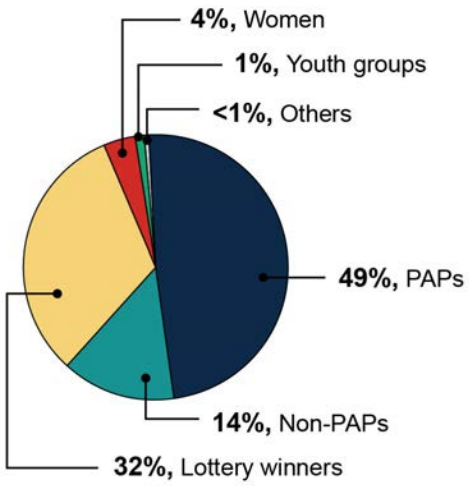
The complementarity in the design of the WMI and DA was nowhere more apparent than for Di perimeter beneficiaries who benefitted from most project activities.

3. The Di perimeter and its beneficiaries

Before the construction of the Di perimeter, most of the land was used for agriculture, but there were also sizeable portions of uncultivated and forested land. The construction of the perimeter necessitated the expropriation of land cultivated by some of the PAPs living in the communities surrounding the perimeter. PAPs received irrigated land within the new perimeter to compensate for their expropriated land. The size of PAPs' plots was based on the estimated value of the plots they lost. Because most lost non-irrigated land,[3] which is less productive than irrigated land, PAPs received a smaller plot in compensation than they had originally owned. Although the PAPs' original landholdings were governed by the prevalent and customary land tenure systems in the region, which vest rights in traditional authorities (Linkow 2016), PAPs received formal titles to these new plots. PAPs also received additional land as leasehold if the household had many members relative to the land received—specifically, if the ratio of the number of adult household members engaged in agriculture relative to the amount of land received in compensation exceeded a given threshold.

Overall, the land that PAP households received amounted to about half of the total amount in the new perimeter. The ADP distributed most of the remaining land to Di Lottery winners and non-PAPs from neighboring communities in the form of leaseholds. Female members of PAP families and PAP household members' children who were over age 15 ("youth") received small amounts of perimeter land, which were held in women's and youth groups (Figure I.3). Three-fourths of the perimeter's land is suitable for polyculture, and the remaining one-fourth is intended for rice cultivation with most rice plots being distributed through the lottery. PAPs, women's groups, youth groups, and non-PAPs received mostly polyculture plots. About one-half of Di Lottery beneficiaries received polyculture plots while the other half received rice plots. For all beneficiary groups except for Di Lottery winners, we do not have baseline information or a control group, so we primarily describe their outcomes. To understand the impact on Di Lottery winners, those applicants to the lottery who did not receive land can be used to construct two control groups.

Figure I.3. Area of Di perimeter land distributed, by recipient group



Source: MCA-Burkina Faso (2014).

Note: "Others" pertain to tree nursery, National research institute (INERA), mixed-gender groups.

[3] Because the land was located close to the Sourou River, in the pre-compact period some PAPs were able to irrigate it using motor-pumps or by relying on naturally occurring flooding. PAPs using motor-pumps received more financial compensation than they would for non-irrigated land of the same size.

All beneficiaries who received land on the perimeter as part of the WMI Activity also received support through the DA activity, which included training in crop diversification, pest control, and irrigated production, as well as starter kits containing seeds and other inputs. The combination of irrigation and land tenure, training, and starter kits was intended to increase land investments, cropping intensity, diversity of crops, and crop yields, leading in turn to increased net revenue. The complementary investments in markets and price information were meant to increase the value of the agricultural production, and the support for water management was meant to ensure the sustainability of the water supply (through the IWRM support) and the irrigation infrastructure (though the O&M Sub-Activity).

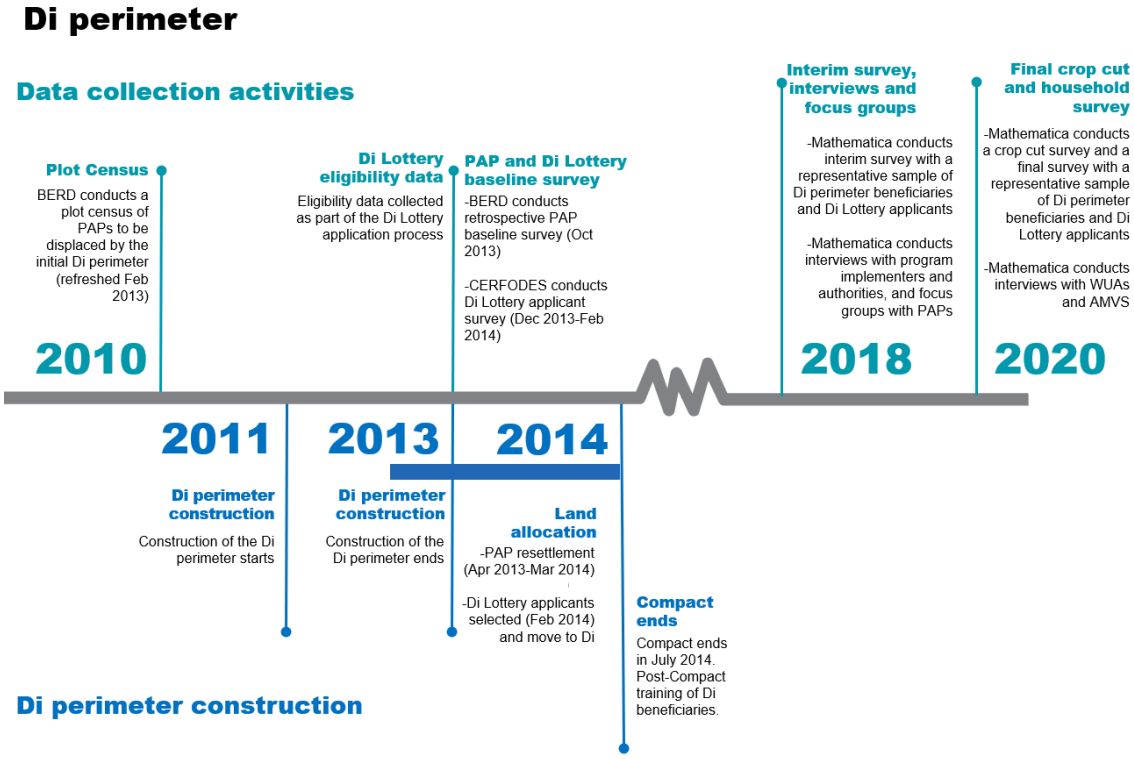
4. The Di perimeter ERR

MCC calculated the economic rate of return (ERR) of MCC's investments in the Di perimeter. MCC finalized the close-out cost-benefit analysis (CBA) model for the Di perimeter on March 7, 2017 (MCC 2017). The CBA compares the post-project increase in agricultural profits to project costs related to the Di perimeter to compute a discount rate at which these two are equal. Regarding costs, the ERR takes into account direct costs—such as costs associated with construction of the perimeter itself—and indirect costs, such as costs of design and supervision, costs related to environmental and social mitigation plans and a share of compact administration and M&E costs. The original ERR was estimated to be 4.2 percent in April of 2008 and the close-out ERR was estimated to be 3.8 percent. We re-estimate the ERR in Chapter II.

5. Implementation summary

The analysis in the interim report concluded that the implementation of all activities was delayed but was generally completed by the end of the post-compact period. Where activities were incomplete, the ADP coordinated the support to beneficiaries through the post-compact entity, the Agence de Partenariat pour le Développement (APD). Outputs—ranging from the construction of the perimeter, farmer training, and land tenure assistance to training and TA for WUAs—were generally considered of good quality by stakeholders (Ksoll et al. 2019). The overall timeline for project activities and the evaluation data collection activities is presented in Figure I.4.

Figure I.4. Timeline of Di perimeter construction and data collection activities



B. Evidence review

The goals of the ADP's investments were to increase agricultural productivity and alleviate poverty through improved irrigation and land provision. In this section, we provide an overview of the literature as it relates to these goals in contexts with agricultural and economic conditions that are like those of Burkina Faso. Specifically, we discuss the existing evidence on (1) access to irrigation, (2) operations and maintenance of irrigation systems, (3) land distribution and titling, and we highlight the key gaps in the evidence that this evaluation hopes to fill.

1. Effects of irrigation

The pressure to meet growing food demands has renewed interest in irrigation investments in sub-Saharan Africa. Although large-scale irrigation systems have often failed to live up to expectations, there is some evidence that irrigation may improve agricultural outputs and economic outcomes, such as employment, wages, income, and poverty (Giordano et al 2020). However, the magnitude and nature of irrigation impacts are highly dependent on various factors and may change over time. We discuss the evidence for benefits of irrigation below.

Irrigation may improve crop yields by increasing the area under cultivation and cropping intensity, and by reducing the risk of crop failure caused by rain variability (Giordano et al 2020, Hussain and Hanjra 2004). For example, Kuwornu and Owusu (2012) found that access to irrigation increased cropping intensity in Ghana by almost three-quarters for rice and about one-third for pepper and okra, and also increased the crops' yield per harvest. An impact evaluation of MCC-funded irrigation investments in rural Senegal found that the project led to an increase in the area of land under production, greater specialization in rice (the dominant irrigated commercial crop), and higher rice yields per hectare (Coen et al. 2019).

Through improvements in crop yields, irrigation has the potential to alleviate poverty though improved food availability for subsistence producers, reduction in food prices for consumers, increased labor demand, and improved nutrition and health (Giordano et al. 2020; Hussain and Hanjra 2004). Hussain and Wijerathan (2004) found that in Asia irrigation reduces poverty by 20 to 30 percent, although impacts on poverty attenuate at tail ends of irrigation systems. Tucker and Yirgu (2010) found that in Ethiopia households experienced a 20 percent increase in annual income on average after adopting irrigation. Its use enabled farmers to grow higher-value crops, intensify production, and reduce losses. However, the authors noted that market interventions are also necessary because farmers face high costs and risks in marketing their crops that limit the returns from irrigation. Access to motorized-pump irrigation in Mali had positive impacts on poverty, agricultural production, and nutrition, increasing household consumption by 20 to 30 percent (Dillon 2008). Also, irrigating households were more likely to save and to share food with neighbors who lacked irrigation, suggesting that impacts go beyond household consumption (Dillon 2011). A mixed-methods evaluation of irrigation infrastructure in northern Ghana found improvements in farm productivity, income, employment, consumption, and food security; however, there were negative effects on health (due to increased waterborne diseases), the natural environment, and the well-being of populations displaced due to dam construction (Akudugu et al. 2016). A study assessing supplemental irrigation as an adaptation strategy to address rainfall variability in south-western Burkina Faso found that the additional irrigation had modest improvements in income, particularly during years with poor rainfall, labor and capital constraints limited these gains (Sanfo et al. 2017).

Overall, irrigation impacts depend on a variety of factors, such as climate conditions/source water, types of crops grown, land type and size, location within irrigation system, socio-economic status, and gender (Giordano et al 2020). A spatiotemporal analysis of an irrigation scheme in Kou Valley in Burkina Faso found that Crop Water Productivity (crop yield per unit of evapotranspiration or irrigation depth) varied by year, crop, and the crop's geographical position in the irrigation scheme (Sawadogo et al. 2020). In Morocco, MCC's irrigation infrastructure improved irrigation efficiency, but the area irrigated did not increase and improvements were palpable only when source water was available, a condition that has been limited due to droughts. Worsening water availability related to climate conditions also limited the effects the project has had on yields, revenues, and profits for olive farmers. In date areas, there was some evidence of positive effects on yields, revenues, and profits, although they varied substantially across and within areas (Borkum et al. 2020). In Moldova, an evaluation of MCC's rehabilitation of irrigation infrastructure found that use of the irrigation infrastructure two years after the project ended had fallen short of expectations because of favorable rains and limited production of high-value crops that required regular irrigation (Borkum et al. 2018).

2. Operations and maintenance of large-scale irrigation

Since the1980s, governments and international actors have been expanding irrigation investments in hopes of improving food security and water use efficiency (Senanayake et al. 2015). Many of these efforts focus on decentralized water management systems, known as Irrigation Management Transfer (IMT) and Participatory Irrigation Management (PIM), which transfer the responsibility of operating and maintaining irrigation systems from the state to local groups of farmers, organized into WUAs (Venot 2014). Farmer involvement in water management is meant to encourage ownership and participation in maintaining the irrigation systems, all while reducing pressure on thinly stretched government finances and ensuring the long-term sustainability of irrigation systems. Despite widespread application of IMT/PIM, the effectiveness of these approaches remains unclear. (Shah 2011). A review of IMT/PIM schemes found that only 20 percent of studies in Africa found successful results in terms of improved crop yields, participation in WUAs, infrastructure quality and functionality, adequate water delivery, financial viability of WUAs, and reduction in frequency of conflicts, among other factors (Senanayake et al. 2015). Specifically, WUAs in sub-Saharan Africa commonly struggle with cost recovery and user participation, and WUA financial sustainability varies greatly based on the socio-technical and economic context of each WUA (Aarnoudse et al. 2018). We explore these phenomena in more depth below.

Suboptimal cost recovery. A common theme in WUA schemes is a lack of financial solvency in the face of high costs and suboptimal fee collection. WUAs rely on collecting membership fees from farmer members, but often farmers struggle to make payments given their unpredictable agricultural sales. Furthermore, fee payments are difficult to enforce. As a result, recovered fees are often not enough to cover O&M costs of WUAs (Aarnoudse et al. 2018). Senanayake et al. (2015) reviewed 181 case studies from Asia, Africa, and Latin America and found that only 33 percent of eligible case studies reported a positive impact of IMT/PIM on the irrigation fee collection rates, and only 35 percent of case studies reported that the WUAs were financially viable. For example, newly established WUAs in Moldova by MCC recovered fewer fees than originally envisioned, because many farmers opted out of membership, so WUAs were not able to cover all their O&M costs despite improving fee recovery rates (Borkum et al 2018). Fee payments are particularly challenging in the context of rice cultivation; in settings with collective water management where both rice and other crops are grown, farmers who only grow rice are the least able to pay water fees (Rasphone et al. 2006). In fact, research suggests that even IMT/PIM interventions with strong incentive systems that provide competitive promotions for canal managers may

not work in rice-based irrigation systems, simply because canal managers are unlikely to achieve cost recovery in these contexts (Senanayake et al. 2015).

Low participation. Another central challenge for WUAs is farmer participation in decision making and collective workdays to ensure smooth operations and irrigation infrastructure maintenance. Based on criteria of elected WUA leaders and member attendance at meetings, Senanayake et al. (2015) found an improvement in farmer participation in less than half of the case studies, and Turiansky (2019) found that only 9 percent of rice farmers in Haiti participated in any voluntary traditional workdays to clean commonly shared canals, despite a monetary compensation offered to all who participated. The lack of participation in communal workdays among Haitian rice farmers was attributed to the transient nature of the population—many landowners farmers live far from their plots, which makes it difficult to organize communal work days, and absentee landowners are not likely to travel to their plots to participate. In a similar context to the Di perimeter, rice farmers at the Korsimoro reservoir in Burkina Faso have stopped participating in infrastructure maintenance despite a fine of US$ 1.25. As a result, the maintenance of canals is long overdue, valves are missing, and emergency repairs are frequent (de Fraiture 2014).

Variable results across and within geographies. Ultimately, the operational and financial success of WUAs is highly variable. The factors influencing their success are complex and hard to predict, but research suggests that the demographic make-up of farmers, types of crops, water source, climate, political environment, and exogenous factors such as availability of source water and crop market prices, are among factors that influence the success of IMP/IMT schemes. Even within the same water systems, WUAs may have heterogenous results; for example, in Moldova, WUAs with just a few wealthy farmer members were in strong financial positions, while WUAs with a sizable proportion of smaller-scale farmer members struggled financially. The overall financial situation of WUAs in Moldova also depended heavily on annual rainfall: fee recovery rates were higher in dry years when farmers were more reliant on irrigation (Borkum et al. 2018). Citing the importance of farmer demographics, climate, and socioeconomic context in determining WUAs' financial success, Shah et al. (2002) stipulate that IMT/PIM is unlikely to work in the African smallholder context as it has with large, commercial farmers of Latin America and China.

3. Effects of land distribution and titling

The literature on land distribution distinguishes between land provision and land titling; the former is the provision of land to actors who did not possess the land before the intervention, and the latter is the formalization of the land rights for a property that actors did possess before the intervention.

Land provision. Ghatak and Roy (2007) and Bardhan and Mookherjee (2007) reviewed the literature on land provision in India, generally finding positive effects of land provision on agricultural productivity and poverty reduction. There are relatively few rigorous impact evaluations on this subject because land provision is rare, and instances where it does occur typically do not allow for rigorous evaluation (for example, provision is not randomized). In addition, few studies document the interactions between the provision of new land and informal needs-based land rights in Africa. The randomized controlled trial (RCT) study of the Di Lottery provides a unique opportunity to provide rigorous evidence on the causal impact of receiving access to irrigated land on agricultural production, agricultural incomes, and household incomes. To our knowledge, it is the only RCT in which a subset of applicants received irrigated land.

Land titling. Research indicates that land titling programs can prevent the negative outcomes of land insecurity. Several reviews of the literature have shown that land titling programs can have positive

impacts on tenure security and land investments, but these impacts can vary substantially depending on the features of the program and the local context (Deininger and Feder 2009; Payne et al. 2009; Besley and Ghatak 2010). There is mixed evidence of the underlying cost of land insecurity in Burkina Faso. For example, Linkow (2016) found a potential for costly land conflicts related to migration as part of MCC's independent evaluation of the Burkina Faso Compact's Rural Land Governance Project. However, Brasselle et al. (2002) found that the traditional village order in Burkina Faso provides the basic land rights required to stimulate small-scale investment. Early interim results from the compact's Rural Land Governance Project (RLGP) suggest a positive impact of the RLGP on perceptions of land tenure security (MCC 2016). Our study will provide evidence of differences in perceptions of land tenure security for land in the perimeter relative to land outside the perimeter. Because land titles were provided together with land and other benefits, it is not straightforward to link land tenure perceptions to outcomes. We use land mediation analysis to disentangle to what extent the effects on agricultural outcomes operate through possible increases in land tenure security.

Land provision and titling, by gender. The literature highlights substantial differences in (1) land tenure security by gender and (2) the impact of land certification and land provision by gender. A number of researchers have investigated land rights by gender in West Africa and found that these rights vary by gender and status as head of household, with important consequences for agricultural inputs, land investments, and outcomes. A few studies have found that land regularization and titling improves female agency and access to land and increases female participation in intra-household decision making, including studies in Ghana (Ali et al. 2014) and Ethiopia (The Cloudburst Group 2016). Even when titles to land are available, women are typically at a disadvantage in having their land rights recorded, though research shows that achieving more equitable outcomes in land tenure is possible in some contexts, including urban Tanzania (Ayalew et al. 2014). Few studies have been able to estimate accurate impacts of providing land by gender or of recording land rights by gender in West Africa. Our study will provide rigorous estimates of the effects of providing land for females versus males because gender was explicitly incorporated into the land lottery.

C. Overview of evaluation approaches and methodology

1. Overview of the ADP evaluation

MCC engaged Mathematica in July 2016 as an independent evaluator to conduct a rigorous evaluation of MCC's investments into the ADP. Our evaluation seeks to answer four overarching questions: (1) What are the project impacts or—where a counterfactual is not available—outcomes of the project in terms of land tenure, agricultural outcomes, and household incomes of project beneficiaries? (2) Are institutions developed by the project functioning and are project results sustainable? (3) What is the overall economic value of MCC's investments? (4) How were the various components of the ADP implemented?

MCC had previously contracted with two evaluators, the Center for Institutional Reform and the Informal Sector (IRIS) and IMPAQ International, to evaluate the WMI and DA activities. After updating the evaluation design (Ksoll et al. 2017), Mathematica analyzed the baseline data collected by the previous evaluators and data collection firms contracted by MCA-BF to assess the plausibility of the assumptions and constraints depicted in the logic model (Ksoll et al. 2018). In 2018, Mathematica's subcontractor Centre de Recherche sur le Développement Appliqué (CRDA) collected quantitative interim data from a stratified representative sample of Di beneficiaries, as well as targeting the entire group of Di Lottery applicants. (The interim survey also collected information on beneficiaries of the ADP's farmer training program, but these beneficiaries are not a focus of the final evaluation.) In addition, through our

qualitative data collector, StatDev, we conducted interviews with implementers and stakeholders, and interviews and focus groups with beneficiaries. Based on our analysis of these data, the interim report investigated questions related to implementation, and it assessed short- and medium-term outcomes hypothesized to lead to the project's long-term goals for the Di perimeter and several smaller project activities (Ksoll et al. 2019).

This final report draws on two sources of information, quantitative and qualitative, to assess MCC's investment in the Di perimeter and to address longer-term outcomes, economic assessment, and sustainability-related questions. We present findings based on a quantitative data collection effort conducted between February and August 2020, about five years after the end of the project. As in the interim survey, this final survey focused on agricultural and land tenure outcomes, as well as household income. The sample of respondents targeted for the final data collection drew on the sample of Di beneficiaries and Di Lottery applicants. In addition to the quantitative data collection, we interviewed stakeholders and beneficiaries about the state of the infrastructure.

Table I.1 presents the research questions that are addressed in the final evaluation and the analytic approaches we used to answer them. (More details on the evaluation design and research questions addressed in the interim report are in the evaluation design report and the interim report, respectively [Ksoll et al. 2017, Ksoll et al. 2019].) To address research questions related to the Di perimeter, given the absence of a baseline and a comparison group, we conducted a performance evaluation using descriptive analysis based on data collected during the survey data collection. We complemented this descriptive analysis with remote sensing techniques to better describe the agricultural outcomes on the Di perimeter. Section A.2 of the Appendix describes the remote-sensing methodologies we implemented. This performance evaluation also comprises an assessment of the economic rate of return (ERR) of the Di perimeter, which we conducted by updating MCC's close-out ERR model with estimated values from our analysis. Due to our inability to obtain price data from the company that took over the market information system, we could not test whether prices changed in the Sourou Valley after construction of the Di perimeter (see Table I.1). However, we investigated interim and final evaluation qualitative interviews and conducted a document review to provide information on price changes.

To estimate the impacts of winning land and receiving the associated benefits through the Di Lottery on agricultural and land tenure outcomes and household incomes, we analyzed quantitative survey data using a randomized controlled trial (RCT). We used information on both lottery participants who were chosen as beneficiaries and those who were not chosen, to estimate the difference in outcomes that can be attributed to winning the lottery.[4] In the baseline report, we presented an assessment of balance and concluded that the two groups were overall balanced before the lottery awarded some of the land on the perimeter (Ksoll et al. 2018).

The analysis of the Di Lottery comprised two additional elements. First, we investigated whether some of the observed impacts can be attributed to changes in land tenure security by conducting mediation analysis. Mediation analysis can untangle the direct effects of a treatment on outcomes from the indirect effects that operate via a mediator, in our case land tenure security. We describe this analysis in more detail in Appendix A. Second, we conducted a methodological study that compares estimates from the RCT with those of a regression discontinuity design (RDD). In particular, we used two newer approaches to RDD developed by Angrist and Rokkanen (2015) and Dong and Lewbel (2015) to investigate to what

[4] Specifically, we estimated the intent-to-treat effect of receiving land, land documentation, training, and starter kits through the project (Ksoll et al. 2017).

extent—in the context of an evaluation of the Di Lottery—RDD methods can provide unbiased estimates of the treatment effect away from the discontinuity.

To address questions related to the operations and maintenance (O&M) of the Di perimeter, we conducted a performance evaluation using mixed-methods analysis based on thematic coding of financial and technical reports and interviews with program participants.

Table I.1. Analytic approaches for the ADP evaluations

Evaluation	Research questions	Analytic approach and data source
Di perimeter	What is the total area planted, average yield/hectare, total production and total profit by focus crop? How do these results differ by type of beneficiary?	Descriptive analysis based on household survey data and crop-cut survey data; remote sensing analysis
	How has PAP well-being changed?	Descriptive analysis of survey data
	What are project results in terms of land tenure security, land conflict and land markets?	Descriptive analysis of survey data
	Have prices for focus crops changed since the completion of the perimeter?	Mixed-methods analysis based on interviews with program participants (interim and final data collection) and document review
	What is the ERR of the Di perimeter?	Descriptive analysis of survey data from interim and final data collection Information on lifespan from interviews with program participants (interim and final data collection)
Di Lottery	What impact does winning the Di Lottery have on agricultural practices, production, total agricultural income, and overall household income of the Di Lottery beneficiaries?	Impact evaluation using a randomized controlled trial (RCT)
	What are the impacts of winning the Di Lottery on land tenure security (perception, transfer rights, land documentation, conflict) and investment?	Impact evaluation using a randomized controlled trial (RCT)
	To what extent do these impacts operate via perceptions of increased land tenure security?	Mediation analysis using data from interim and final data collection
	To what extent are the estimated impacts using a regression discontinuity design similar to those from the randomized controlled trial (RCT), both at the cutoff and far from the cutoff?	Impact evaluation using random assignment compared with impact evaluation using regression discontinuity
O&M	To what extent is the Di perimeter effectively and sustainably operated and maintained? What is the current state of the infrastructure (main canals, roads, pumping station) and functioning of the infrastructure?	Mixed-methods analysis based on financial and technical reports and interviews with program participants
	How well are the WUAs currently functioning with respect to (a) governance, (b) O&M and (c) administrative and financial management?	Mixed-methods analysis based on financial and technical reports and interviews with program participants
	What is the expected lifespan of the perimeter given current levels of maintenance?	Thematic analysis based on interviews with program participants (interim and final data collection)

Notes: The ADP funded the development of a market information system for agricultural prices. We planned on using this information to compare trends in prices for markets near the Di perimeter and those outside of the Di perimeter. We were, however, unable to obtain this information.

2. Quantitative data collection

The Di perimeter and Di Lottery evaluations required follow-up information from farmers on the ADP activities' key outcomes. We collected this information through two quantitative data collection efforts, a crop-cut survey and a household survey, with representative samples of Di beneficiaries. The sampling design was a stratified random sample of beneficiaries, stratified by the type of beneficiary (PAP, Di neighbors, members of women's groups and youth groups, all Di Lottery beneficiaries) and, in the case of PAPs, the gender and size of land holdings. For more detail on the sampling strategy, please refer to the interim report (Ksoll et al. 2018). In addition, we included all Di Lottery applicants in the household survey. By the time of the interim evaluation, Di perimeter land was being rented and had been sold. As a result, we also interviewed farmers who had rented or purchased land from sample respondents. These farmers were included in the final evaluation to the extent that they still cultivated land on the Di perimeter. We refer to these respondents in the subsequent tables and figures as the group of Di rentals and sales. Mathematica procured a local data collection firm, CRDA, to collect this information from farmers.

Crop-cut survey

To provide high quality measurements of yields for the six focus crops maize, rice, tomatoes, onions, cowpeas and soybeans, we implemented a crop-cut survey on selected Di perimeter plots, from January 2019 – January 2020. The households that were selected for the crop-cut survey were a stratified subsample of Di perimeter beneficiaries who had participated in the interim data collection. The interim sample itself was a stratified random sample of Di perimeter beneficiaries. Appendix Table A.1 presents the number of observations in the interim evaluation sample by type of beneficiary, while Table A.2 provides information on the number of households selected for the crop-cut survey and the number of yield measurement squares that were placed by season. In total, 230 and 270 fields were surveyed in the dry and rainy seasons, respectively.

The crop-cut survey proceeded as follows. After contacting the households, interviewers first collected some information on the plot owner and the type of crops that had been planted. If the plot was planted with more than one crop, was very large, or had differing productivity within the field, interviewers subdivided the plot into subplots for separate crop cuts. Enumerators then paced the outline of each subplot with the GPS-enabled tablet, recording the outline of the plot. After the interviewer captured the subplot's outline, a computer program directed the interviewer to a random location for the measurement square in the subplot. There the interviewer placed 5m by 5m measurement squares—four poles with a string attached between them—in the ground to mark the area in which measurements were to be taken. Between the placement of the measurement squares and harvesting, interviewers regularly returned to the fields to observe whether measurement squares were still in the initial place and strings were tightly strung. At harvest time, interviewers returned to harvest and weigh the crops within the measurement square. The geo-coded data on crop type and yields is used to provide ground-truthing information for the remote sensing effort, as well as information on yields.

Household survey

We used a common ADP survey with separate modules focusing on the Di perimeter and the Di Lottery. The final household survey largely followed the interim survey, which was conducted from January

through April 2018 (referencing the 2016/2017 agricultural season) (see Ksoll et al. 2018).[5] The endline survey field work began in February 2020, but it was halted before data collection was completed due to heightened insecurity in the Boucle du Mouhoun region where in-person data collection was being implemented. Although no staff members were harmed, the insecurity in the region created too great a risk for the respondents and the data collection team to continue the work safely. When survey work was halted, approximately 38 percent of the sample members had been surveyed.

To obtain information on the remaining 62 percent of the sample in a safe manner, we continued data collection by telephone, using the phone numbers collected during the interim survey.[6] In order to ensure high quality data and survey completion, the questionnaire from the in-person survey was shortened to adapt to the challenges posed by the phone mode, such as poor connections and short phone battery life. In addition to dropping questions that were not directly related to agricultural profits, land tenure security, and well-being, we limited the number of plots for which we asked detailed questions to three for the agricultural outcomes and two for land tenure security outcomes. As a result, the number of questions in the instrument was reduced by more than half. To correct for the missing plots of land in the phone surveys, we conducted a multiple imputation analysis to impute values for the plots of land not included in the survey, based on the values that were included. Because of the switch to the telephone survey, we were also unable to interview renters and buyers of land who were not part of the interim data collection effort. This change to the sample results in some missing data, for example, totals of land cultivated or crop yields across the perimeter, and may result in some bias if renters or new buyers who should have been added to the sample are systematically different from those in the sample. The phone survey was completed in August 2020. The 2019 agricultural dry and rainy seasons were the reference periods for both the in-person and phone surveys. The results presented in this report were therefore not affected by COVID-19. Table I.2 provides an overview of the topics and samples included in the endline surveys.

[5] Because some land tenure outcomes were not collected for the control group during the interim data collection, Mathematica implemented a phone-based survey of land tenure outcomes in July and August 2019 designed to reference the same time period as the interim data collection. These indicators were not assessed in the interim report but are used in the analysis of land tenure outcomes (Chapter III, Section B, RQ2).

[6] In response to the COVID-19 pandemic, which unfolded just as the switch to the phone survey data collection took place, we set up a distributed call center data collection whereby interviewers followed training through pre-recorded videos and participated in WhatsApp groups for interactive training. Interviewers then made calls from their own premises to reduce exposure.

Table I.2. Primary quantitative data collection overview

Sample	Sample size: in person	Sample size: phone	Total surveyed	Modules
Di perimeter households (incl. Di Lottery beneficiaries)	389	914	1,303	• Agricultural practices (crop choice, area planted, input use) • Agricultural outcomes (production, sales, total agricultural income) • Household income (self-employment, wage employment) • Land tenure outcomes
Di Lottery applicant households	948	1,558	2,506	• Agricultural practices (crop choice, area planted, input use, agricultural techniques) • Agricultural outcomes (production, sales, total agricultural income) • Household income (self-employment, wage employment) • Land tenure outcomes
Crop-cut survey	N/A	N/A	271*	• Crop-cut measurements • Plot and subplot outlines

Notes: Household survey data collection was conducted in 2020, covering the 2018–2019 dry season and the 2019 rainy season. Crop-cut survey was conducted in 2019 and 2020, covering the same dry and rainy seasons.

* Sample indicated for crop-cut survey refers to number of plots.

3. Qualitative data collection

The Di O&M evaluation primarily relied on qualitative data collection and administrative documents. We conducted key information interviews with AMVS staff as well as leadership and staff of all of the seven WUAs, whose knowledge and perspectives differ and complement each other. This variety of sources allowed us to compare and contrast different perspectives on the current state of the Di perimeter infrastructure and WUA capacity and operations. The key informant interviews focused on the state and functionality of the irrigation infrastructure, how it is maintained, the capacity of the WUAs, and the lifespan of the infrastructure. Qualitative notes were translated from Dioula to French, and coded. We then identified themes that emerged from the data for each research question and created summaries of the themes, integrating the findings across all data sources into a cohesive narrative. In addition, we collected administrative data such as technical and financial reports from the WUAs to triangulate with the qualitative findings for the O&M evaluation. The WUA reports included the following:

- Minutes of the General Assembly meeting from the 2019 rainy season for each sector
- Minutes from the budget adoption meeting from the 2019–2020 growing seasons for each sector
- Technical reports on the condition of the electro-mechanical components of the irrigation system from the 2019 rainy season for each sector

Table I.3 summarizes the respondents and themes included in the qualitative data collection.

Table I.3. Qualitative data collection by sources

Data source	Data collection method	Number	Themes
Document review			
WUA reports, meeting notes, and water user payment information	Desk review	n.a.	• WUA meeting frequency and participation • Status of pumping stations • O&M budgeting and reporting • Financial management including budget preparation and submission, financial sustainability, and reserves
Respondents			
Current AMVS staff (engineer, extension, management)	Interviews	3	• Irrigation infrastructure state, functionality, and maintenance on the Di perimeter • WUA capacity and determinants of capacity • Lifespan and current condition of irrigation infrastructure
Leadership of WUAs and the Union of WUAs	Interviews	8	• Irrigation infrastructure state, functionality, and maintenance on the Di perimeter • WUA capacity and determinants of capacity • Role of WUA in land market
WUA technical and financial staff	Interviews	3	• Irrigation infrastructure state, functionality, and maintenance on the Di perimeter • WUA capacity and determinants of capacity • Lifespan and current condition of irrigation infrastructure

n.a. = not applicable.

O&M = operations and maintenance; WUA = water-user association; AMVS = Autorité de la Mise en Valeur de la Vallée du Sourou.

II. Di Perimeter Evaluation

In this chapter, we present the findings from the Di perimeter performance evaluation. First, we provide background information on the perimeter and a summary of the evaluation design. Next, we present results on the agricultural and land tenure–related outcomes on the perimeter, including results disaggregated by beneficiaries. We then provide estimates of the Di perimeter ERR.

A. Background

As we discuss in Chapter I, several groups of beneficiaries—PAPs, lottery beneficiaries, non-PAPs from neighboring villages, women's groups, and youth groups—benefited from the irrigated land in the Di perimeter. These groups also received several forms of assistance from the WMI and DA activities that were designed to be complementary and to improve agricultural and land security outcomes, ultimately leading to higher production, sales, agricultural income, and household income. In Table II.1, we summarize all assistance offered to different groups of Di perimeter beneficiaries as part of the Di perimeter investments during the compact.[7]

Table II.1. Summary of Di perimeter subactivity

Objective	• Increase land productivity through irrigation • Compensate PAPs for lost income and land associated with perimeter construction
Funding	$89 million ($39,626 per hectare)
Target population	PAPs, lottery winners, non-PAPs from neighboring villages, women's groups, and youth groups
Benefit	• Constructing a perimeter of irrigated land: new irrigation and drainage canal networks, seven pumping stations, drains, a levee, and roads and paths throughout the perimeter • Distributing land on the perimeter: formal titles to full ownership to PAPs for land received in compensation; formal leases to PAPs and other beneficiaries for non-compensation–related land. PAPs were able to choose the type of land received, Lottery beneficiaries received either two hectares of rice plots or one hectare of polyculture land; women's groups and youth groups received small polyculture plots of about one-twentieth of one hectare of polyculture land. • Providing financial compensation to PAPs for harvest losses during construction of the perimeter • Providing training in agricultural technologies for irrigated land and starter kits (land preparation and inputs) during first growing seasons • Establishing water user associations and the Centre d'Appui Technique et de Gestion (CATG), and providing AMVS with technical assistance to implement reforms (see O&M evaluation)
Timeline	Construction and resettlement completed in 2014
Exposure period	2014 – endline survey reference period (2018/2019 dry season; 2019 rainy season)
Data Collection	• Crop-cut survey: January 2019 through December 2019 (2018/2019 dry season; 2019 rainy season) • Household survey: – Interim: January through April 2018 (in person) (2016/2017 dry season; 2017 rainy season) – Endline: February through August 2020 (combination of in-person and phone) (2018/2019 dry season; 2019 rainy season)

[7] Post-compact support to beneficiaries through the APD and CATG, and ongoing support from AMVS and the Ministry of Agriculture are not included in the table.

B. Endline findings

In this section, we present endline findings for the Di perimeter subactivity evaluation, based on household surveys, crop-cut surveys, and remote sensing analysis. The evaluation aims to understand outcomes including agricultural practices, yields, income, and land tenure security for the different types of beneficiaries on the perimeter. We present results by research question.

RQ1. What is the total area planted, average yield per hectare, total production, and total profit by focus crop? How do agricultural outcomes differ for different beneficiary groups?

Key findings

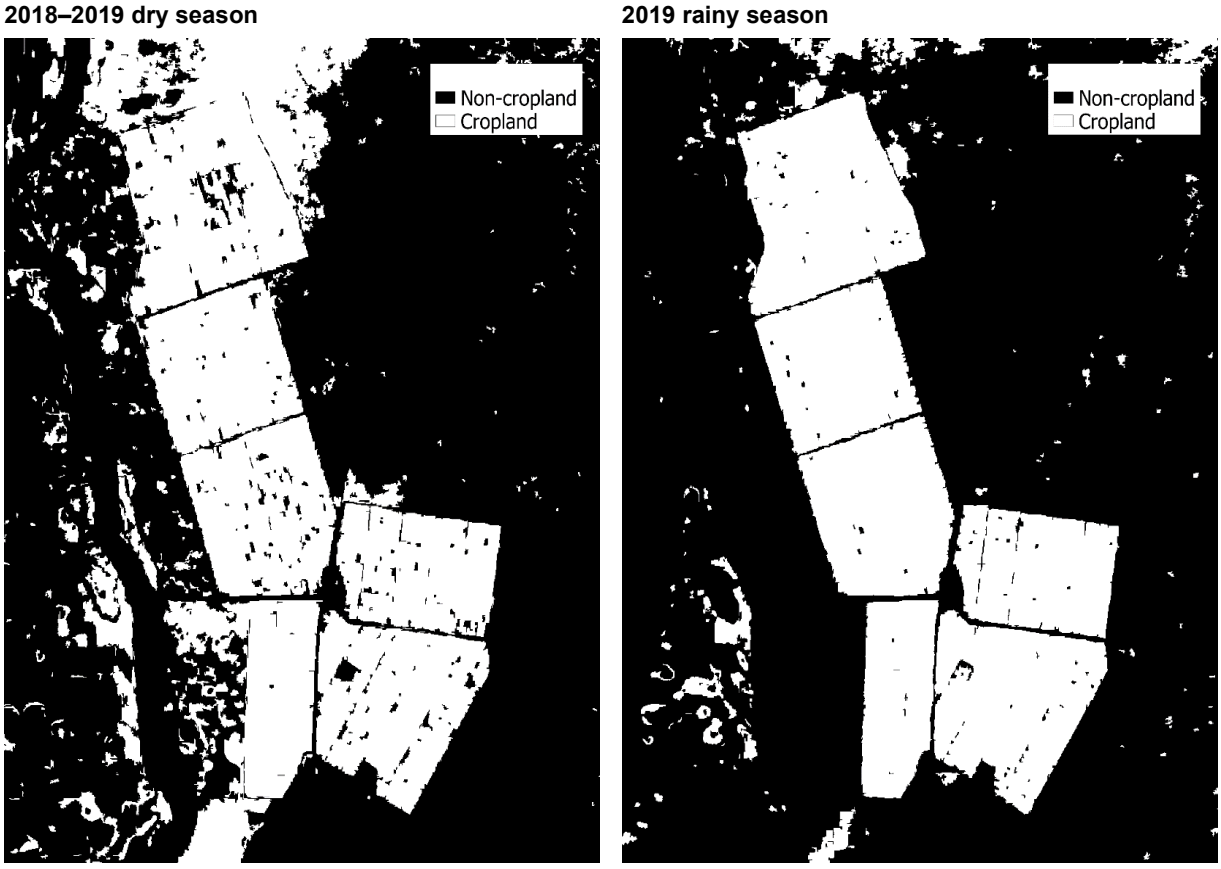
Land on the perimeter is extensively farmed in both seasons, with 96 and 99 percent of the 2,246 hectares of perimeter land cultivated in the dry and rainy seasons, respectively. The area cultivated in the Di perimeter during the rainy season is more than twice as large as at baseline. The land cultivated during the dry season constitutes a 20-fold increase. Dry season profits per hectare were more than 10 times higher than rainy season profits, with the highest profits for onions and the lowest for maize. Di neighbors and women's groups achieved the highest profits per hectare over the course of the year, while Di PAP households earned the lowest, but differences across beneficiary types were small. Overall, profits did not meet expected profits under MCC's close-out ERR estimated in 2017, largely due to lower onion profits than expected.

Estimates of yields and area cultivated differ substantially across data collection methods. The estimate of area and crops cultivated based on survey data performs poorly compared with remote sensing data, likely due to the switch to telephone surveys and our inability to follow renters. Based on crop-cut information, yields for all crops exceed program targets. For all crops, total and per-hectare yield estimates from survey data are lower than estimates based on crop-cut measurements. The yield discrepancies do not affect the ERR recalculation, which is based on the self-reported profits from the survey.

The satellite imagery–based cropland masks for the dry and rainy seasons show that almost the entire perimeter is cultivated in both seasons. The cropland mask generated for the 2018–2019 dry season and the 2019 rainy season (Figure II.1) shows cropland in white and non-cropland in black. (Section A.2 of Appendix A provides more information on the remote -sensing methodologies we used.) Both images clearly delineate the Di perimeter and four out of the seven sectors (because sector C3 straddles sectors C1 and C2, these three sectors appear as two sectors in the map). Overall, almost 99 percent of the 2,246 hectares of land in the Di perimeter is cultivated in the rainy season and 96 percent in the dry season. At baseline, as per the information available in the CBA model, 906 hectares were cultivated in the rainy season and 110 hectares in the dry season.[8] As such, the area cultivated during the rainy season is more than twice as large as at baseline. The area cultivated during the dry season constitutes a 20-fold increase over the land under cultivation during the dry season at baseline.

[8] Because of a lack of reliable information in the baseline surveys, we are not able to verify the exact number of hectares under cultivation at baseline.

Figure II.1. Di perimeter cropland mask



Source: Remote sensing analysis.

Note: See Appendix A for the remote sensing methodology.

Aggregating remote sensing data to the plot level show that most plots are cultivated on the perimeter, with nearly all plots cultivated in the rainy season. The pixel-level cropland masks in Figure II.1 provide information on cultivation status at the level of a 10m-by-10m pixel. This makes it difficult to compare to data on cultivation status from a household survey, which is typically available only at the level of a plot. We therefore use the boundaries from the Di perimeter cadastral map to determine which plots were predicted to be agriculturally inactive over the season, to make our remote-sensing findings more meaningful in comparison to survey findings. The images in Figure II.2 aggregate the images from Figure II.1 to the plot level and classify plots as agriculturally active if 80 percent or more of the pixels contained in the plot are classified as cropland in the pixel-level mask. Agriculturally inactive plots are primarily located in the North sector (see also Chapter IV for a discussion about the issues facing rice plots in the North sector).

Figure II.2. Di perimeter cropland mask over cadastral map

2018–2019 dry season **2019 rainy season**

Note: Cropland mask created by using Di perimeter cadastral boundaries and 80 percent plot-wide threshold. See Appendix B for the remote sensing methodology.

The estimate of area cultivated based on survey data performs poorly in our context (Table II.2). According to estimates calculated from survey information, 87 percent of the total area in the Di perimeter is reportedly cultivated in the rainy season. We based the estimate on the area reportedly cultivated divided by the area of land on the Di perimeter to which survey respondents have access, according to cadastral maps. For the dry season, we estimated the proportion of cultivated land at 85 percent. These numbers are substantially lower than those derived from the remote sensing analysis, suggesting that over 98 and 95 percent of the perimeter is cultivated in the rainy and dry seasons, respectively. The endline survey was not able to gather information on cultivation associated with land rental and sales that occurred between the midline and endline surveys. Given the switch to the telephone survey, we were not able to interview new renters and buyers of Di land beyond those sampled in the interim survey. In addition, with the need for the telephone survey to be significantly shorter, we collected information from the households in the in-person survey only on the plot area cultivated, not on the area cultivated by crop. As a result, only 40 percent of our total sample provides information on area cultivated; in other words, the estimates are much noisier than estimates that draw on both the in-person and telephone surveys or on the remote sensing approach that provides predictions for all plots of land. Even though we do present weighted averages and adjust our sampling weights for survey nonresponse, our approach reaches its limits in the area of land cultivated and cropping patterns. That is, the survey

estimates rice crops to be cultivated only on 10 percent of the perimeter, but the remote sensing analysis suggests that the figure is closer to 20 percent (Table II.3).

Estimates of area cultivated from the remote sensing pose separate challenges. The area cultivated in the dry season as estimated by the remote-sensing analysis (2,340 hectares) is about 4 percent larger than the actual size of the perimeter (2,246 hectares). One reason that remote sensing-based methods may overestimate cultivated area is the binary nature of cropland status classification. Each 10 meter by 10 meter pixel for a given season is classified as either agriculturally active or not, even though the full 100 square meters may not be cultivated. If at least half of the pixel area is cultivated, then the algorithm will indicate the pixel as agriculturally active. Misclassification, or classification that is only partly accurate, may be driving results that do not exactly equal survey-based estimates. The estimate is, however, also consistent with project documentation that lists net perimeter size at 2,246 hectares and gross perimeter size at 2,368 hectares. In calculating the percent cultivated, we divided by the gross perimeter size.[9]

Table II.2. Total area cultivated on Di perimeter

	Household survey		Remote sensing	
	Rainy season	Dry season	Rainy season	Dry season
Total area cultivated (hectares)	1,839	1,784	2,340	2,267
Total area cultivated (percent) as a proportion of cadastral area	87.4%	84.8%	98.8%	95.7%
Sample size	**246**	**246**	**4,398**	**4,398**

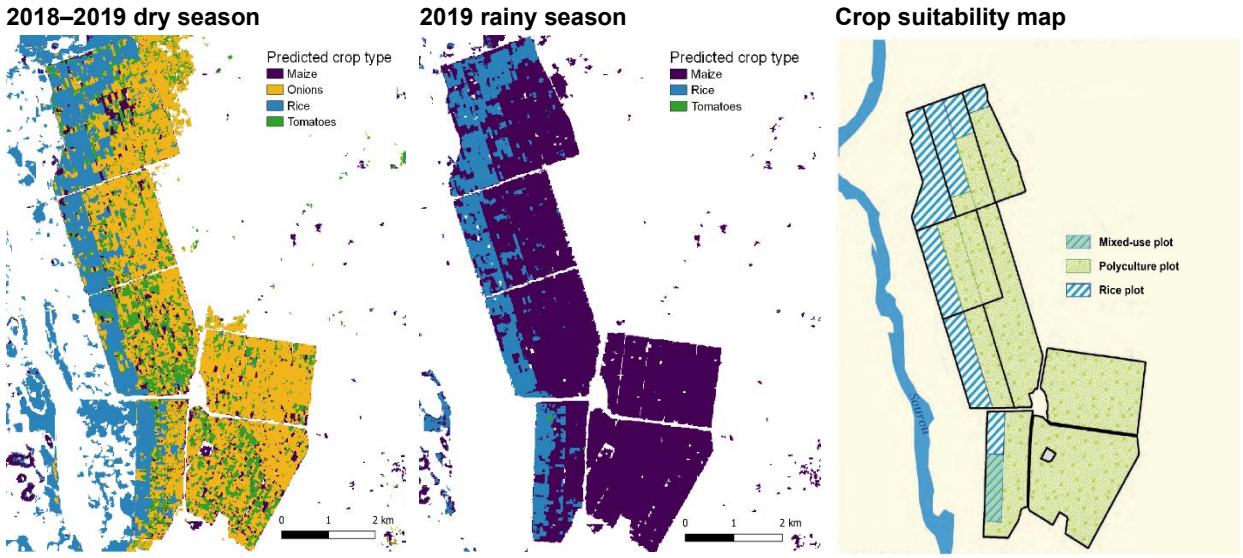
Source: Endline survey (2020); Remote sensing analysis.

Note: Household survey includes information from the in-person sample. We applied survey weights to generate perimeter total values. We calculated the percent total cultivated as the percent of the area cultivated on the Di perimeter by sample households as a proportion of the landholdings, according to information from the land registry.

Crop-type remote sensing analysis shows that farmers are generally following cropping patterns that are consistent with the type of land received. Lottery beneficiaries were allocated land suitable to either rice or polyculture as part of the lottery process. It is possible to analyze satellite-derived reflectance data to predict which of a set of crops is grown in a location if the crops have different reflectance properties. For example, the wave lengths and intensity of light reflected from the crop back out to the atmosphere differ for different crops and at different times of their growing season. In Figure II.3, we depict the predicted crops grown by season around the Di perimeter region. Farmers are generally following the projected cropping patterns of the CBA model (shown in the far-right panel). In the dry season, land suitable for rice cultivation is predominantly cropped with rice, and polyculture plots are cultivated with a mix of onions and tomatoes. During the rainy season, farmers primarily cultivate rice on rice plots and predominantly cultivate maize on polyculture plots. However, there is some maize and onion cultivation on rice plots in the rainy and dry seasons, consistent with anecdotal evidence that some land meant for rice is unsuitable for rice because of unlevel fields. Similarly, some of the relatively low-lying polyculture plots that become flooded are repurposed for rice cultivation.

[9] It is possible that farmers can cultivate some of these residual areas along the borders of their field. Without higher-resolution imagery, we are not able to provide evidence on whether this is the case.

Figure II.3. Di perimeter crop mask

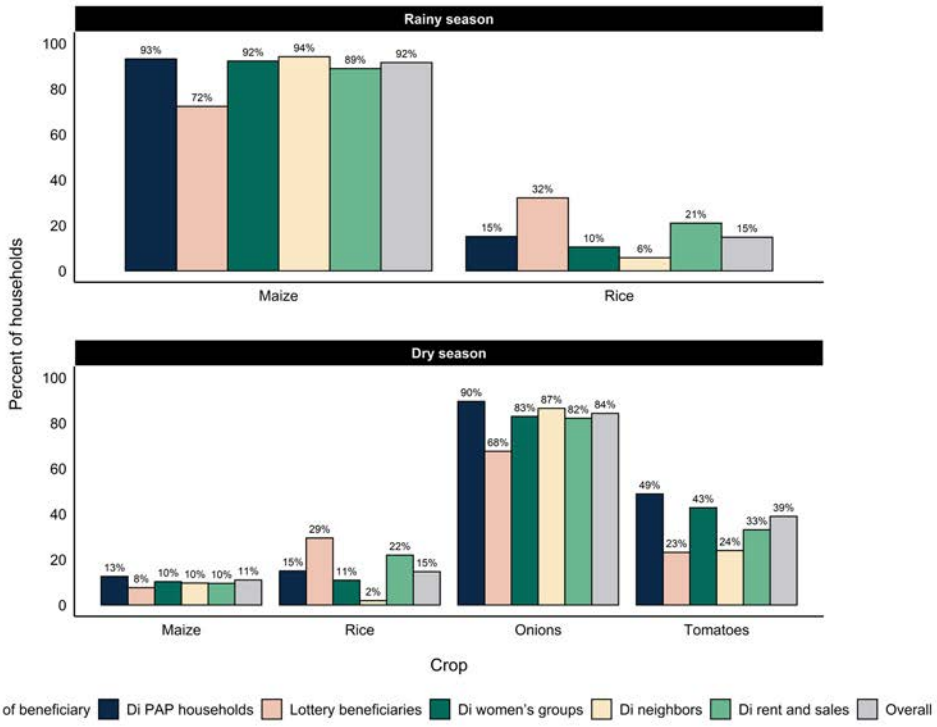


Source: Remote Sensing analysis.

Note: See Appendix A.2 for the remote sensing methodology.

Except for lottery beneficiaries who received rice plots, most farmers' reported crop choices are similar across beneficiary groups; most farmers plant maize in the rainy season and onions or tomatoes in the dry season (Figure II.4). According to survey estimates, 92 percent of farmers cultivate maize in the rainy season, while 15 percent cultivate rice. In the dry season, 84 percent cultivate onions, 39 percent cultivate tomatoes, 15 percent cultivate rice, and 15 percent cultivate maize. Most beneficiary groups follow similar cultivation patterns, with the exception of lottery beneficiaries. This difference is due to the fact that half of lottery beneficiaries received rice plots; about half of the rice plots—most of which were distributed in the lottery—are suitable only for rice during both seasons. Only 68 percent of lottery beneficiaries cultivate onions in the dry season, while 29 percent—about twice the overall average—cultivate rice. Tomatoes are the second-most cultivated crop in the dry season, but Di PAP households and women's groups are much more likely to cultivate onions (48 and 43 percent, respectively) than are other types of beneficiaries (23 to 33 percent). This higher rate of cultivating onions among PAPs and women's groups may be due to the higher likelihood that farmers in these groups were given land suitable for growing onions. As expected, a smaller number of farmers cultivate maize and beans during the dry season, while the proportion of farmers who cultivate rice remains the same. During the rainy season and again in line with the type of plot received, the Di lottery beneficiaries differ from other farmers on the perimeter. The lottery beneficiaries are more likely to grow rice (32 percent compared with 6 to 24 percent among other groups) and less likely to grow maize (72 percent compared with 87 to 94 percent among other groups). Appendix Figure A.1 disaggregates the cultivation patterns by receipt of a rice versus polyculture plot. It shows that recipients of a polyculture plot generally cultivate the expected crops whereas about half of rice plot recipients are cultivating maize in the rainy season.

Figure II.4. Crop choices on Di perimeter, by type of beneficiary



Source: Endline survey (2020).

Note: Includes information from both in-person and telephone survey respondents.

Like the estimates of total area cultivated, estimates of area cultivated by crop based differ between survey data and remote sensing data (Table II.3). For most crops, remote sensing analysis detected as much or more land cultivated than was reported by survey estimates; the one exception was dry season maize, which accounted for nearly 8 percent of cultivated land according to the survey but less than 1 percent according to remote sensing estimates. For tomatoes and rice, remote sensing estimates were substantially higher. These differences are likely attributable to lack of information on land that was let or sold between the midline and endline surveys and the switch to the telephone survey, as we discuss above.

Table II.3. Total area cultivated on Di perimeter, by focus crop

	Household survey		Remote sensing		MCC Projections	
	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
Total area cultivated by focus crop (percentage), conditional on cultivation						
Tomatoes	-	10.8%	-	19.3%	-	3.9%
Onions	-	62.0%	-	57.2%	9.0%	81.1%
Maize	81.1%	7.7%	79.3%	0.7%	82.9%	2.2%
Rice	13.5%	11.8%	20.6%	21.4%	7.0%	10.3%
Cowpeas	0.7%	0.6%	-	1.5%	0.2%	0.1%
Soybeans	-	-	-	-	-	-
Sample size	**246**	**246**	**4,398**	**4,398**	**n.a.**	**n.a.**

Source: Endline survey (2020); remote sensing analysis.

Note: Endline survey includes information from the in-person sample. We applied survey weights to generate perimeter total values. We calculated the percentage total cultivated as the percentage of the area cultivated on the Di perimeter by sample households as a proportion of the landholdings, according to information from the land registry. The survey allowed for respondents to report other crops, but we only report the key crops in this table, so the total is less than 100 percent.

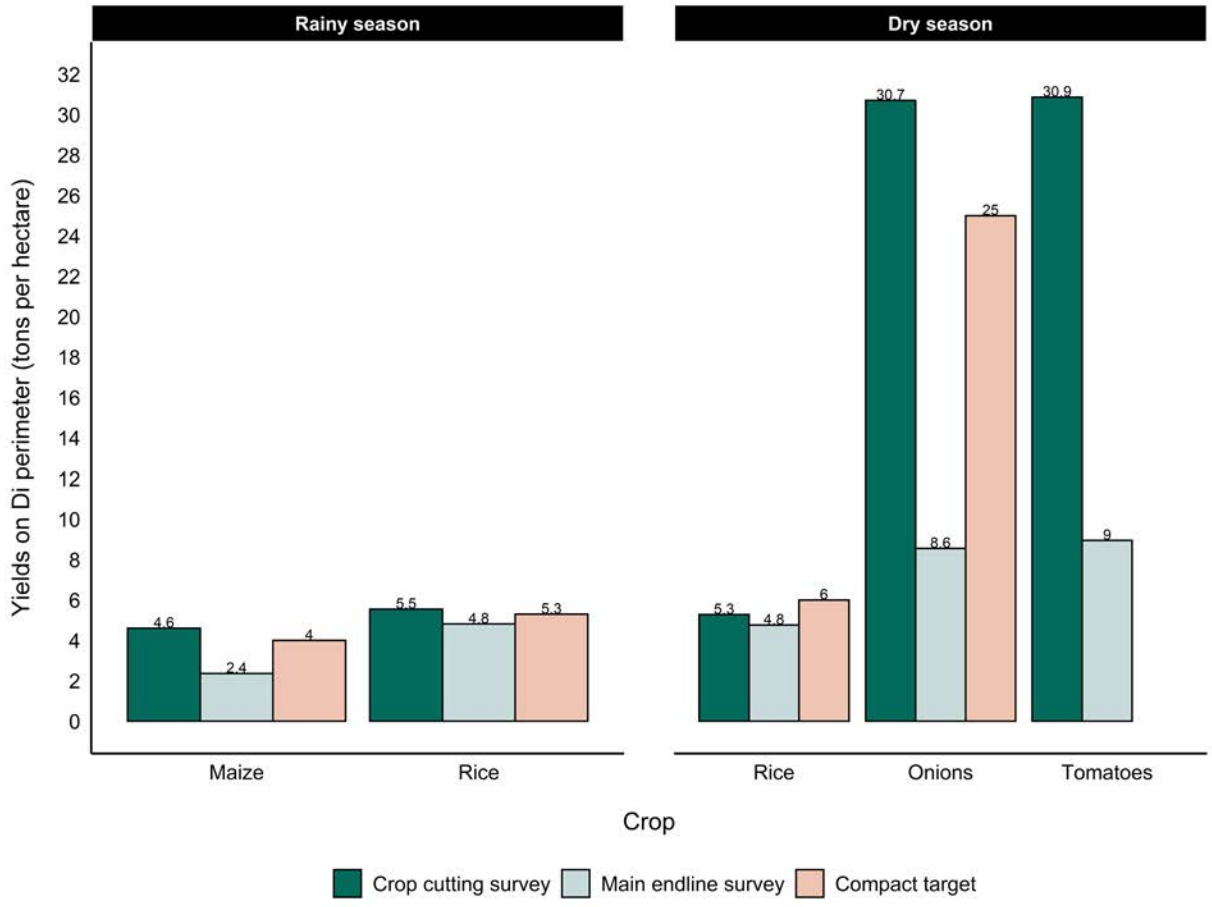
For most crops, yield estimates derived from survey information are much lower than estimates based on crop-cut measurements. Farmers on the Di perimeter report average yields during the dry season of 9.0, 8.6, and 4.8 tons per hectare for tomatoes, onions, and rice, respectively (Figure II.5). Crop-cut estimates show average yields of 30.9, 30.7, and 5.3 tons per hectare for the same three crops. During the rainy season, surveyed farmers report average yields of 2.4 and 5.1 tons per hectare for maize and rice, respectively, although crop-cut estimates show yields of 4.6 and 5.5 tons per hectare for the same crops, respectively. These discrepancies for all crops except for rice are large and are consistent with significant survey underreporting of yields on plots of larger sizes. In one wave of their surveys and crop cuts, Desiere and Jollife (2018) find that maize crop cuts for farmers in the largest quartile of plots—who with an average of 0.3 hectares of land are most similar to farmers on the Di perimeter—provide yield estimates that are 2.5 to 3 times higher than survey reported yields. Even though this finding is consistent with prior evidence, this finding is still surprising given that errors in plot size are unlikely to be a key source of bias in our context because farmers are aware of the size of their land due to the titling activities.[10] We note that the yield discrepancies do not affect the ERR recalculation, which primarily

[10] Many academic papers document survey and crop-cut yield differences; several papers find survey reports exceeding crop-cut yields and others find the opposite. Gourlay, Kilic, and Lobell (2019) show that, particularly for small-holder plots, the survey reported yields are often larger on average than yields from crop cuts. Paliwal and Jain (2020) and Wahab (2019) on the other hand find crop-cut yields exceed yields estimated from survey responses. Paliwal and Jain (2020) find that survey yields in their setting are 40 percent lower than crop-cut yields and conclude that self-reported yields cannot be used to train remote-sensing algorithms. Wahab (2019) finds crop-cut yields are more than three times larger than self-reported yields. This raises the question about which results should be trusted: Several papers suggest that crop cuts outperform survey responses in measuring yields (for example, Carletto et al. 2015), but several pieces of evidence suggest this determination is not clear cut. In the setting documented in Wahab (2019), farmers adapt the area cultivated over the course of the season, reducing the effective plot area under cultivation as the season unfolds. However, the area on which the measurement square is placed less likely to be abandoned. Along a similar line, Desiere and Joliffe (2018) note that crop cuts might be measuring potential yields, while the information on production contained in the surveys might measure actual harvests across a wider area.

relies on the value of sales and cost information gathered from farmers. Farmers report sales and costs separately from yields.

Average yields on the Di perimeter, based on estimates from the crop-cut survey, met or exceeded program targets for most crops. Yield estimates from the crop-cut survey demonstrate that productivity met or slightly exceeded target levels for rice in both seasons and for rainy-season maize, and greatly exceeded target levels for dry-season onions (Figure II.5). Yield estimates computed from the household survey, on the other hand, fall below the targets for all crops. When compared with the interim survey, onion yields as reported in the survey also dropped substantially between the interim and endline data collection, while yields for other crops remain relatively similar between the two surveys.

Figure II.5. Grain and vegetable yields on the Di perimeter (tons per hectare) reported in the in-person and crop-cut surveys



Source: Endline survey (2020); Crop-cut survey.

Note: The indicator tracking table does not have a target for tomatoes.

The crop-cutting exercise for rice weighed the rice with the hulls, so the measured weights were multiplied by 0.62 to convert them into hulled weights to be comparable with survey measures (MAAH 2009).

Survey estimates of total production on the Di perimeter, like survey estimates of yield per hectare, are lower than the estimates based on crop cutting for most crops. Survey estimates of total production are much lower than estimates calculated using yield estimates from the crop-cutting survey and remote-sensing estimates of area under cultivation by crop for all crops (Table II.4), and lower than crop-cutting estimates in both seasons for tomatoes, rainy season maize, and rice. The differences between survey-based and crop-cut estimates are most dramatic for tomatoes and onions, with the latter showing total production that is more than six times higher for tomatoes and more than twice as high for onions.

Table II.4. Total production on Di perimeter (tons), by focus crop

	Household survey		Remotely sensed area & survey yield		Remotely sensed area & crop cut yield	
	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
Tomatoes	-	2,070	-	3,714	-	12,804
Onions	-	14,440	-	10,522	-	37,756
Maize	6,694	-	4,163	-	8,105	-
Rice	1,859	1,743	2,202	2,192	2,536	2,428
Cowpeas	-	-	-	-	-	-
Soybeans	-	-	-	-	-	-
Sample size	**936**	**919**	**4,398**	**4,398**	**270**	**240**

Source: Endline survey (2020); Crop-cut survey. Remote sensing yield predictions based on survey data and crop-cut yield measurements.

Note: Includes information from both in-person and telephone survey respondents.

The crop-cutting exercise for rice weighed rice with hulls, so the measured weights were multiplied by 0.60 to convert them into hulled weights to be comparable with survey measures (MAAH 2009).

Production of onions and tomatoes drives the economic value of the perimeter in the dry season, with dry season profits per hectare more than 10 times higher than in the rainy season. Average costs per hectare are more than twice as high during the dry season as during the rainy season, while the value of agricultural production (the value of all the crops produced, including those sold and those consumed at home, but excluding costs of production) is more than five times as high (Table II.5). As a result, average profits (value of production minus agricultural cost) per hectare exceed one million FCFA per hectare during the dry season and fall below 50,000 FCFA during the rainy season. Profits per hectare from polyculture plots were twice as high as profits per hectare in rice plots during the dry season; profits were lower for both types of plots in the rainy season than during the dry season, with rice profits substantially exceeding polyculture profits per hectare.

Table II.5. Di perimeter agricultural outcomes (per hectare in 1,000 FCFA)

Full sample	Dry season	Rainy season
Agricultural costs per hectare	359	178
Value of agricultural production per hectare	1,490	293
Agricultural profit per hectare	1,050	31
Rice plots		
Agricultural costs per hectare	468	317
Value of agricultural production per hectare	909	368
Agricultural profit per hectare	576	149
Polyculture plots		
Agricultural costs per hectare	349	167
Value of agricultural production per hectare	1,560	289
Agricultural profit per hectare	1,110	22
Sample size	**648**	**817**

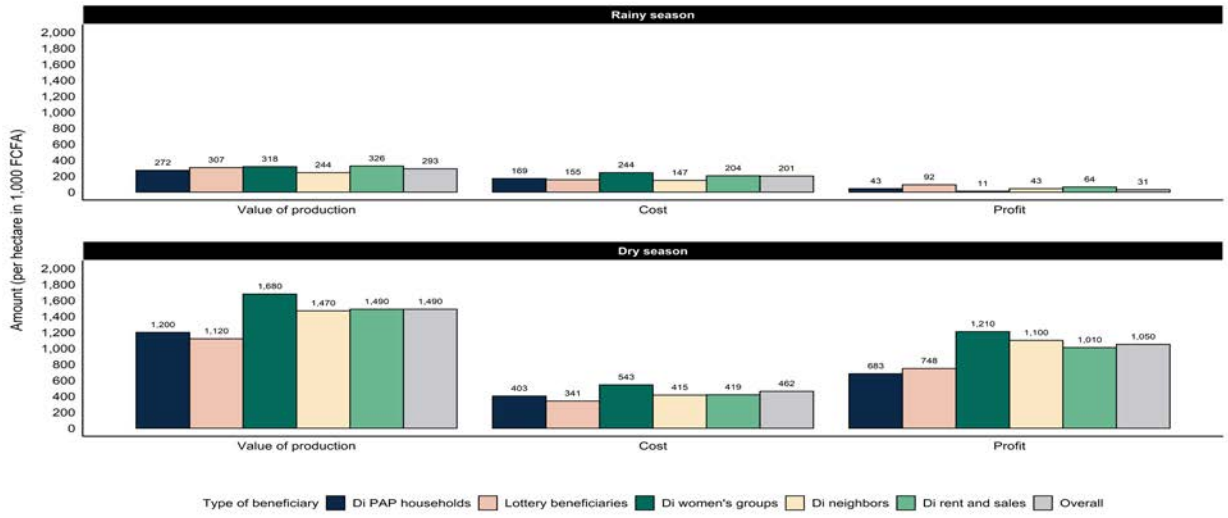
Source: Endline survey (2020). The agricultural costs comprise (1) costs of hired labor for land preparation, weeding, and harvesting; (2) the costs of fertilizer, seeds, and pesticides; 3) rental costs of machinery; and (4) contributions to the WUAs. Post-harvest and marketing costs are included indirectly since we use the revenue from sales to calculate the value of agricultural production.

Note: Includes information from both in-person and telephone survey respondents.

Sample includes 149 rice plots and 459 polyculture plots in the dry season, and 169 rice plots and 601 polyculture plots in the rainy season. We use the project categorization into rice and polyculture plot for this disaggregation, not its current use.

Agricultural outcomes vary somewhat by beneficiary type, with Di PAP households earning the lowest profits per hectare over the course of the year, and Di neighbors and women's groups achieving the highest profits. Both production costs and the value of production vary across beneficiary types, but not drastically (Figure II.6). On a per hectare basis, women's groups, who had received small vegetable plots, experience the highest costs in both seasons and the highest production values during the dry season; production values during the rainy season do not vary meaningfully between beneficiary types. Over the course of the entire year, women's groups achieve the highest annual profits, followed by Di neighbors; PAP households account for the lowest profits. Because beneficiary groups vary across many dimensions including the area of land they received, prior experience in irrigated agriculture on a perimeter, landholdings outside the perimeter, the distance between plots on the perimeter and their home, and probably a number of other characteristics, we are not able to assess why certain groups have higher outcomes than others. Dry season profits are much higher than rainy season profits for all beneficiary types. Appendix Figure A.2 disaggregates profits per hectare by type of plot and documents that profits per hectare for polyculture plots are significantly higher for polyculture plots.

Figure II.6. Di perimeter agricultural outcomes, by type of beneficiary (per hectare in 1,000 FCFA)



Source: Endline survey (2020).

Agricultural profits per hectare are highest for onions and lowest for maize. Survey respondents reported per hectare profits of close to 1.2 million FCFA for dry season onions, while profits after fees were 60,000 FCFA for rainy season maize (Table II.6). Farmers reported profits of approximately 258,000, 189,000, and 219,000 FCFA per hectare for rainy season rice, dry season rice, and dry season tomatoes, respectively. Onions and tomatoes are cash crops grown primarily for sale, while other crops are for self-consumption and for sale, so profits were expected to be higher for onions and tomatoes.

Table II.6. Di perimeter profits per hectare, by focus crop (in 1,000 FCFA)

	Household survey	
	Rainy season	Dry season
Tomatoes	-	219
Onions	-	1,160
Maize	2.3	-
Rice	258	189
Sample size	**666**	**475**

Source: Endline survey (2020).

Note: Profits per hectare by focus crop are conditional on cultivating that crop. Estimates include information from all plots from in-person respondents and from plots cultivated with a single plot by respondents in the telephone survey.

RQ2. How has PAPs' well-being changed?

Key findings

Three-fourths of PAPs reported higher agricultural profits, and 9 of 10 reported improved food security after perimeter construction. PAPs agricultural profits and household incomes increased by 6 and 34 percent, respectively, since the interim survey.

Because the construction of the perimeter required PAPs to give up their previous landholdings, the change in PAPs' well-being is of particular interest. We present several survey-based indicators of economic well-being at interim and endline as well as PAPs' self-reports of their well-being.

Agricultural profits and household incomes increased between interim and endline. In Table II.7, we present average profit and income of PAPs for the 2016–2017 (interim) and 2018–2019 (endline) agricultural years. On average, PAPs reported household earnings of about 1,040,000 FCFA (US$1,860) per year at interim and $1,390,000 FCFA (US$ 2,480) at endline. One of the reasons contributing to this increase is price increases. Respondents in our qualitative interviews noted that prices had been low during the period of the interim evaluation and had since risen (see Chapter IV). The small difference between household income and agricultural income—which includes agricultural profit, agricultural wage employment, income from land rental, and income from transformation of agricultural products—suggests that PAP households dedicate themselves primarily to agricultural activities.

Table II.7. Average household profit and income (in 1,000 FCFA)

	Interim	Endline	Difference	*p*-value
Agricultural profit	963	1,020	57	0.58
Agricultural income	982	1,150	168	0.12
Household income	1,040	1,390	350	< 0.01
Sample size (PAPs)	**242**	**242**		

Source: Interim and endline surveys (2017 and 2020).

Note: The indicators for agricultural profit, agricultural income, and household income include the estimated value of the agricultural production that was consumed as subsistence consumption or given as a gift to other households.

Baseline values are not presented because it is not possible to construct profit, income, or household income from the baseline survey in the absence of cost information.

PAPs reported being better off now than they were before perimeter construction in terms of agricultural profits and food security. During the interim data collection, about three-quarters of PAPs reported increased agricultural income compared with 2010; this share increased to nearly 9 out of 10 by the endline (Table II.8). At the same time, 96 percent of PAPs reported reduced food insecurity in the interim survey; this share declined to 91 percent by endline.

Table II.8. PAP perspectives on income, costs, and food security (percentage)

	Interim	Endline	Difference	*p*-value
Agricultural profits have increased compared with 2010	73	88	15	<0.01
Food security has increased compared with 2010	96	91	-5	.07
Sample size (PAPs)	**242**	**232**		

Source: Interim and endline surveys (2017 and 2020).

RQ3. What are the project results in terms of land tenure security, land conflict, and land markets?

Key findings

Project activities led to high levels of land tenure security; about three-quarters of farmers possess formal land documents, and about 85 percent of farmers believe that it is very unlikely that they would lose access to their land within the next five years. Very few farmers reported any land conflicts.

There is some confusion about land transfer rights on the perimeter. Most beneficiaries understand their right to bequeath or rent their land, but only about one-quarter know that they have the right to sell or lease their land. Perceptions of land security do not vary by type of beneficiary.

There is an active rental market. Seven percent of beneficiaries rented out land. More than one-fifth of farmers on the perimeter have applied for loans, but few of those had used their land on the perimeter as collateral for loan applications. Rates of land investments are slightly higher than in the interim survey.

Across all beneficiary groups on the perimeter, farmers generally feel secure about their tenure on the perimeter. More than three-quarters of farmers claim to possess formal land titles or leasehold documents following the allocation of land on the perimeter, and about 85 percent of farmers think it is very unlikely that they would lose access to their land within the next five years (Table II.9). Very few farmers reported any land conflicts. Qualitative findings support their claim, with WUA leaders reporting that they have experienced fewer conflicts since the establishment of the perimeter. Despite the low frequency of conflicts and most respondents believing that it is unlikely they would lose access to their land, over half of beneficiaries still worry about this possibility. Among farmers who believe that they might lose their land or are worried about it, most think that either a family member or the government is most likely to take over their plot if it is lost (about 28 and 36 percent, respectively).[11] Just over 10 percent of farmers believe that the WUA could take over their plot.

Table II.9. Di perimeter land tenure outcomes

	Percentage
Output: Formal land documentation	
Has formal land tenure documentation	78.0%
Short-term outcome: Perceptions of land tenure security	
Worried about loss of land access in next five years: Not at all	50.3%

[11] The fear of government expropriation is common in Burkina Faso, where three-fifths of those who feel insecure cite government expropriation as a source of their feeling of insecurity (Prindex 2020). Relative to those high levels, Di perimeter beneficiaries are comparatively less worried about government expropriation.

	Percentage
Worried about loss of land access in next five years: A little	33.9%
Worried about loss of land access in next five years: A lot	15.8%
Perceived likelihood of loss of land access in next five years: Not at all likely	85.3%
Perceived likelihood of loss of land access in next five years: A little	8.6%
Perceived likelihood of loss of land access in next five years: Very likely	6.1%
Most likely to take over if plot lost[a]	
Family member (not spouse)	23.5%
Government	38.0%
Previous owner or their family	3.5%
Owner (if plot is rented)	7.7%
WUA	13.8%
Rights associated with the land	
Right to bequeath land	75.9%
Right to sell land	27.7%
Right to let land	70.1%
Short-term outcome: Conflict	
Involved in land conflict on the perimeter	1.9%
Short-term outcome: Land rental and sales	
Rented out land (any season)	6.9%
Sold lease or title for Di plot	0.0%
Short-term outcome: Access to credit	
Applied for a loan with bank or microfinance institution in last two years	21.7%
If applied for a loan, used Di perimeter plot as collateral	14.2%
Long-term outcome: Land investment and use of inputs	
Any land investment in last two years	10.1%
Value of land investment in the last two years (excluding unpaid household labor) (FCFA)	25,900
Total value of inputs (FCFA per hectare)	616,000
Sample size	**1,836**

Source: Endline survey (2020).

[a] Includes only respondents to the in-person survey. Land investments refer to investments with a payoff horizon of several seasons, while agricultural inputs boost yields and profits for one or a few seasons at most.

Most farmers understand that bequeathing or letting their plots is an option, but only about one-quarter believe that they have the right to sell their land or leasehold. In terms of the rights associated with the Di perimeter, not all households are fully aware of their land transfer rights. More than three-fourths understand that they have the right to bequeath their land, and over two-thirds recognize their

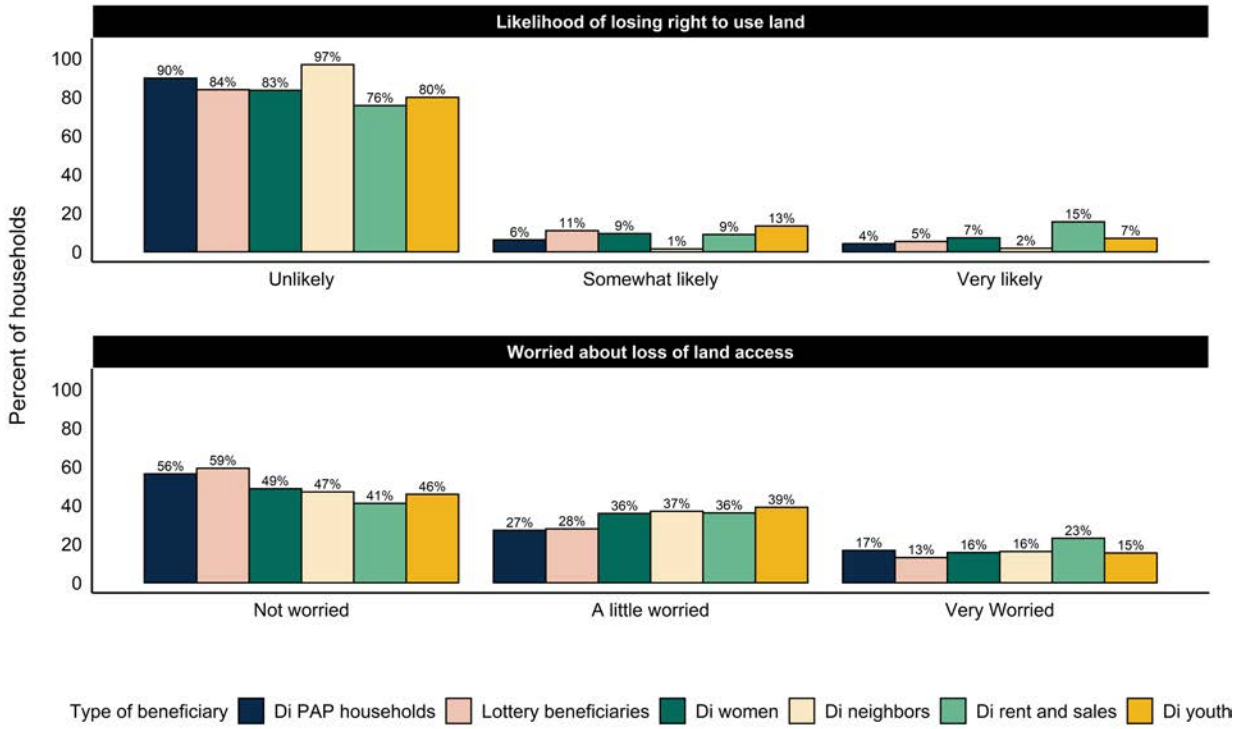
right to rent the land, but only about one-quarter know that they have the right to sell their land or leasehold.[12]

Levels of collateralized credit are similar to those at interim, but rates of land investment are slightly higher than in the interim survey. Of the 22 percent of farmers who applied for a loan since the interim survey, 14 percent have used their land on the Di perimeter as collateral for a loan. (Collateral is not a requirement for an agricultural loan in Burkina Faso.) During the past two years, since the interim survey, 1 in 10 farmers has made any land investments with a longer-term, multi-season investment horizon, and those farmers spent less on long-term land investments relative to the value of annual investments in agricultural inputs. This pattern suggests that any effect of land tenure security on long-term land investment would be small, at least within the short period of this evaluation. In fact, in an analysis of the drivers of long-term land investment, we did not find evidence that increased perceptions of land tenure security drive investment (see Chapter III for this analysis).

Perceptions of land security did not vary substantially across beneficiary types. The perceived likelihood of losing land in the next five years is somewhat higher among those who rented or bought land on the perimeter as opposed to other groups; 22 percent of farmers believe that it is somewhat or very likely that they could lose their land as compared with 17 percent among youth groups, 15 percent among women's groups and lottery beneficiaries, and fewer than 10 percent among Di neighbors and PAPs (Figure II.7). Even though—except for renters—few farmers perceive that the risk of losing their land is high, a significantly larger number of farmers worry about the possibility of losing land. The percentage of farmers who worry about losing land at least a little bit ranges from 40 percent of lottery beneficiaries to 56 percent of those with rented or purchased land. The fact that, in this context, perceptions of land security for women's and youth groups are as strong as for other beneficiaries is a key finding, as perceptions of land tenure security typically differ by gender and other characteristics.

[12] The leases provided to Di beneficiaries for land that was not received in compensation specify that the permission to rent out land is granted after a written notification of the intent to rent out land, unless the Ministry of Finance objects in writing within a month of receiving the notification (Burkina Faso Ministry of Finance). However, some stakeholders believe that Di beneficiaries do not have the right to rent land. Di PAPs have full ownership to rent and sell land they received in compensation.

Figure II.7. Di perimeter perception of land tenure, by type of beneficiary (percentage)



RQ4. Have prices for focus crops changed since completion of the perimeter?

Key findings

Onion prices are reported to be lower due to the construction of the perimeter. They vary between years and by farmer and fluctuate within seasons. Many farmers on the perimeter struggle to plant onions earlier or to store them until after the peak harvest season when supply is low in order to sell at higher prices early or late in the season. Poor roads and lack of market information since MIS became defunct hurt farmers' positions in onion price negotiations with buyers. Recently, onion prices had recovered somewhat after a low in 2017 but they remain lower than they were before the perimeter construction.

In our evaluation design, we planned to use information from the MIS created as part of ADP to implement a difference-in-differences analysis of market prices, comparing price trends in markets near the Di perimeter with those further away. However, this data source was not available for our analysis. Instead, we used the interim qualitative data, as well as reports from the Ministry of Agriculture and Hydro-agricultural developments on vegetable production on the Di perimeter (available for the years 2014–2019), to shed some light on the changes in onion prices, in particular, which drive the results we observe in terms of overall profits and the economic analysis.

Onion prices are lower due to the construction of the perimeter. Stakeholders and PAP focus group discussion (FGD) participants during the interim data collection consistently reported that prices were lower due to the higher local supply and the poor state of the roads leading to the perimeter. Focus group members noted that onion prices fell to as low as 7,500 FCFA per bag of 120 kg in 2017, which is lower

than before the construction of the perimeter and lower than assumed in the CBA model. Data from the Ministry of Agriculture support these findings in the post-compact period; their reports show that annual price highs per bag of 120 kg dipped from 80,000 FCFA in 2015 to 65,000 FCFA in 2017, recovering somewhat to 75,000 FCFA in 2019 (price lows followed a similar pattern of dipping in 2017 and recovering in 2019) (Ministry of Agriculture 2020).

Market prices for onions fluctuate depending on various factors, including local supply and supply in competing areas. Onion prices differ by a factor of nearly 10 within each agricultural season. For example, in 2017 the highest price reported in these reports was 65,000 FCFA and the lowest was 7,500 FCFA per bag of 120 kg. Producers who can plant onions earlier and harvest at the very beginning of the season when supply is low in December sell at the highest prices. Onion prices steadily decrease as supply increases in the following months— prices are lowest in March and April, and they increase somewhat at the tail end of the season in May, giving an advantage to farmers who have the capability to preserve onions and the financial means to wait to collect profits until onion supply in the market decreases. Most FGD participants did not have the ability to preserve or store their onions until prices became more favorable and were obligated to sell as soon as they harvested. In addition to the availability of onions in the Sourou Valley, the supply of onions in other parts of Burkina Faso and the greater region including Niger also affects onion prices according to FGD participants.

"We agreed to sell my onions for 25,000 FCFA. But when they loaded my onions onto the truck together with that of other farmers, the buyers said that the truck won't move until we all agree to a lower price of 20,000 FCFA. And even negotiating for this price was difficult. They told us that even though normally in January the prices are good, they have already fallen before February. This year everyone sold their onions cheap... no one got the high prices of the beginning of the season. How can we pay the water fees in these conditions?" – Woman PAP FGD 2018

Poor quality of roads and lack of market information limit farmers' ability to secure favorable prices for onions. The poor quality of roads leading to the perimeter increases the time and cost of transportation and results in more produce damage in transit, reducing profitability for the intermediary, so buyers demand lower selling prices from the farmers. Poor roads also limit the farmers' ability to travel to markets where they could sell their produce at more favorable prices. Some FGD participants also noted that they were able to get better prices before 2017, when the MIS was providing information to farmers. The MIS allowed them to make market-based decisions at the time of planting and to be well informed to negotiate favorable prices for their produce. The combination of poor roads and limited access to market information gives farmers little leverage during price negotiations.

"Previously, they [the MIS] publicized everything so everyone was in the know. They also put pressure on one another to respect the prices, this worked well. Since they went away, we don't even know what the prices are anymore, so prices have fallen." – WUA leadership 2018

RQ5. What is the economic rate of return (ERR) of the Di perimeter?

Key findings

The estimated ERR is slightly negative and significantly below MCC's stated 12.5 percent threshold for investments for Burkina Faso at the time of the compact; it is also below the original ERR of 4.2 percent and the close-out ERR of 3.8 percent. The ERR on the Di perimeter is estimated to be between -0.7% and -2.4%, using baseline assumptions, or between -4.5% and -0.4% when we vary the assumption on the perimeter lifespan between the minimum and maximum suggested lifespans of 10 and 30 years. The ERR is lower than expected mainly because the area cultivated with onions and the per-hectare profits for onions were lower than expected, and the close-out ERR estimated that onions would account for about 87 percent of the total annual profit.

In this section, we conduct a cost-benefit analysis (CBA) of the Di perimeter to assess the extent to which the project's benefits are commensurate with its costs. To that end, we re-estimate the CBA model used by MCC to calculate the close-out ERR, but we update the CBA model's estimates of agricultural outcomes with estimates based on the final evaluations' quantitative analysis and then vary estimates of the lifespan based on our qualitative analysis.

a. Description of close-out ERR model

MCC uses CBA models to assess whether its projects are sound investments. The ERR is a summary statistic from the CBA model that reflects the economic merits of an investment. Conceptually, it is the discount rate at which the benefits of an intervention are exactly equal to its costs; a higher ERR implies relatively higher benefits and lower costs. MCC finalized the close-out CBA model for the Di perimeter on March 7, 2017 (MCC 2017). MCC's analysis computed the increase in agricultural profit for the land encompassed by the Di perimeter.

The MCC calculations are based, in part, on realized agricultural outcomes that APD collected as part of post-compact monitoring activities (see MCA-BF 2014c for the post-compact M&E plan). This information on agricultural outcomes includes the area planted and the agricultural yields for the primary crops grown in the Di perimeter—that is, maize, rice, cowpeas, onions, and tomatoes. Soya is a proxy for any other crops. Total production for a crop is calculated as the area planted with a crop multiplied by its average yield.

To estimate the value of the Di perimeter's agricultural production, the CBA model makes assumptions about post-harvest losses and prices. The model assumes that crop prices are fixed over time and across season and further assumes that losses vary by season but are fixed across time. Agricultural profits subtract the cost of inputs from the value of total production. The main costs are (1) labor costs for land preparation, weeding, and harvesting; (2) the costs of fertilizer, seeds, and pesticides; (3) post-harvest and marketing costs; and (4) contributions to the WUAs. The calculation assumes that the amounts of inputs differ across crops and dry and rainy seasons but that input prices remain constant across years and seasons.

The value of production had the perimeter not been built is based on a similar calculation that uses information from the pre-compact period on the area planted by crop, the quantities produced, the inputs used, the cost of inputs, and prices for crops.

Regarding program costs, MCC's CBA model takes into account direct costs, such as those associated with construction of the perimeter itself, and indirect costs, such as costs of design and supervision, costs related to environmental and social mitigation plans, and a share of compact administration and M&E costs. These costs do not include costs incurred by the post-compact entity APD after the close of the compact.[13] Total costs per hectare amount to US$ 39,626 when compact administration costs are excluded and US$ 44,944 when they are included.[14]

To estimate future agricultural profits, MCC uses the values for agricultural production from 2016 and assumes that prices for inputs and agricultural production remain stable and that long-term land productivity will equal about 90 percent of the 2016 value. MCC calculates an increase in agricultural profit from about 242,425 FCFA to a long-term value of 1,968,910 FCFA per hectare per year, resulting in an increase of 1,864,227 FCFA (about US$ 3,550) per hectare per year.[15] The period of analysis for the model is 25 years; the close-out ERR (including compact administration costs) is estimated to be 3.8 percent, while the initial ERR estimated before implementation was 4.2 percent.

The CBA model makes several implicit assumptions about benefit streams that we maintain in our recalculation of the ERR (we are not constructing a new CBA model). We list the assumptions in Table II.10.

Table II.10. Key assumptions of the CBA model

Assumption	Description
Project benefits stream to the agricultural profit derived from cultivating land on the perimeter	The CBA model does not include any project benefits that might accrue to persons who are not owners or cultivators of the land on the perimeter. For example, the model does not estimate the benefits to labor hired on the perimeter.
No spillovers from the additional production outside the perimeter	The CBA model does not include any spillovers—positive or negative—that could result from the additional production in the Di perimeter. For example, the interim report presents perceptions from stakeholders that prices for onions and tomatoes dropped as a result of additional production in the perimeter. This price decline could lead to a decline in prices for farmers in nearby perimeters and reduce their profits. The model also does not account for positive spillovers in the form of consumer surpluses if prices decrease further.
Step-wise reduction in productivity	The CBA model includes constant productivity in the first three years followed by a lower productivity that remains constant through the perimeter lifespan.
Model does not incorporate distortions	In the calculations, the CBA model does not incorporate market or policy distortions that might mean the prices and profits computed by us do not reflect shadow prices. Distortions could take the form of subsidies or taxes that would make fertilizer or transportation prices artificially inexpensive or expensive, respectively.

[13] As not all Di beneficiaries were trained by the end of the compact, the government of Burkina Faso committed to funding the training that occurred during the post-compact period. In addition, the government provided subsidies to CATG during a transition period. The inclusion of these costs would likely not substantially change either the overall cost of the perimeter or the ERR.

[14] We calculated the per hectare value based on the assumption that the total land area in the Di perimeter comprises 2,246 (MCA-BF 2014d). We note that the Atlas of Achievements computes a cost per hectare of $US37,554 , using the same total cost of the perimeter. This is a clerical error.

[15] We calculated these values by dividing total profits by 2,246 hectares.

b. Recalculation of ERR

The recalculation of the ERR relies on estimates of agricultural outcomes without the project and estimates of total cost from the close-out ERR as well as on agricultural outcomes under the project estimated during the final evaluation. We do not update the close-out CBA model's estimates on agricultural outcomes in the absence of the project because we do not have access to better information, as the baseline data do not include information on production of crops before the project. As a result, we determined that the information that guided the close-out ERR and that was based on the information used to calculate the ERR at baseline is likely the most reliable information we could use.

To provide updated estimates of the agricultural outcomes for the Di perimeter, we use estimates derived from our analysis. In view of the limitations we identified above with respect to the exclusive use of survey data, we set up two calculations based on two combinations of sources of information. The first recalculation uses survey information on agricultural outcomes for cultivated plots and information on hectares cultivated from the survey. The second recalculation uses information on agricultural outcomes estimated separately for each focus crop and information from the remote sensing crop-type maps. The second approach uses the information on the cropping patterns and the differential profitability of different crops, but the profit information relies on a smaller subset of households and exclusively on focus crops. We describe several other assumptions in Table II.11 below

Table II.11. Key assumptions of the reestimation

Assumption	Description
Non-respondents obtain the same agricultural outcomes as respondents	We recalculate the ERR using the average profit per hectare on the perimeter as estimated by our model, assuming that non-respondents obtain the same agricultural profits as respondents. This is a strong assumption when applied to new renters who have started renting out a plot since the interim survey, since we were not able to interview them.
Future profits are the same as those from the final evaluation	Profits remain constant at endline values for the remainder of the perimeter's lifespan. This includes the assumption that soil fertility remains constant.
Maintenance costs remain the same going forward	We assume that maintenance costs remain constant and are sufficient to maintain the perimeter at its current level of functioning to the end of the lifespan, at which point it suddenly fails.
The benchmark estimate assumes the remaining perimeter lifespan to be 18 years as in the CBA model	Given that the remaining lifespan estimates vary quite widely from 10 to 30 years and the interim lifespan estimates implied a remaining lifespan of 18 to 23 years, we assume a remaining lifespan of 18 years as our benchmark and vary the lifespan around that in sensitivity analyses.

The ERR of the Di perimeter is slightly negative and substantially lower than the close-out ERR, with a large range in values depending on the lifespan of the perimeter (Table II.12). We present the close-out ERR, the estimated ERR using survey data alone, as well as the ERR using a combination of estimates of cultivated area from remote sensing and the crop specific profits per hectare in columns 1-3 of Table II.12, respectively. The estimated ERR of the Di perimeter is -0.7 percent when using survey information alone, and -2.4% when using the estimated cultivation area based on remote sensing. Overall, the undiscounted benefits are slightly exceeded by the undiscounted costs. When deviating from the benchmark remaining perimeter lifespan of 18 years, the ERR varies substantially under different scenarios. If the perimeter were to function for another 10 years with the cultivation pattern identified through the crop-type mask and then become fully non-functional, the estimated ERR would be -4.5%. With a 30-year lifespan including the year 2020, the ERR would be -0.4%.

Table II.12. ERR estimates of the ADP

MCC Estimates		Re-estimated ERR			
Original ERR	Close-out ERR	Plot-level survey data and cropland mask	Plot by crop level survey data and crop-type mask	10-year lifespan	30-year lifespan
4.2%	3.8%	-0.7%	-2.4%	-4.5%	-0.4%

Source: MCC(2016); Endline Survey (2020).

The primary reason for the lower than expected ERR is the much lower than projected total value from onion production on the perimeter. The close-out ERR estimated that about 87 percent of the total annual profit across both seasons and all perimeter plots would be earned from onion production on polyculture plots. However, our total estimate of the value of onion production on the perimeter is about 60 percent lower than in the CBA model. This is due to a lower cultivation area for this crop, which remains the most profitable on a per-hectare basis. The ERR assumption is that in the dry season slightly more than 80 percent of cultivated land would be planted with onions. Both the analysis using survey data and the remote sensing analysis estimate the area cultivated to be 14 and 23 percentage points lower than this projection. Further details about crop-specific profits and areas planted in both the close-out and evaluation-based CBA models are presented in Appendix Table A.7.

C. Summary of findings

Our key findings regarding the Di perimeter evaluation are summarized in Table II.13.

Table II.13. Key findings for the Di perimeter evaluation

Research question	Findings
1. What is the total area planted, average yield per hectare, total production, and total profit by focus crop? How do agricultural outcomes differ for different beneficiary groups?	**Almost all land on the perimeter is cultivated in both seasons but yields and profits per hectare are lower than anticipated across all types of beneficiaries.** • Land on the perimeter is extensively farmed in both the dry and rainy seasons with over 95 and 99 percent cultivation in the dry and rainy seasons, respectively. During the rainy season, the area cultivated in the Di perimeter is more than twice as large as at baseline. The land cultivated during the dry season constitutes a 20-fold increase. • Based on crop-cut information, yields for all crops meet or exceed program targets, while survey-based estimates are much lower and fall short of program targets for many crops. • Dry season profits per hectare were more than 10 times higher than rainy season profits, with the highest profits for onions and the lowest for maize. Profits do not meet expected profits under the ERR. • Di neighbors and women's groups achieve the highest profits per hectare over the course of the year, while Di PAP households earn the lowest. **Survey estimates of yields and area cultivated differ substantially from remotely sensed estimates.** • The estimate of area and crops cultivated based on survey data performs poorly compared with remote sensing data, likely due to the switch to telephone surveys and our inability to follow renters. • For all crops, total and per-hectare yield estimates from survey data are lower than estimates based on crop-cut measurements.

Research question	Findings
2. How has PAP well-being changed?	**PAPs are better off than at the time of the interim evaluation, and a large majority report being better off than before the construction of the perimeter.** • Nearly three quarters of PAPs reported being better off now than before perimeter construction in terms of agricultural profits, while nine out of ten reported experiencing higher food security. • Agricultural profits and household incomes, as estimated from our surveys, increased for PAPs between interim and endline.
3. What are project results in terms of land tenure security, land conflict, and land markets?	**Project activities have led to high levels of land tenure security and an active rental market, though some confusion about land transfer rights remains.** • Farmers generally feel secure about their tenure on the perimeter. About three-quarters possess formal land documents, and about 85 percent of all farmers believe that it is very unlikely that they would lose access to their land within the next five years. Very few farmers reported any land conflicts. • About seven percent of farmers have rented out land. • As in the interim survey, not all households are fully aware of their land transfer rights. Most understand their right to bequeath or rent their land, but only about one-quarter know that they have the right to sell their land or leasehold. • As in the interim survey, more than one in five farmers have applied for credit, and 14 percent of those used land as collateral for credit. Rates of land investments are slightly higher than in the interim survey. • Perceptions of land security do not vary by type of beneficiary.
4. Have prices for focus crops changed since completion of the perimeter?	**Onion prices are reported to have decreased due to the construction of the perimeter.** Many farmers on the perimeter struggle to plant onions early in the season or to store them until after the peak harvest season and to sell when supply is low and prices high. Poor roads and lack of market information since MIS became defunct hurt farmers' positions in onion price negotiations with buyers. However, recently onion prices had recovered somewhat after a low in 2017—the reference period for the interim survey—but they remain lower than before the perimeter construction.
5. What is the economic rate of return of the Di perimeter?	**The estimated ERR is slightly negative and significantly below 12.5 percent, which was MCC's stated Burkina Faso-specific threshold for investments at the time of the compact, and also below the original ERR of 4.2 percent and the close-out ERR of 3.8 percent.** • The economic rate of return on the Di perimeter is estimated to be between -0.7% and -2. 4%. • Varying the assumption on the perimeter lifespan between the minimum and maximum suggested lifespans of 10 and 30 years results in an ERR between -4.5% and -0.4%.

This page has been left blank for double-sided copying.

III. Di Lottery Evaluation

A. Background

As discussed in Chapter I, approximately 30 percent of the land in the Di perimeter was distributed to selected eligible applicants from the Boucle du Mouhoun region via a public lottery—the Di Lottery. The Di Lottery beneficiary selection process was a multi-stage process (described in detail in Ksoll et al. 2018). Applicants who met certain requirements and scored highly on a set of scoring criteria—including location of residence, available household members for agriculture, and experience in irrigated agriculture—were allowed to participate in the Di Lottery. The winners were then selected from among participants in a public lottery on February 25, 2014 to receive either a plot suitable for growing rice or a polyculture plot—primarily used to grow maize in the rainy season and onions and tomatoes in the dry season. The selection of participants in the lottery was designed to ensure that—with high probability—at least 20 percent of beneficiaries were female.

Table III.1 provides a summary of the Di Lottery, including its target population, program implementers, and all forms of assistance offered to lottery winners—including land, leaseholds, and agricultural assistance.

Table III.1. Summary information on the Di Lottery

Objective	Distribute land in the Di perimeter in a transparent manner to: (1) Select applicants who would likely put the land on the perimeter to good use (2) Meet distributional criteria with respect to gender
Target population	Applicants in the Boucle du Mouhoun region who meet certain eligibility criteria and who score highly on a set of scoring indicators
Benefit	• Access to land on the Di perimeter as leasehold, with beneficiaries randomly receiving either land suitable for polyculture or rice cultivation • Leasehold documents • Training in agricultural technologies for irrigated land • Starter kits (land preparation, materials, and inputs)
Planned timeline	Lottery beneficiaries were meant to receive access to land at completion of the perimeter, and receive two years of support and training during the compact.

B. Final evaluation findings

The evaluation of the Di Lottery aims to understand the impacts of receiving land on the perimeter on agricultural outcomes, perceptions of land tenure security, long-term investment in the land, and household income. We present results by research question.

RQ1. What impact does winning the Di Lottery have on agricultural practices, production, total agricultural income, and overall household income?

Key findings

Lottery beneficiaries cultivated more land than non-beneficiaries, but they do not cultivate all of the land they received on the perimeter themselves. Among those who cultivated land during the dry season, treatment and control group households generally grew the same types of crops and employed most agricultural practices to the same extent. However, lottery beneficiaries were more likely to grow rice and to hire labor than non-beneficiaries.

As a result of this access to land, Di Lottery beneficiaries made significantly more sales, obtained higher agricultural profits, earned higher agricultural incomes leading to significantly higher household incomes.

Winning the lottery has a significant impact on amount of land cultivated, but lottery winners cultivate significantly less land on the perimeter than they received. During the 2018-2019 dry season, Di Lottery winners cultivated around half a hectare more land than control group households (Table III.5; we present results for the rainy season, which focuses on food crop consumption, in Appendix Table A.3.). This is significantly less than the additional irrigated land they received in the lottery which was one hectare of land for recipients of polyculture plots and two hectares for rice plots. During the interim survey which covered the 2017 season, households cultivated about 0.4 more hectares of land (see the interim report for details about interim agricultural practices. Among farmers who cultivated any land in the dry season, there are not major differences in the types of crops grown between treated and control farmers; treated farmers grow more of every crop, and the distribution of crops grown is approximately the same for all farmers. Onions were the most common in both groups, followed by rice, tomatoes, and maize. The exception is rice; a larger share of treated farmers who cultivated land during the dry season grew rice, likely because they were given plots designated for rice cultivation.

Lottery winners are more likely than non-beneficiaries to hire labor; three-fourths of beneficiaries hire labor compared with two-thirds of non-beneficiaries. Use of agricultural inputs and improved agricultural practices such as fertilizers and agricultural equipment do not differ between treatment and control groups.

Table III.2. Land access, crop cultivation, and agricultural practices for Di Lottery applicants and their households (dry season)

Outcome	Treatment group mean	Control group mean	Estimated difference	*p*-value of difference
Irrigates land (percentage)[a]	88%	59%	29%	0.00
Cultivates any land on the Di perimeter (percentage)	79%	20%	58%	0.00
Total area cultivated-dry season (hectares)	0.89	0.41	0.48	0.00
Crops cultivated during dry season (percentage):				
Tomatoes	24%	15%	9%	0.00
Onions	69%	44%	25%	0.00
Maize	9%	3%	6%	0.00
Rice	31%	15%	16%	0.00

Outcome	Treatment group mean	Control group mean	Estimated difference	*p*-value of difference
Use of agricultural inputs during dry season (percentage):				
Chemical fertilizer	100%	99%	1%	0.37
Organic fertilizer	17%	19%	-2%	0.48
Phytosanitary products	96%	94%	2%	0.28
Improved seeds	83%	82%	2%	0.60
Hired labor during dry season (any plot) (percentage)	75%	66%	9%	0.02
Number of different types of modern agricultural equipment used in the dry season	4.3	4.2	0.1	0.61
Cost of inputs (1,000 FCFA) [a]				
Chemical fertilizer	99,412	98,017	1,394	0.92
Organic fertilizer	2,757	1,832	925	0.48
Phytosanitary products	8,064	9,064	-1,000	0.55
Improved seeds	32,677	35,643	-2,966	0.63
Hired labor	27,222	24,560	2,662	0.65
Sample size: Lottery participants	418	783		
Sample size: Respondents to in-person survey	166	345		

Source: Endline Survey (2020).

Note: [a] Information for this indicator is only available for all plots for the in-person survey.

Winning the lottery has a significant impact on productivity and income. Lottery winners' total annual agricultural sales revenue—or total sales before accounting for costs—during the 2018-2019 seasons was almost 75 percent higher than that of the control group (Table III.3). The impact on total annual profits—or sales revenue minus costs—is substantial at 464,000 FCFA (around US$840). However, the impact on profits is smaller than the impact on sales because lottery beneficiaries farm more intensively on the Di perimeter, leading to higher input costs. The impact on agricultural income and total household income are slightly smaller than the impacts on agricultural profits. Relative to the interim evaluation, the impact on all three outcomes is about 50 percent higher.

Table III.3. Impact on sales, profits and income (in 1,000 FCFAs)

Outcome	Treatment group mean	Control group mean	Estimated difference	*p*-value of difference
Value of agricultural production	2,057	1,181	876	0.00
Total cost of inputs	892	469	423	0.00
Agricultural profits[a]	1,178	714	464	0.00
Agricultural income[a]	1,125	683	441	0.00
Total household income[a]	1,254	857	397	0.00
Sample size (Di Lottery participants)	**449**	**783**		

Source: Endline Survey (2020).

Note: Agricultural input cost includes rental cost of machinery and WUA fees, in addition to costs of inputs and labor. Agricultural income includes agricultural profit, income from agricultural land rental, and income and losses from agricultural employment and transformation of agricultural products. Household income includes income from all other sources.

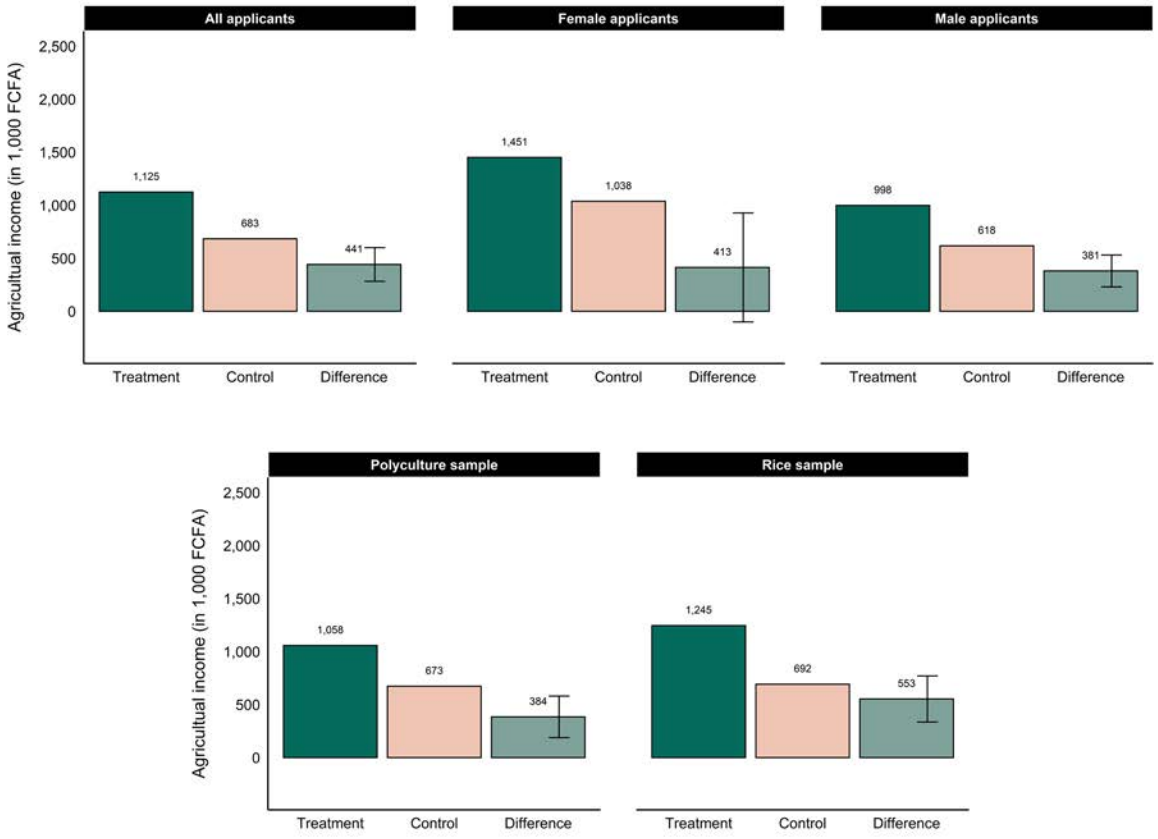
Multiple imputation used to impute plot level profits and household member other sources for plot and household members for which detailed information was not collected.

[a] Primary outcomes.

FCFA = Franc CFA.

Winning the lottery increased agricultural income and household income for all types of beneficiaries, but the increase is not statistically significant for female applicants (Figures III.1 and III.2). In both figures, confidence intervals are shown for the difference between treated and control farmers; a confidence interval that includes zero indicates that the difference for that subgroup is not statistically significant. Winning the lottery increased both agricultural income and household income by between 340,000 and 550,000 FCFA for all lottery beneficiaries and for all sub-groups except for female farmers; the point estimate for the increase in agricultural income for female farmers was similar to that of other farmers for agricultural income, though the impact was not significant—likely due to the much smaller sample size and less precisely estimated impact.

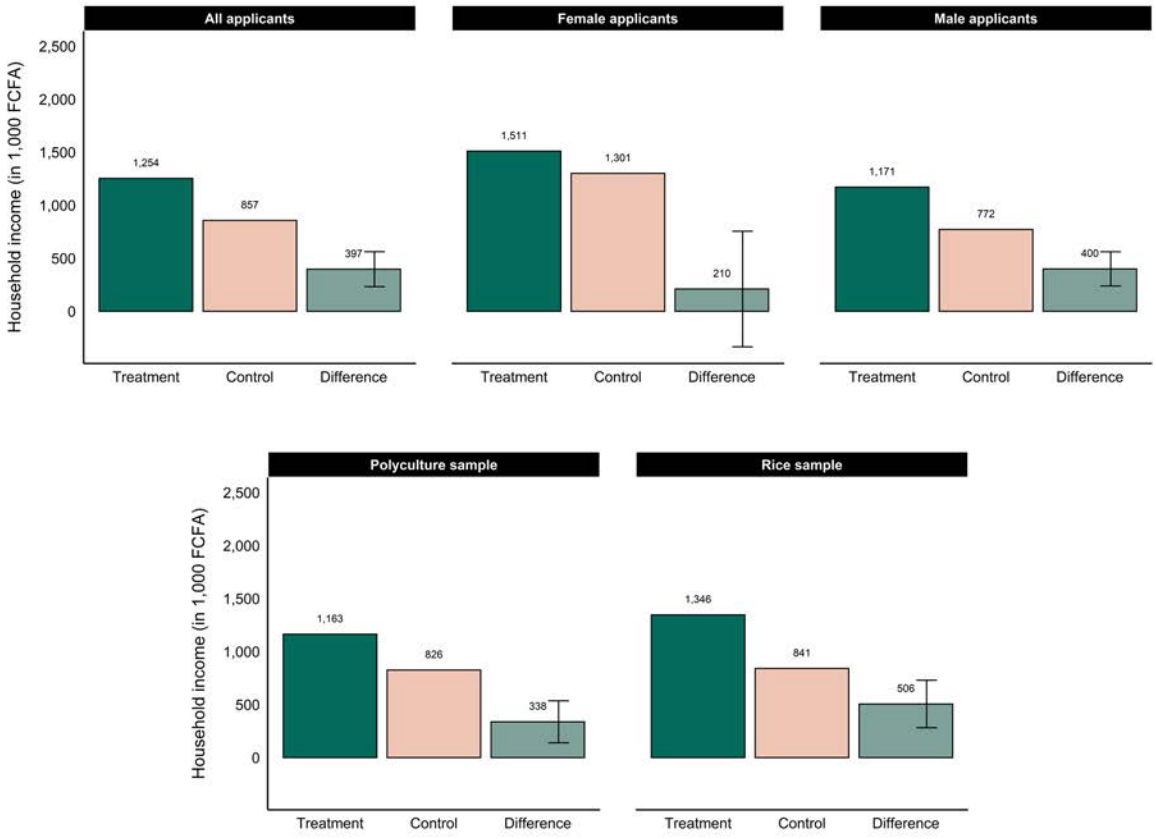
Figure III.1. Impacts on agricultural income, by gender and by land suitability



Source: Endline Survey (2020).

Note: Polyculture sample includes beneficiaries of polyculture plots (treatment) as well as non-beneficiaries who would have accepted a polyculture plot (control) but excludes lottery participants who would not have accepted a polyculture plot. Rice sample includes beneficiaries of rice plots as well as non-beneficiaries who would have accepted a rice plot (control) but excludes those who would not have accepted a rice plot.

Figure III.2. Impacts on household income, by gender and by land suitability



Source: Endline Survey (2020).

Note: Polyculture sample includes beneficiaries of polyculture plots (treatment) as well as non-beneficiaries who would have accepted a polyculture plot (control) but excludes lottery participants who would not have accepted a polyculture plot. Rice sample includes beneficiaries of rice plots as well as non-beneficiaries who would have accepted a rice plot (control) but excludes those who would not have accepted a rice plot.

RQ2. What are the impacts of the lottery on long-term land tenure security (perception, transfer rights, land conflicts), land markets, and investment?

Key findings

As anticipated, beneficiaries of the Di Lottery are four to six times more likely than non-recipients to have formal land documentation. However, many farmers are not aware of the type of land documentation they hold, and confusion about documentation has increased since interim.

Perceptions of land tenure security have increased since interim data collection, and both beneficiaries and non-beneficiaries report high levels of land tenure security. The two groups have different sources of perceived land insecurity, with lottery beneficiaries being more concerned about losing their land to formal institutions and non-beneficiaries more concerned about previous landowners taking over their land. There were few meaningful differences in terms of land tenure security between farmers allocated rice and polyculture plots, but the impact of the lottery on male farmers was greater than on female farmers for some measures of land tenure security. Land conflicts are very rare among all farmers in both the treatment and control group.

Land on the Di perimeter is more likely to be part of formal transactions than off-perimeter land, with lottery beneficiaries more likely than non-beneficiaries to let land, apply for a loan, and use land as collateral. Lottery beneficiaries are also approximately twice as likely as non-beneficiaries to have made physical investments in their land, with one in eight beneficiaries reporting at endline having made long-term physical investments in their land.

Understanding the possible link between the different components of the program and agricultural incomes requires analysis of the causal pathways. The impacts of the Di Lottery on long-term land investment outcomes appear to be operating through the direct components of the program, including irrigated land, land documentation, and agricultural training, rather than through increased perceptions of land tenure security.

Project beneficiaries continue to report high rates of formal land documents, but confusion about the type of documentation has increased. As anticipated in the program logic and because it was a project output, a substantial majority of the beneficiaries of the Di Lottery reported possessing formal land documents, with beneficiaries being more than four times more likely than non-recipients to have any formal land documentation and six times more likely than non-recipients to have a title or a lease (Table III.4).[16] The confusion about the type of land tenure and land documentation Di Lottery beneficiaries believe they have has increased since interim. At interim, more than half of beneficiaries said they had lease documents—formal leasehold documents that assert their right to the plot—while one-quarter believed they had a land title that would confer full ownership of the plot. At endline, the number of beneficiaries claiming to have lease documents dropped to one-third while half of beneficiaries now claim to possess land titles. This apparent increase in confusion over the types of land documents people have may be because leases are an unfamiliar concept, and with the government unlikely to revoke leases, farmers have become more likely to say that their lease is a land title. Because of low literacy levels, it is also possible that many farmers simply do not understand the content of their documents and are unable to differentiate between a lease and a title.

[16] A significant number of control group farmers who hold formal land documents have land on the perimeter. Of the control group farmers who claim to have formal land documentation, 44 percent have land on the perimeter, compared with only 15 percent of those who don't have land documentation.

Slightly more lottery beneficiaries than non-beneficiaries reported having rural land possession certificates—which were not distributed in the Di perimeter—while the same number have written notes from customary process, and almost none in either group have written contract with landowner (all of these types of land documentation account for only a very small number of farmers). There were no significant differences in terms of land documentation by gender or by the type of plot (Appendix Table A.4.). A recent World Bank review of land tenure in Burkina Faso found that women have a very limited access to land (World Bank 2020). In 2010, 24 percent of women indicated that they had a joint possession right over their farmland and 12 percent had documentation in their own name alone. It is a key project output that men and women are equally likely to possess formal documents.

Table III.4. Program effects of winning the Di Lottery on land documentation

	Interim			Endline		
Dependent variable	**Treatment**	**Control**	***p* value**	**Treatment**	**Control**	***p* value**
Output: Formal land documentation						
Has any formal land documentation	97%	9%	<0.01	87%	20%	<0.01
Has rural land possession certificate	11%	6%	<0.01	7%	4%	0.03
Has land title	23%	2%	<0.01	50%	9%	<0.01
Has lease document	62%	1%	<0.01	34%	4%	<0.01
Has written contract with landowner	<1%	<1%	0.99	<1%	1%	0.95
Has written notes from customary process (Procès Verbal de l'Arbre à Palabre)	<1%	<1%	0.29	5%	4%	0.67
Sample size plots	**410**	**710**		**449**	**783**	

Source: Interim (2016) and Endline (2020) Surveys.

Note: Analysis estimates impact on land documentation for lottery winners for the Di perimeter plot with land documentation for plots not on the Di perimeter for lottery controls, accounting for preference strata.

A rural land possession certificate is a document granting its holder a long-term right to possess and use a plot of land; it provides formal legal recognition of a customary land right (*attestation de possession foncière rurale* in French).

Most respondents in both the treatment and control groups perceive their land tenure to be secure, but one in seven farmers in both groups still report being very worried about losing their land. At interim, treatment group farmers reported greater land tenure security; they were 20 percent more likely to report that they were not at all worried about losing their land and 25 percent less likely to report that they were very worried about losing their land than control group farmers (Table III.5). At endline, however, beneficiaries and non-beneficiaries report similar levels of worry about losing land access, showing a slight increase in land tenure security for control group farmers and a slight decrease in land tenure security for treatment group farmers between midline and endline. Treatment group farmers are slightly less likely than control group farmers to think it is very likely that they would lose their land in the next five years. A bigger shift occurred in both groups between the share reporting being very worried about losing their land and those reporting being a little worried; around one-fourth of respondents in both groups reported being very worried about losing their land at midline; this share shifts to one-seventh of respondents by endline. The similar levels of land tenure security between treatment and control groups

suggests that farmers in this area, regardless of whether they won the lottery, feel more secure in their land than farmers in the country as a whole; according to the Prindex report, only 59 percent of people in rural areas feel secure in their land (Prindex 2020). Across both groups, four-fifths think loss of land access in the next five years is not at all likely. This may be because conflicts are very rare overall and equally infrequent among beneficiary and control group members, as was found at interim.

While levels of perceived insecurity are similar for beneficiaries and non-beneficiaries, the sources of perceived insecurity differ. Beneficiaries and non-beneficiaries are equally worried about the possibility of losing their land, but their expectations differ in terms of who they think will take over their land if they lose it. Lottery beneficiaries are more concerned than non-beneficiaries about losing their land to formal institutions, such as the government or the WUAs. One-fourth and one-fifth of lottery beneficiaries, respectively, think that the government or the WUA is the most likely to take over their land if it is lost, compared with 14 and 2 percent, respectively, of non-beneficiaries. Even lottery beneficiaries are still much less likely than the general population in Burkina Faso to be worried about the government seizing their land; this share is 60 percent of those living in rural areas according to the Prindex report (Prindex 2020). One-fourth of non-beneficiaries, on the other hand, think that the previous landowner will take over their land, compared with only 8 percent of beneficiaries. Approximately one-fourth of both beneficiaries and non-beneficiaries think that a family member is the most likely to take over their land if it is lost; this share is slightly lower than the one-third reported in the Prindex report who cite disagreements with family as the reason for land insecurity (Prindex 2020). These differences likely stem from the formality of land tenure rights. Beneficiaries, who are more likely to have formal rights, are more likely to lose their land in a formal process to the government or to the WUA; perimeter bylaws allow the WUA and other perimeter authorities to take land from beneficiaries if they do not pay their fees or adhere to other bylaws.

Winning the lottery did not affect perceptions of one's ability to bequeath or sell land, but beneficiaries were more likely than non-beneficiaries to believe they can let land. Approximately 80 percent of members of both groups believe that they can bequeath land—for both groups this marks an increase from interim, when non-beneficiaries were more likely than beneficiaries to believe they could bequeath land. At interim, beneficiaries were more likely than non-beneficiaries to believe they could sell land, but by endline there was no difference between the groups. On the other hand, non-beneficiaries were more likely than beneficiaries at interim to believe they could let land (46 and 38 percent, respectively); by endline, the share of both groups believing they could let land had increased, but more so for beneficiaries (72 percent compared with 59 percent).

Beneficiaries are more engaged in the land rental market and are more likely to both apply for credit and use their land as collateral in loan applications. Unsurprisingly given their higher likelihood of believing they have the right to let land, lottery beneficiaries were much more likely to do so: 14 percent let land in any season, while only 2 percent in the control group do so. Both shares are increases from interim, when 8 percent of beneficiaries and no members of the control group let land. Lottery recipients are also more likely to have applied for a loan (22 percent versus 14 percent)and much more likely to use land as collateral (14 percent versus 2 percent). Among beneficiaries, farmers with polyculture plots were five times more likely than farmers with rice plots to use their land as collateral for loans, likely due to the higher earnings potential of polyculture plots. Interestingly, non-beneficiaries were more likely than beneficiaries to have applied for a loan at interim; the share of beneficiaries who have applied for a loan did not change between interim and endline, while the share of non-beneficiaries who

have done so decreased by half. These findings suggest that land on the Di perimeter plays a larger role in formal transactions (land rental and collateralized credit) than land outside the perimeter.

Table III.5. Impact of winning the Di Lottery on short-term land tenure outcomes

	Interim			Endline		
Dependent variable	**Treatment**	**Control**	***p*-value**	**Treatment**	**Control**	***p*-value**
Short-term outcomes: Perception of land tenure security and transfer rights						
Worried about loss of land access in next 5 years: not at all	63%	52%	<0.01	55%	58%	0.30
Worried about loss of land access in next 5 years: a little	15%	19%	0.16	30%	28%	0.47
Worried about loss of land access in next 5 years: a lot	22%	29%	0.03	16%	14%	0.57
Perceived likelihood of loss of land access in next 5 years: not at all likely				82%	79%	0.36
Perceived likelihood of loss of land access in next 5 years: a little				11%	11%	0.66
Perceived likelihood of loss of land access in next 5 years: very likely				7%	10%	0.07
Most likely to take over if plot lost						
Family member (not spouse)				22%	28%	0.26
Government				23%	14%	0.07
Previous owner or their family				8%	24%	<0.01
Owner (if plot is rented)				13%	11%	0.63
WUA				20%	2%	<0.01
Rights associated with the land						
Right to bequeath land (with or without external approval)	37%	54%	<0.01	78%	80%	0.40
Right to sell land (with or without external approval)	22%	9%	<0.01	22%	25%	0.17
Right to let land (with or without external approval)	38%	46%	0.04	72%	59%	<0.01
Not worried about losing land after divorce				86%	90%	0.28
Not worried about losing land after spousal death				85%	88%	0.42
Short-term outcome: Conflict						
Involved in land conflict	2%	3%	0.12	1%	2%	0.13
Short-term outcome: Land rental						
Rents out land in any season	6%	<1%	<0.01	14%	2%	<0.01
Rents out land in dry season	5%	<1%	<0.01	11%	1%	<0.01

Dependent variable	Interim			Endline		
	Treatment	Control	*p*-value	Treatment	Control	*p*-value
Rents out land in rainy season	4%	<1%	<0.01	9%	1%	<0.01
Short-term outcome: Access to credit						
Applied for a loan with bank or microfinance institution in past three years	23%	27%	0.09	22%	13%	<0.01
Used plot of land as collateral	18%	2%	<0.01	14%	2%	0.01
Sample size plots	540	1322		536	1346	
Sample size Di Lottery applicant households	393	1114		340	666	

Source: Interim (2017) and Endline (2020) Surveys.

Note: Estimates account for preference strata. Questions on 1) the likelihood of losing land and 2) the identity of the person most likely to take over land, 3) worry about losing land after divorce, and 4) losing access to land after spousal death, were not asked in the interim survey.

The impacts of the project on some measures of land tenure security are stronger for male farmers than women farmers. Disaggregating by gender, the lottery appears to have increased perceptions of land tenure security for men but not for women. Fewer than half as many male beneficiaries as non-beneficiaries report that it is very likely that they would lose their land in the next five years, whereas women in the treatment group are six percentage points more likely than those in the control group to report that it is very likely that they would lose their land (Table III.6; full results for the final data collection disaggregated by gender in Appendix Table A.5.). Among lottery beneficiaries, both men and women reported similar levels of land tenure security along most measures; this result is similar to findings from the Prindex report, which noted the same share of men and women across the country (not disaggregated by rural and urban areas) reported land insecurity (Prindex 2020). Men are more likely than women to believe they have the right to sell their land and are also more likely to rent out their land; the lottery increased the likelihood of renting out land for men, but slightly decreased the likelihood of renting out land for women. Women are more likely than men to be worried about losing their land in the event of divorce or the death of a spouse.

Farmers who were allocated different types of land reported similar levels of worry about the possibility of losing their land, but they reported some differences in terms of the source of insecurity (Appendix Table A.5). Polyculture farmers were more likely than rice farmers to think that a family member may take over their plot or that the government may seize the land, while rice farmers were more likely to think that the owner or previous owner may ask them to leave.

Table III.6. Gender differences in program effects on perceptions of land tenure

Dependent variable	Men		Women		*p*-value on difference
	Effect size (Men)	*p*-value	Effect size (Women)	*p*-value	
Short-term outcomes: Perception of land tenure security and transfer rights					
Worried about loss of land access in next 5 years: not at all	0.00	0.95	-0.07	0.37	0.37
Worried about loss of land access in next 5 years: a little	0.03	0.37	-0.04	0.33	0.33
Worried about loss of land access in next 5 years: a lot	-0.03	0.19	0.11	0.03	0.03
Perceived likelihood of loss of land access in next 5 years: not at all likely	0.05	0.08	-0.02	0.26	0.26
Perceived likelihood of loss of land access in next 5 years: a little	0.01	0.52	-0.03	0.32	0.32
Perceived likelihood of loss of land access in next 5 years: very likely	-0.06	0.00	0.06	0.02	0.02
Short-term outcome: Land rental					
Rents out land in any season	0.13	0.00	0.07	0.10	0.10
Rents out land in dry season	0.12	0.00	0.06	0.16	0.16
Rents out land in rainy season	0.09	0.00	0.02	0.02	0.02
Sample size plots	**1379**		**289**		

Source: Endline (2020) Survey.

Note: Estimates account for preference strata.

Winning the lottery appears to have increased farmers' investment in their land, with one in eight beneficiaries reporting at endline having made long-term physical investments in their land. Beneficiaries are approximately twice as likely as non-beneficiaries to have made physical investments in their land (Table III.7). The share of both beneficiaries and non-beneficiaries who have made investments has increased somewhat since interim data collection, and the difference between the two groups remains approximately the same. Most of the investment they have made is in planting trees: 7 percent of beneficiaries planted trees, while only 2 percent of non-beneficiaries did so. Far fewer farmers invested in fencing, irrigation, or landscaping in either group. Men and women were equally likely in both the treatment and control group to have made investments in their land.

Table III.7. Impact of winning the Di Lottery on long-term land outcomes

Dependent variable	Interim			Endline		
	Treatment	Control	*p*-value	Treatment	Control	*p*-value
Long-term outcome: Land investment						
Any land investment in past two years	10%	4%	<0.01	13%	7%	<0.01
Invested in land by planting trees	8%	2%	<0.01	7%	2%	<0.01
Invested in land by building a fence	<1%	1%	0.97	<1%	<1%	0.16
Setting up an irrigation system	2%	<1%	0.02	1%	<1%	0.12
Undertaking landscaping	<1%	1%	0.0	2%	<1%	<0.01

Dependent variable	Interim			Endline		
	Treatment	Control	*p*-value	Treatment	Control	*p*-value
Value of land investment in the last two years (excluding unpaid household labor) (FCFA)	36,517	24,314	0.27	61,721	50,361	<0.01
Labor time invested into land (days)	33.8	7.2	0.15	5.6	11.3	0.13
Sample size	396	1,262		537	1,346	

Source: Interim (2017) and Endline (2020) Surveys.

Note: Estimates account for preference strata.

Among households who have made physical investments in their land, beneficiaries invested more than non-beneficiaries in terms of money but not in terms of labor time. At interim, there was no evidence that beneficiaries who made physical investments spent more money or labor time on those investments than non-beneficiaries who invested. Among beneficiaries, all groups are similarly likely to have made investments in their land, but polyculture farmers who have made investments have spent more than twice as much time as rice farmers who have made investments (Appendix Table A.6). In fact, the impact of winning the lottery on the amount of money spent on investing in the land is negative for rice farmers, while it is positive for all other groups. Male farmers who have invested in their land spent more labor on land investments than women who have invested, but differences between men and women in terms of money invested were small.

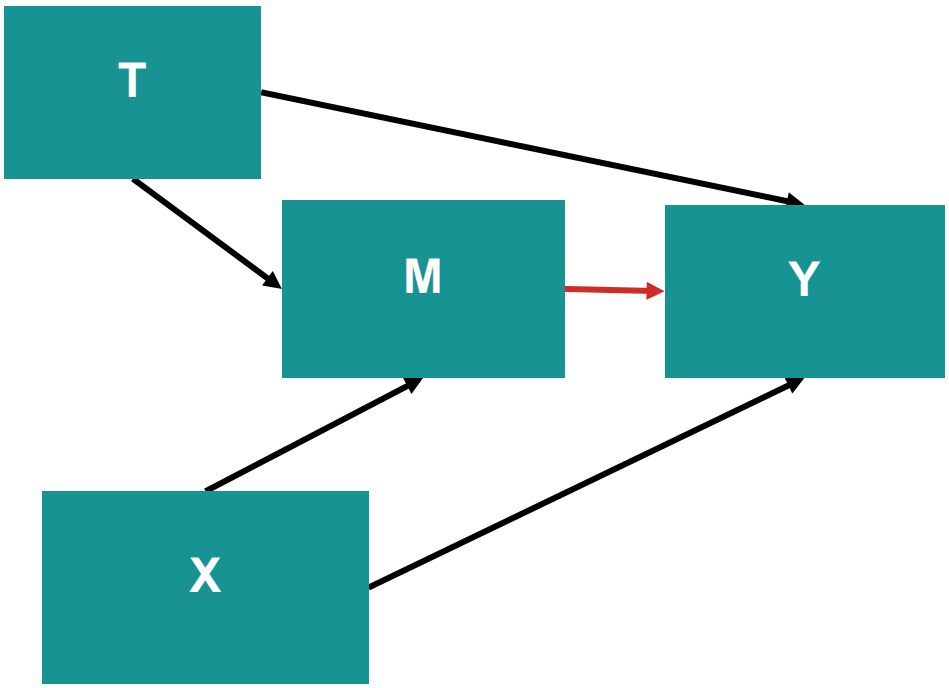
To understand whether the land tenure activities affected agricultural incomes requires an analysis of the causal pathways. A limitation of simple impact analysis is that it cannot determine the causal pathway through which impacts manifest in the logic model. Because winning the Di Lottery results in a package of benefits—land access, land irrigation, land tenure, and starter kit and training—the impacts on land investments and input use could be due to any, or all, of these benefits. Any attempt to disentangle the effect of the land tenure mechanism must allow for the other benefits, such as irrigated land (and potentially other household characteristics), to have a direct effect on outcomes, in addition to the effect of an increase in land tenure security. At the same time, the analysis also must account for potential reverse causality whereby land investment might itself strengthen perceptions of land tenure security.

To meet these two challenges, we conducted an analysis known as mediation analysis. We used a method developed by Huber (2013), that enables us to disentangle the direct effect of the package of benefits from the indirect effect that operates through an increase in perceived land tenure security. To address reverse causality, this method assesses the effect that operates through the perception of land tenure security at interim on longer-term land investments, access to loans, and land transactions. We were able to conduct this analysis in this case, because we have an interim estimate of the impact of winning the lottery on land tenure security and endline measures of long-term land investment. Because we measure land tenure security before land investment, we do not need to worry about the possible reverse causality of the latter on the former.

Figure III.3 shows the general approach of mediation analysis. In Figure III.3, T is the treatment (winning the Di Lottery), X are pre-treatment covariates, M is the mediator (increased perception of land tenure security), and Y is the outcome (long-term investment in the land). Under suitable conditions, mediation analysis enables the researcher to estimate the indirect effect of a treatment via M while allowing for a direct effect from T on Y. In the present analysis, the direct effect of the treatment (T) on the outcome of interest (Y) would be the direct effect of the package of benefits including irrigated land, land

documentation, and training on land investments. The mediator M is the interim perception of land tenure security and transfer rights. X covariates include baseline covariates that might affect both land tenure security and land investments. Appendix A.3 provides details about the methodology and underlying assumptions.

Figure III.3. Estimated mediation model



We analyzed the direct and indirect effects on the outcomes of land investments and land rentals made between the interim time period and the end line, using different measures of interim perceptions of land tenure security as mediators. We used expectations of the loss of land in the next five years, belief in the right to sell and let land, and using land as a collateral for loans as interim indicators of land tenure security. Our methodology allows for only one outcome and one mediator, so we conducted a separate analysis for each combination of mediator and outcomes, using the same methodology for each. The analysis is limited to the sample of respondents for whom we have complete information for all covariates, interim mediators and final outcomes.

We present our results in Table III.8, including both the total effect (the effect of the whole package of benefits, including receiving irrigated land and training on land investment) and the indirect mediator effect (the effect of and increased perception of land tenure security on land investment) for each pair of mediators and measure of land investment. For example, in the second column, we see that the estimated total effect of winning the lottery on having invested in the land in the last three years is 3 percentage points ($p = 0.11$). In the third column, we see the estimated effects of each measure of land tenure security on having invested in the land in the last three years; in the first row, we see a small negative coefficient with a high p-value, signifying that we have no evidence that having a lower expectation of losing one's land increases the likelihood of investing in one's land.

Table III.8. Effects of perception of increased land tenure security on land investments (mediation analysis)

	Invested in the land in the last three years		Value of land investment		Lets land in any season	
Mediator	Total effect Coeff. (*p*-value)	Mediator effect Coeff. (*p*-value)	Total effect Coeff. (*p*-value)	Mediator effect Coeff. (*p*-value)	Total effect Coeff. (*p*-value)	Mediator effect Coeff. (*p*-value)
No worry of loss of land in the next 5 years	0.03 (0.11)	-0.01 (0.69)	8,643.84 (0.15)	-119.49 (0.91)	0.07 (<0.01)	0.00 (0.50)
Right to sell land	0.03 (0.11)	-0.01 (0.10)	8,643.84 (0.16)	-2162.96 (0.63)	0.07 (<0.01)	0.00 (0.57)
Right to let land	0.03 (0.11)	0.00 (0.67)	8,643.84 (0.16)	-1461.06 (0.44)	0.07 (<0.01)	0.00 (0.82)
Using land as collateral for loan	0.03 (0.11)	0.00 (0.97)	8,643.84 (0.16)	-1870.56 (0.47)	0.07 (<0.01)	0.00 (0.23)

Source: Interim Survey (2018), Endline Survey (2020).

Note: Because this analysis uses observations with complete records for all covariates and interim outcomes, the total estimated effect differs from previous tables. Uses Program Causal-Mech.R following Huber (2013). Pre-treatment control covariates are age, literacy, household size, relationship to the household head, years of experience as a farmer, experience with irrigation, experience with rice production, experience with intercropping, region, ownership of agricultural tools and draft animals, number of plots operated, rental of agricultural land, hired labor, number of people in the household with property rights, and income sources; post-treatment interim covariates include total area cultivated in both seasons, use of agricultural inputs in both seasons, number of types of agricultural equipment, and agricultural income.

The Di Lottery does not appear to impact long-term investment in the land through increased perceptions of land tenure security. The mediation analysis shows no indirect impact through any of the land tenure security mediators on any of the land investment outcomes; none of the coefficients on the mediators in any of the analyses (Columns 3, 5, and 7) is statistically significant. This finding suggests that the impacts of the Di Lottery on these land investment outcomes are operating directly through the other components of the package of benefits, including the provision of irrigated land and agricultural training. Holding these other factors constant, the impact of an increased perception of land tenure security on its own does not explain the observed increase in land investment.

RQ3. To what extent are the estimated impacts from the regression discontinuity design (RDD) similar to those from the RCT, both at the cutoff and far from the cutoff?

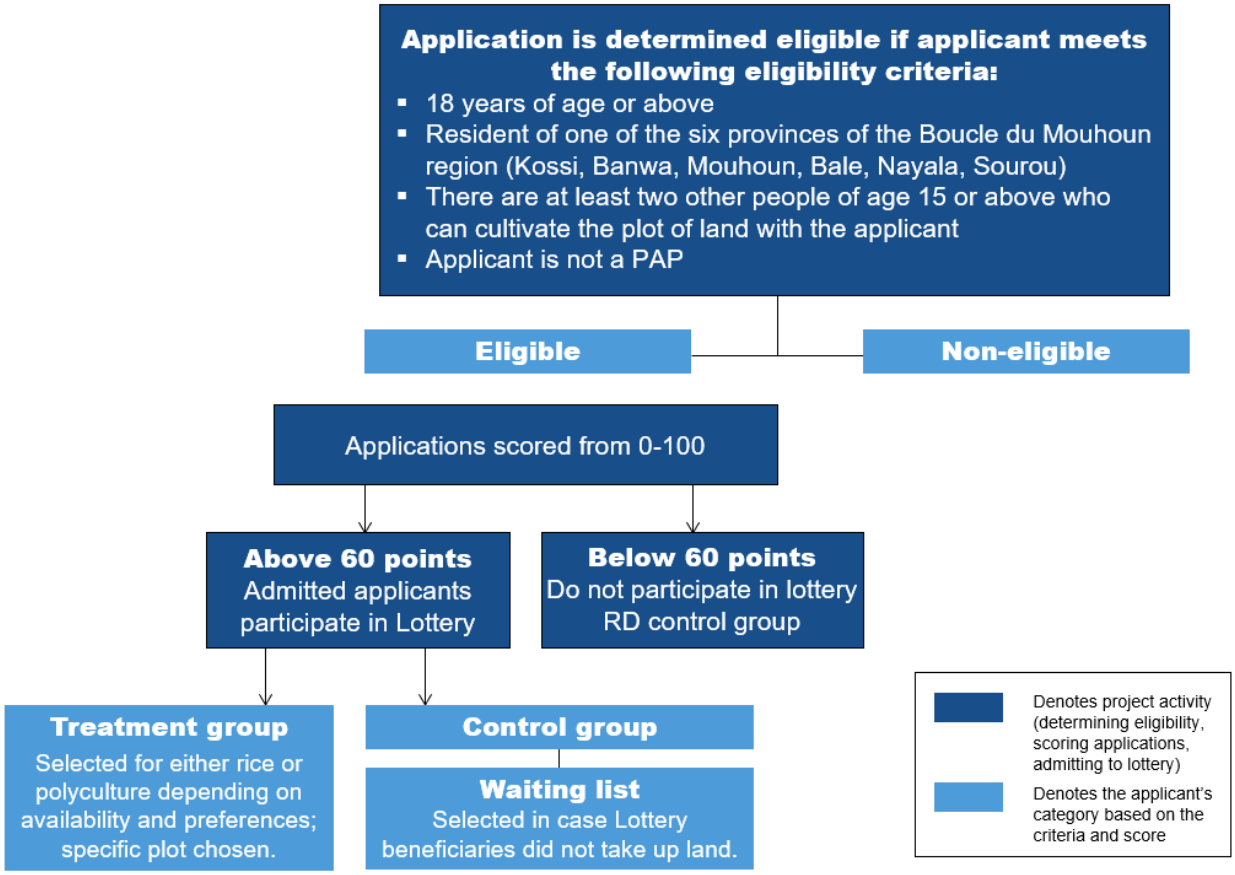
Key findings

The RDD treatment estimates at the cutoff for agricultural profit and income measures are about one-third lower than the RCT estimates and are not statistically significant. Using an approach developed by Angrist and Rokkannen (2015) that extrapolates away from the cutoff seems more promising, as the estimated impacts are much closer to the RCT estimates.

Some applicants to the Di Lottery were not admitted to the lottery because they scored low on the eligibility criteria, but they were surveyed. As a result, it is also possible to conduct a regression discontinuity design (RDD) (a second type of rigorous design) to estimate the impact of winning the lottery. In the RDD, we compare the outcomes of Di Lottery beneficiaries just above the cutoff for admission to the lottery with those of applicants who were not admitted to the lottery because they score below the cutoff. We then conduct a methodological study—known as a within-study comparison (WSC)—that compares the estimated impacts of the Di Lottery RCT—considered the gold standard in impact evaluation—with the impacts estimated through the RDD. This study provides evidence of the efficacy of the RDD in situations where an RCT is not feasible.

Figure III.4 shows the process of recruiting applicants and selecting Di Lottery beneficiaries; this process resulted in one treatment group of beneficiaries and two control groups of nonbeneficiaries. The RCT compares the outcomes of the treatment group, the Di Lottery beneficiaries, with the outcomes of the control group who participated in the lottery but did not receive a plot of land. The RDD compares the Di Lottery beneficiaries to applicants who scored below 60 points and were thus not admitted to the lottery.

Figure III.4. Di Lottery beneficiary selection process

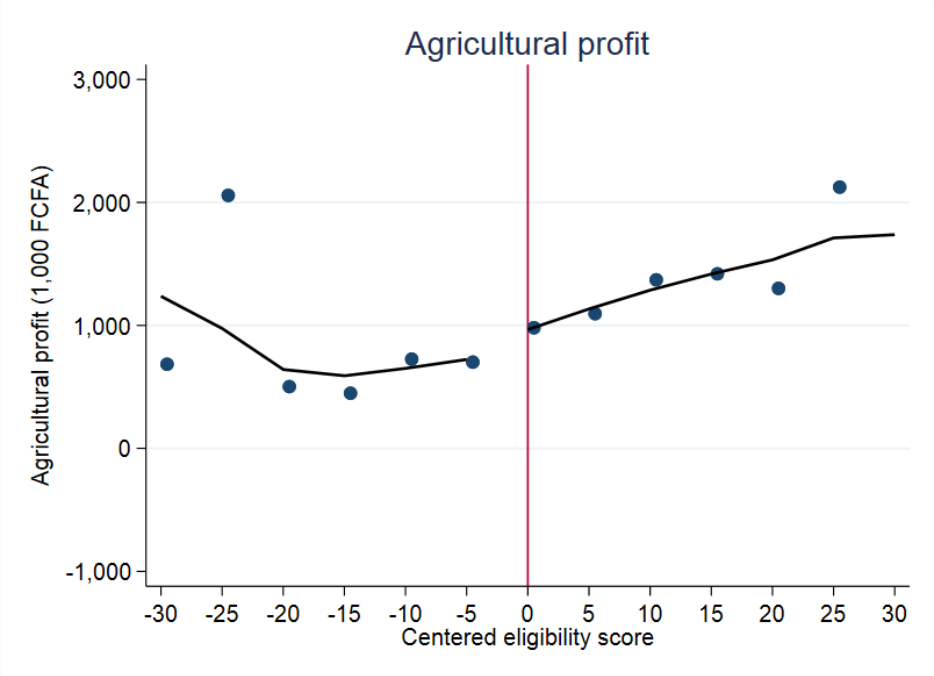


This selection process met three criteria for the evidence standards for the RDD, as we concluded in the baseline report (Ksoll et al. 2018): (1) the scores were used to select beneficiaries for lottery participation only, (2) the scores—based on objective and verified application information—were not known to applicants until very far into the process and there is no evidence that scores were systematically manipulated, and (3) the baseline values of two key outcomes do not show any discontinuity at baseline,

suggesting that any observed effect on Di Lottery beneficiaries after the project was due to winning the lottery.

The first step in any RD analysis is to visually present and inspect the outcome against the eligibility score to see if there is a clear relationship between the cutoff and the outcome and to be able to detect any non-linearity in the outcomes around the cutoff. Figure III.5 shows the average agricultural profits for nonbeneficiaries and Di Lottery beneficiaries for each level of the eligibility score, which we centered around zero by subtracting the cutoff value of 60 from all raw scores. We also present a smoothed mean for reference.[17] The visual inspection of agricultural profit at the cutoff for participation in the lottery does not show an unambiguous discontinuity and it is unclear whether we might expect the lottery to have had an impact on agricultural profit. There also do not seem to be any non-linearities around the cutoff that would seem to contradict the use of the regression discontinuity design.

Figure III.5. Agricultural profit and eligibility score



The second step in the RD analysis is to provide an estimate of the impact at the cutoff. To estimate the impact of winning the lottery nonparametrically, we used the same local linear regression we used to smooth the mean in Figure III.5, applying an edge kernel and calculating the bandwidth separately for each outcome, following DesJardins and McCall (2008) and Imbens and Kalyanaraman (2012). Table III.9 provides empirical evidence that there is no clear impact of winning the lottery at the cutoff. Column 2 in Table III.9 presents the RCT estimate for context and Columns 3 and 4 present two RDD estimates, with Column 3 corresponding to Figure III.5. The estimated impact of winning the lottery and being a Di Lottery beneficiary on agricultural profit at the cutoff is only about half the size of the RCT estimate, and the estimate is not significantly different from zero. This is a surprising result, given that we know from the RCT that winning the Di Lottery had a significant impact on agricultural profit. However, our RCT included all applicants who were admitted to the lottery, whereas the RDD only estimated the impact for

[17] To construct the smoothed mean, we conducted local linear regression using an edge kernel and the bandwidth calculated following DesJardins and McCall (2008) and Imbens and Kalyanaraman (2012).

the marginal applicant, that is the applicant whose eligibility score just exceeded the cutoff. Because of this difference the two parameters are not directly comparable.

Table III.9. Impact on sales, profits, and income (in 1,000 FCFAs)

(1) Outcome	(2) RCT (SE)	(3) Nonparametric RD estimate at cutoff (SE)	(4) Extrapolated RD (SE)
Agricultural profits	447	226	576
	(85)	(176)	(95)
Agricultural income	468	247	586
	(79)	(174)	(86)
Total household income	486	180	545
	(92)	(226)	(100)
Sample size	**1,138**	**844**	**837**

Source: Endline survey (2020).

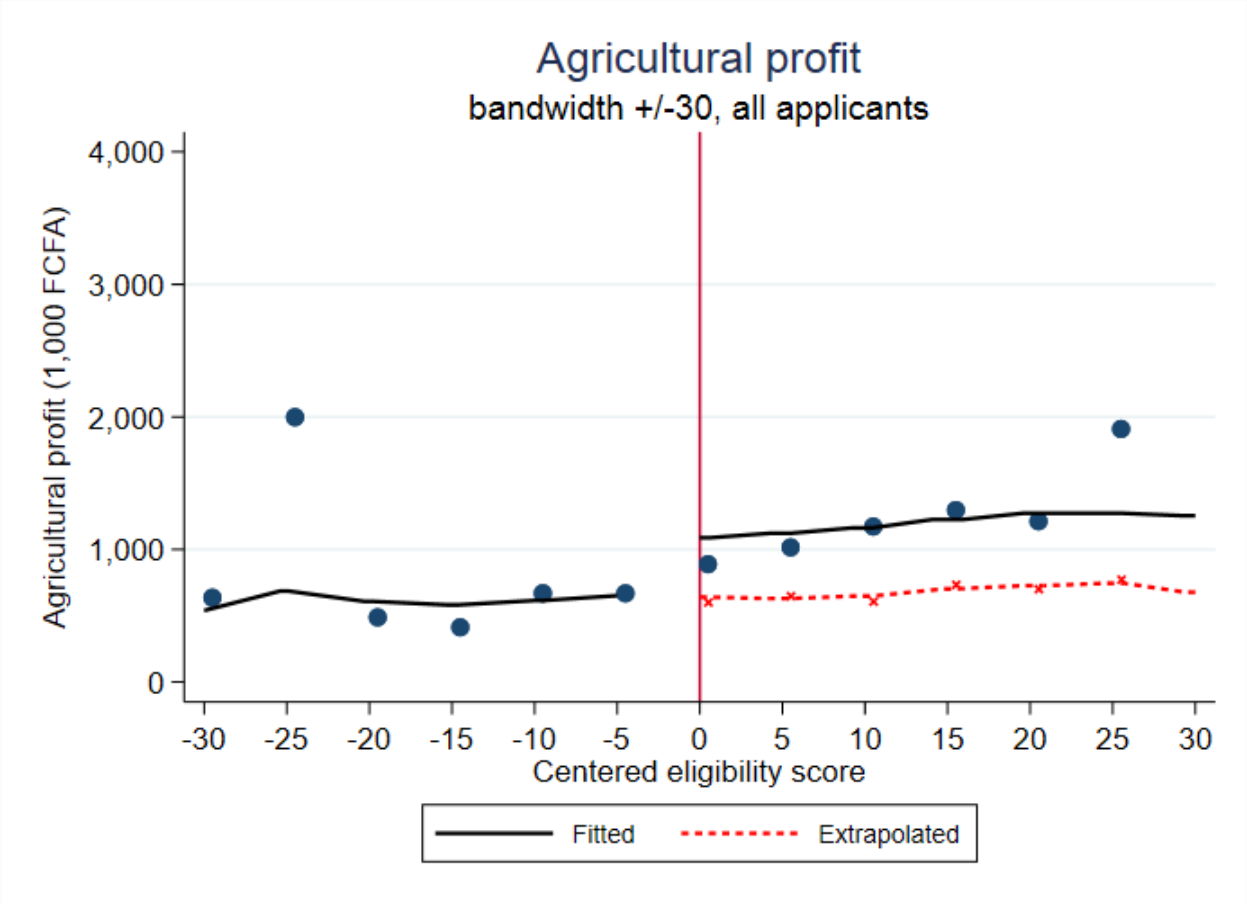
Note: Simple imputation used to impute plot-level profits and other sources of income for plots and household members for whom detailed information was not collected. The RCT estimate used the entire sample of Di Lottery participants. The RDD estimations considered observations within a window of +/- 30 points on the eligibility score around the cutoff, used an edge kernel, and chose the optimal bandwidth following DesJardins and McCall (2008) and Imbens and Kalyanaraman (2012).

FCFA = Franc CFA ; SE = standard error.

We also implemented a newer RDD-based method following Angrist and Rokkannen (2015). Their method extrapolates estimates from a discontinuity away from the cutoff. We followed their approach to estimate the impact of winning the lottery on agricultural profit, agricultural income, and household income within a larger window away from the cutoff. Angrist and Rokkannen's (2015) approach relies on selecting and conditioning on a set of covariates such that the outcomes of interest for beneficiaries and nonbeneficiaries separately become mean independent of the eligibility score. An implication of mean independence is that the score and the outcome are not correlated anymore (although conditional mean independence is a stricter requirement).[18] Figure III.6 shows that once we control for a series of baseline covariates predicted agricultural profit—represented by the solid line—is flat on both sides of the cutoff. , Figure III.6 also shows the extrapolated estimates of agricultural profit, represented by the dashed red line. (Because agricultural profit constitutes the largest component of agricultural income and household income, figures for these two other primary outcomes look similar.)

[18] To follow the Angrist and Rokkannen (2015) approach, we implemented a linear reweighting estimator (Kline 2011).

Figure III.6. Extrapolation of agricultural profit away from the cutoff



Column 4 of Table III.9 presents the estimated impact for the three primary outcome variables within a window of 30 points on the eligibility score around the cutoff. Across all three primary outcome variables, the estimated impact using the Angrist and Rokkannen approach is closer to the RCT estimate than the simple RDD estimate. For these three outcomes at least, the approach developed by Angrist and Rokkannen (2015) seems more promising than the simple RDD approach. However, based on a simple comparison of estimates we cannot reject the possibility that the RDD estimates at the cutoff and the extrapolated RDD estimates are the same as the RCT estimates. As a result, our analysis cannot conclude whether the simple RDD or the Angrist and Rokkannen approach are the more appropriate designs in this context. Three possible future extensions of this work are to (1) make the estimates more comparable by limiting the RCT estimation to lottery participants who are within the same window as for the two RDD estimates, (2) use bootstrap test statistics to directly test whether these three estimates are similar, and (3) consider other outcomes apart from these three primary outcomes, or other functional forms of these outcomes, for which the statistical power to detect differences might be higher.

C. Summary of findings

Our key findings regarding the Di perimeter evaluation are summarized in Table III.10.

Table III.10. Key findings for the Di perimeter evaluation

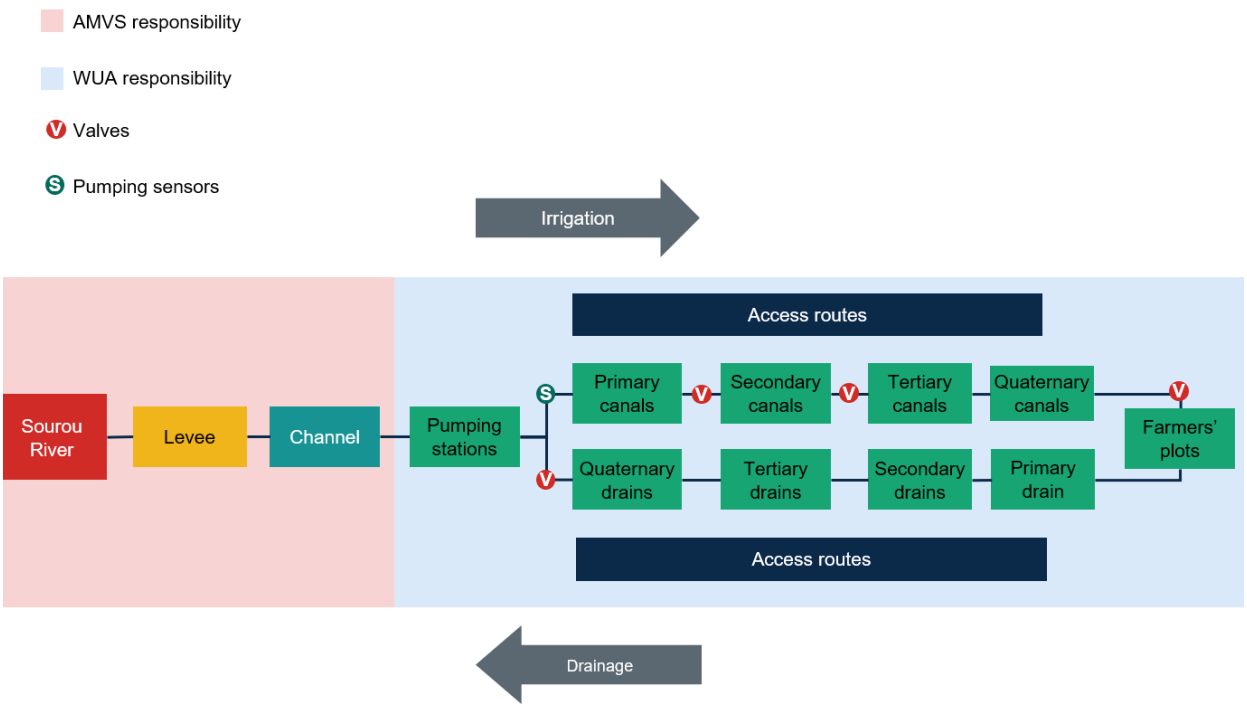
Research question	Findings
1. What impact does winning the Di Lottery have on agricultural practices, production, total agricultural income, and overall household income?	**Winning the Di Lottery increased the amount of land cultivated and the likelihood that farmers hire labor.** Lottery beneficiaries cultivate more land than non-beneficiaries, but significantly less than they received on the perimeter. Treatment and control farmers who cultivated generally grow the same types of crops and employ mostly similar agricultural practices. Lottery beneficiaries hire more labor than non-beneficiaries. **Lottery beneficiaries had higher incomes.** Di Lottery beneficiaries made significantly more sales and obtained higher agricultural profits, agricultural incomes, and household incomes.
2. What are the impacts of the lottery on long-term land tenure security (perception, transfer rights, land conflicts), land markets, and investment?	**Lottery recipients are more likely to have formal land documentation, but do not report higher levels of land tenure security than non-recipients.** Beneficiaries of the Di Lottery are more than four times more likely than non-recipients to have formal land documentation and six times more likely to have a lease document. Confusion about land tenure and land documentation has increased since interim, with only one-third of beneficiaries understanding that they have lease documents and half incorrectly claiming to possess land titles. Perceptions of land tenure security have increased, and both beneficiaries and non-beneficiaries report high levels of land tenure security. Beneficiaries and non-beneficiaries had different sources of perceived land insecurity. Lottery beneficiaries are more concerned about losing their land to formal institutions, such as the government or the WUAs, while non-beneficiaries are more concerned about previous landowners taking over their land. There were few differences in terms of land tenure security along most measures between farmers allocated rice and polyculture plots. The lottery increased some measures of land tenure security more for male farmers than for female farmers. **The lottery increased investment in the land and participation in both the land rental market and collateralized debt** Lottery beneficiaries are twice as likely as non-beneficiaries to have made physical investment in their land, mostly in the form of planting trees. The Di perimeter appears to play a larger role in formal transactions than off-perimeter land, with lottery beneficiaries more likely to let land, apply for a loan, and use land as collateral than non-beneficiaries. **Land tenure security does not appear to be the sole driver of long-term investment in agricultural land.** The impacts of the Di Lottery on long-term land investment outcomes appear to be operating directly through the direct components of the program, including irrigated land, land documentation, and agricultural training, rather than through increased perceptions of land tenure security. Mediation analysis results show no indirect impact through any of the interim land tenure security mediators on any of the land investment outcomes.
3. To what extent are the estimated impacts from the regression discontinuity similar to those from the RCT, both at the cutoff and far from the cutoff?	The RDD treatment estimates at the cutoff are about one-third lower than the RCT estimates and are not statistically significantly different from zero. Using an approach developed by Angrist and Rokkannen (2015) that extrapolates away from the cutoff seems more promising, as the estimated impacts are much closer to the RCT estimates.

IV. Di Operations and Maintenance

A. Background

In Chapters II and III, we presented the analysis of beneficiary outcomes on the Di perimeter and the impact of winning the Di Lottery. In this chapter, we investigate the operations and maintenance (O&M) of the Di perimeter infrastructure. To provide context for this analysis, we present an overview of the irrigation infrastructure that WUAs need to operate and maintain. The new irrigation infrastructure includes seven electricity-powered pumping stations to pump water to and from the plots, a network of canals to deliver water from the river to farmers' plots, drains to remove excess water from the plots when flooded, routes for accessing the canals and drains for maintenance purposes, and a levee to protect the perimeter from river flood waters during the rainy season. The canal and drainage networks are divided into primary, secondary, tertiary, and quaternary levels in the direction of the water flow (Figure IV.1). At all four levels, canals have valves to control the water flow circulating throughout the system, and the quaternary drains have valves that can be closed or opened to allow flood water to run off into the river. In additional to the access routes, some livestock routes were built to divert livestock herds, preventing damage to the irrigation infrastructure.

Figure IV.1. Infrastructure network

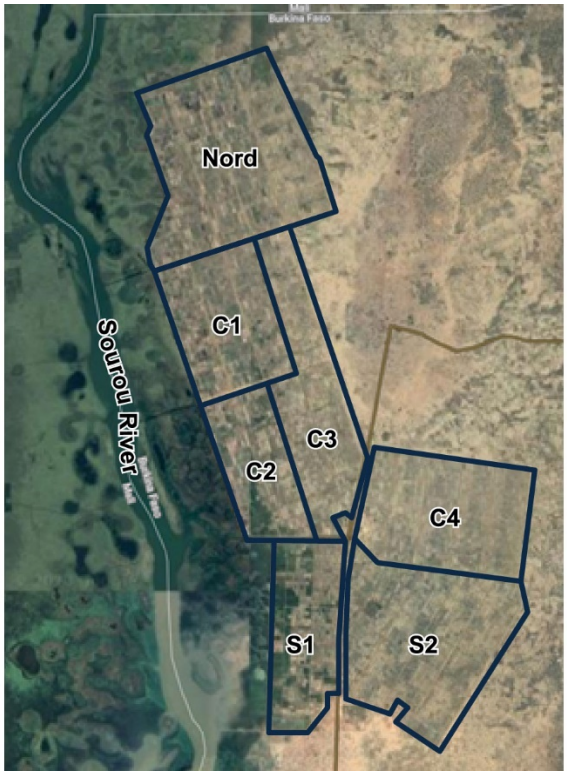


The perimeter is divided into seven sectors, each equipped with a pumping station. The pumping stations pump water from the channel to the quaternary canals to deliver water to farmers' plots. When enough water has been delivered to a sector, the pumping sensor corresponding to that sector signals the pumping station to stop pumping water. If the farmers have paid the water fees, the WUA opens the valves along the appropriate canals leading to the farmers' plot for irrigation during each farmer's water turn. In Figure IV.2, we provide images of the infrastructure.

Figure IV.2. Infrastructure components, in photographs

To ensure sustainable and efficient management of the perimeter, the WMI Activity created seven new WUAs in Di, each responsible for one of the seven sectors on the perimeter: S1 and S2, C1 through C4, and North (Figure IV.3). Specifically, the WUAs were charged with collecting the membership fees from farmers in their sectors and using the fees (1) to operate and maintain the irrigation infrastructure from the pumping station to the farmers' plots and (2) to pay a fee to the Autorité de Mise en Valeur de la Vallée du Sourou (AMVS), the local division of the Ministry of Agriculture. Each WUA is further divided into smaller units—Unités Autonomes d'Irrigation (UAI)—that help coordinate the WUAs' work with the farmers. The WMI Activity provided the WUAs with training and TA on maintenance techniques during the compact, while the APD funded additional training post-compact. Meanwhile, AMVS was charged with providing TA and overseeing the work of the WUAs in the Di perimeter on an

Figure IV.3. Map of sectors on the Di perimeter



ongoing basis, in addition to carrying out its responsibilities with other perimeters in the Sourou Valley. AMVS's mandate included maintenance of the infrastructure between the river and the pumping stations (excluding the stations, whose maintenance is the responsibility of the WUAs).

B. Final evaluation findings

RQ1. What is the current state of the infrastructure (main canals, roads, pumping stations) and functioning of the infrastructure?

Key findings

Most of the infrastructure components on the perimeter are functional, despite sustaining some damage. Overall, the perimeter receives adequate levels of water; however, some plots receive too much water and others too little. Sectors that were constructed first received better quality infrastructure than those that were constructed last. Some WUAs and farmers have had to adjust the initial infrastructure to make it work properly.

Most of the infrastructure components on the perimeter are functional, despite sustaining some damage. Six years after completion of the project, the pumping stations are in good condition and continue to function as designed. The canals have incurred some damage but still operate relatively well, providing most farmers' plots with adequate water. Though still functional in most areas, some of the access routes have deteriorated, creating maintenance difficulties. The largest threats to the system's functionality are the clogged drains and defective drainage valves, which cause flooding in some parts of the perimeter during the rainy season. In Table IV.1, we provide more details on each infrastructure component. Examples of damaged infrastructure appear in Figure IV.4.

Table IV.1. Summary of infrastructure functionality, by component

 **Pumping Stations**	**Minimal damage and high functionality.** Of all the infrastructure components, the pumping stations are in the best condition. A few pumping stations have incurred some damage, mostly as a result of the poor quality of the electricity supplied by the Société Nationale d'Électricité du Burkina Faso (SONABEL), but the resulting damage has been repaired. Except for a few small dents and cracks in the building structure, the stations are generally in very good condition and function as designed.
 **Canals**	**Some damage but high functionality.** The larger canals that were constructed from concrete are in good condition, except for the joints, which evidence cracks. According to most respondents, the cracks at the canal joints are the result of normal wear and tear. In addition, livestock damaged a portion of the larger canal in the North sector. Nonetheless, most primary and secondary canals function well, although respondents report that leaks cause substantial water loss. The tertiary and quaternary canals on the rice plots have sustained higher levels of damage. Because they are made from earth, these canals are clogged and deteriorating from erosion. However, farmers' plots still receive adequate water despite the damage.
 **Drains**	**Damaged and clogged in most sectors, causing perimeter flooding.** The drains are the most damaged infrastructure component in the irrigation network; they are deteriorating in most sectors from erosion caused by rainwater and cattle herding because they are made from earth rather than concrete. In most sectors, the drains are also becoming clogged with earth and organic matter, reflecting a lack of maintenance; only a few sectors can maintain the smaller drains properly. The WUAs lack the ability to unclog the larger drains because they are too deep for manual cleaning. The clogged drains contribute to the flooding in some parts of the perimeter during the rainy season. The flooding in turn causes damage to the access routes and threatens the integrity of the levee.

Some reports indicate that farmers take advantage of the clogged drains to syphon off water to irrigate their lands for free.

Valves

Poor state and poor functionality in most sectors. Some of the drainage valves were defective from the beginning, and others have suffered significant damage because they were not durable enough for the Di perimeter operation. Specifically, in most sectors, the drainage valves are becoming clogged and evidence cracks at the joints. The defective drainage valves on the larger drain let water enter from the river back into the plots, contributing to the flooding of some plots and placing undue pressure on the levee. Several participants suspect that the water coming from the drains may contribute to the accumulation of potentially harmful chemicals in the perimeter from agricultural inputs. This issue affects four of the seven sectors (C1, C2, North, S1). In addition, one sector reported the theft of valves, which were replaced by locally manufactured valves of poorer quality. Finally, canal valves do not exist for the rice plots, preventing WUA staff from cutting access to farmers who fail to make water payments.

Access routes

Some damage from erosion and livestock, but functional overall. Flooding and cattle herding have damaged some portions of the access routes, which are constructed from soil. Access routes near the main drain have sustained the greatest damage; the routes erode when the nearby drains flood. Some access routes also have small traversing drains for rainwater runoff, but these drains are too small and overflow, further damaging the routes. Although a sperate pathway was designated for herding livestock, it has been flooded and eroded since it too was made from soil. As a result, the muddy livestock path is not usable; instead, herders use the access routes and have caused further deterioration. Respondents estimate that approximately one-tenth of the access routes are not usable because of damage, leading to difficulties in accessing infrastructure for maintenance.

"In the beginning, the main drain was 1.2 meters deep, now it's only 50 cm. The problem of the main drain is aggravated by the deterioration of the access routes along the drain." – WUA leadership

Figure IV.4. Damaged infrastructure, in photographs

Eroded and flooded access route

Eroded protection levee

Clogged primary drain

Clogged tertiary canal

Overall, the perimeter receives adequate levels of water; however, some plots receive too much water as a result of construction errors and others too little because of defects and damage. Most of the plots on the perimeter receives enough water. However, some plots located far from the pumping station do not receive adequate water, particularly in sectors that were not properly leveled during construction of the perimeter, mainly C1, C2, C4, and S2 (this issue reportedly affects approximately 90 hectares, about 35 percent of the area, in each sector). A few WUA presidents also complained that insufficient amounts of water are pumped to some plots in their sectors because of errors in the pumping sensors, which falsely signal that enough water has been pumped. Respondents all agree that water flow to the plots is easy for the WUAs to control, except for rice plots, where canals do not have valves. The valves are needed to stop the water from flowing to the farmers' plots. On the other hand, some plots receive too much water during the rainy season when the perimeter experiences flooding. Due to their proximity to the river, plots near the primary drain and the North sector experience the highest degree of flooding, which is aggravated by defective drainage valves and clogged drains.[19]

Sectors that were constructed first received better quality infrastructure than those that were constructed last. The quality of the original infrastructure is not consistent throughout all the sectors. Several WUA staff attribute the variation in construction quality to the order in which the construction was carried out; the sectors that were constructed first report receiving the best quality infrastructure, but the sectors that were constructed last report receiving the worst quality infrastructure. For example, the S2 valves and drains have the best quality materials and construction; the S2 perimeter was one of the first to be constructed. On the other hand, the North sector is considered to have the worst quality valves and access routes; North was the last sector to be constructed.

Some WUAs and farmers have had to adjust the initial infrastructure to make it work properly. For example, one WUA modified the size of the valves on tertiary canals to adjust the flow of water to allow enough water to reach the plots that initially were not receiving enough water. In other cases, the WUAs are working to install canal valves on rice plots where they are missing in order to control water flow to these plots. Individual famers with unlevel plots have tried to level the fields with tractors to ensure that adequate water reaches their fields.

RQ2. How well are the WUAs currently functioning with respect to (a) O&M, (b) governance, and (c) administrative and financial management?

Key findings

The WUAs do routine maintenance for the pumping stations, but most sectors struggle to clean canals and drains given low farmer participation and the lack of equipment. The damaged portions of the access routes and valves have not been repaired in many sectors. These challenges are exacerbated in the North sector because of its farmer characteristics, the types of crops cultivated, and its proximity to the river. The WUA union is effective in addressing and preventing some emergency breakdowns. WUAs have strong self-governance and financial transparency, but late fee payments and low long-term fee-recovery rates (particularly in sectors with rice plots), as well as high electricity costs, low farmer participation in communal work, and leaky canals, threaten their financial solvency and cash flow.

[19] Some farmers cultivate crops that are not appropriate for rice plots, such as maize. This increases the likelihood that flooding causes damage as well as the extent of damage. Inappropriate crop choice can therefore exacerbate the flooding problems caused by parts of the infrastructure that are nonfunctional.

a. Operations and maintenance

Pumping stations are maintained well, but most WUAs struggle to perform maintenance on the other infrastructure components. The pumping stations undergo thorough maintenance twice a year, in between the planting seasons (October and May). In addition, the WUA engineer performs small maintenance checks on the pumping stations biweekly. However, drains, canals, and access routes do not undergo optimal maintenance in most sectors. The WUAs lack funds to buy the equipment needed to unclog the deep quaternary drains. Canals and smaller drains require manual cleaning in order to prevent clogging; originally these structures were meant to be cleaned by the farmer members on communal workdays. Although farmer participation was initially high, it has since declined in most sectors due to a tragedy of the commons. In other words, in most sectors, farmers can avoid the communal work and get a "free ride" without consequences.[20] Thus, many WUAs have had to rely on hired labor to unclog the canals and drains. AMVS staff members see hired laborers as poorer quality workers than farmer member labor and blame hired staff for some of the maintenance problems, such as poor tertiary canal and drain unclogging. In addition, hiring labor for maintenance was not a foreseen cost for the WUAs, and many lack the financial ability to hire labor and therefore are not able to perform as much maintenance as needed.

Maintenance quality varies by WUA because of differences in farmers' characteristics, type of plots, and proximity to the river. The best maintenance is observed in sector S2 and S1, and the worst is in North. Sectors that struggle with maintenance have a larger portion of farmers who are not residents of the region and therefore are less motivated to make long-term investments in the plots, according to WUA presidents and AMVS staff. They are less likely to contribute labor to maintenance of the infrastructure and less likely to pay membership fees, limiting the financial resources available for maintenance. In addition, as the sector characterized by the greatest flooding, the North sector struggles to perform the maintenance associated with its proximity to the river and the resultant damage. Finally, due to the highest percentage of rice plots in the North sector, which do not have shut off valves used to cut off water for farmers who have not paid their membership fees, the WUA struggles to force farmers to pay as there are no consequences to the farmers for not doing so. Meanwhile, S1 and S2 perform the best maintenance thanks to a healthier financial situation with higher fee-recovery rates and new tactics that motivate farmers to participate in infrastructure maintenance. The WUAs in these two sectors impose fines on farmers who do not participate in cleaning canals and drains.

"The North WUA also struggles to organize the farmers to do collective work. The combination of low fee-recovery rates and low collective work participation negatively affects the quality of maintenance in the North sector. Farmers think, since I am a renter, maintenance does not concern me, I just want to get as much as I can out of the plot, and tomorrow the landlord may throw me out. Some farmers also lack the labor to make the most of their plots." – AMVS staff

Much-needed repairs are overdue. Besides overdue drain and canal cleaning, many of the leaks in canal and drain joints have not been repaired. Although maintenance of the canals and drains between the pumping stations and the plots falls under the purview of the WUAs, the WUAs have turned to AMVS for assistance in replacing the broken canal joints because of lack of finances. To this day, only a few have been fixed due to issues with coordination between WUAs and AMVS about when to stop irrigation so that the canals can be repaired. Defective and damaged valves are considered beyond repair by many

[20] An exception is the S2 sector. This WUA foresaw the maintenance issue and included a deposit in the water fees to guarantee farmer participation in communal work. The deposit is refunded to farmers who participate in maintenance activity. Otherwise, farmers lose the deposit and even pay a penalty for failure to participate.

respondents, they need to be replaced with better quality valves. Access routes were originally also the responsibility of WUAs, but they have asked AMVS for help due to lack of funding. However, AMVS has also struggled to find the necessary funding, leaving damaged portions of access routes unrepaired. Unrepaired infrastructure is believed to cause more damage; approximately half of the WUA staff members believe that better and regular maintenance could have potentially averted emergency breakdowns.

"Unfortunately, certain valves do not work since they were constructed. The valves are poor quality; I think that the company, when they first received the materials, showed them to the engineer and said look, they don't work. They need to be replaced entirely; they are beyond repair." - AMVS leadership

The WUA union has developed an effective system for addressing and preventing some emergency breakdowns. The WUAs have created a union for all seven of the WUAs on the perimeter. The union employs three full-time staff members, an accountant, an electromechanical engineer, and a secretary, all of whom are dedicated to the management of all the WUAs. These staff members have assessed which parts of the equipment are most likely to need replacing and ordered the parts, creating an inventory of replacement pieces for emergency repairs, mostly for pumping station repairs. Bulk purchasing has allowed the WUAs to be able to secure lower prices for the replacement parts, many of which are not available in the local market. This system has been highly effective in allowing the WUAs to make quick and affordable repairs when needed.

"The union of WUAs recruited an engineer to do maintenance on the pumping stations for all of the WUAs. The union has also made group purchases of replacement parts for the pumping stations. The combination of these two factors has been working very well. Many emergency repairs were avoided thanks to this system. Some of the replacement parts are not available on the local market; ordering and delivery of these parts takes a long time, so doing this in advance has helped address emergency situations in a timely manner."– WUA leadership

AMVS technical support in the perimeter is limited because of lack of financial and human resources. Almost no WUA staff members or leaders had witnessed a field visit from AMVS in the past year, and none received information in advance about any such visits in the last year. AMVS staff agree that they do not have the capacity to be present in the perimeter as intended, after the departure of a staff member dedicated to the perimeter. However, AMVS does consistently participate in the WUAs' general assemblies, during which they offer advice. In addition, AMVS reviews the budgets prepared by the WUAs at the beginning and end of each season.

"I think we could do better if we had the proper means. Especially given the insecurity situation, the AMVS needs additional funds to do a better job in the Di perimeter." – AMVS staff

Maintenance responsibilities between the WUAs and AMVS are clear for the most part, but the few disagreements have damaged the relationship. The electric network at the S1 pumping station broke down and required emergency repair so that farmers could continue to get water. The WUA purchased an expensive replacement transformer at a cost of 5.6M FCFA (approximately US$ 10,000) to fix the problem and has asked AMVS to reimburse the cost, but AMVS staff members believe that the cost is the responsibility of SONABEL. The debate has led to tension and mistrust between the WUAs and AMVS. As a result, the WUAs have collectively decided to stop paying the *taxe d'ammenagement* to AMVS (a fee of 5,000 FCFA, approximately US$ 9, per hectare, paid once per season, to help contribute to AMVS's costs for repairing infrastructure on the Di perimeter). Some AMVS staff members believe that

the Di WUAs do not respect the authority of AMVS because AMVS was not involved in the creation of the perimeter.

b. Governance

WUAs are successfully self-governed, both financially and technically. WUA leaders and staff members as well as most AMVS leaders agree that the WUAs are well managed through self-governance. Financial records, prepared by the WUA accountant, are rigorous, current, organized, and regularly submitted to AMVS. All the WUAs consistently follow protocols for democratically electing and renewing leadership. WUA leaders are elected for three years, with one-third of the leaders replaced every year; individuals may be re-elected once. The leadership is split into three committees: management committee (responsible for general management tasks such as budget projections), oversight committee (responsible for overseeing the financial accounts at least twice during each season and for performing random checks as believed necessary), and arbitration committee (responsible for resolving conflicts involving WUA members). During the assemblies, WUA work with their members to establish crop calendars and water tour schedules for each season.

"When comparing the [. . .] WUAs [on the Niassan perimeters] to the new ones in the Di perimeter, there is nothing in common. The WUAs in Di are way more advanced; they are more disciplined, and people are more educated. The WUAs in the old perimeter had tried to create a union but it never worked. The maintenance of the infrastructure is also way better in Di than in the old perimeters, as well as the financial management." – AMVS staff

c. Financial management

WUAs' savings vary by sector, but are diminishing. All the WUAs have set aside some savings from the members' fees for emergencies, however, they are spending the savings faster than they are able to replenish them. In addition, savings amounts vary widely among the sectors; the most secure WUAs, Sectors S1 and S2, have saved approximately 44,000 FCFA per hectare (approximately US$ 80, or roughly the equivalent of total membership fees for the rainy season, or 80 percent for the dry season). The least secure WUAs, Sectors C3 and C4, have saved only approximately 60 FCFA (US$ 0.11 cents) per hectare (Table IV.2).

Table IV.2. Descriptive statistics for each sector's WUA

	Characteristics			Outcomes			
Sector	Total area (ha)	Rice area (percentage)	Number of farmers	Savings (FCFA)	Savings per hectare (FCFA/ha)	End-of-season recovery rates (2019)*	Long-term fee - recovery rates **
S1	234	14%	1754	10,340,000	44,188	61%	93%
S2	424	0%	373	18,700,000	44,104	77%	94%
C1	271	33%	300	9,600,000	35,424	40%	78%
C2	198	48%	150	8,040,000	40,606	42%	88%
C3	285	0%	500	18,375	64	58%	88%
C4	330	0%	500	18,543	56	70%	91%
North	505	58%	600	8,600,000	17,030	35%	61%
Total	**2,246**	**23%**	**4,177**	**55,316,918**	**24,629**	**55%**	**85%**

Source: WUA financial reports.

Notes: The savings come from WUA budget meeting notes from April 2019.

* Fee-recovery rates at end of season come from the most recent two seasons for which data are available: the 2019–2020 dry season and the 2019 rainy season. The total shows the average fee-recovery rate across all seven sectors and includes membership fees paid only before the end of the corresponding season.

** Long-term fee-recovery rates are computed as the average fee-recovery rate for the seasons 2015–2019 as of April 2019. These rates include on-time payments as well as all late payments made by April 2019.

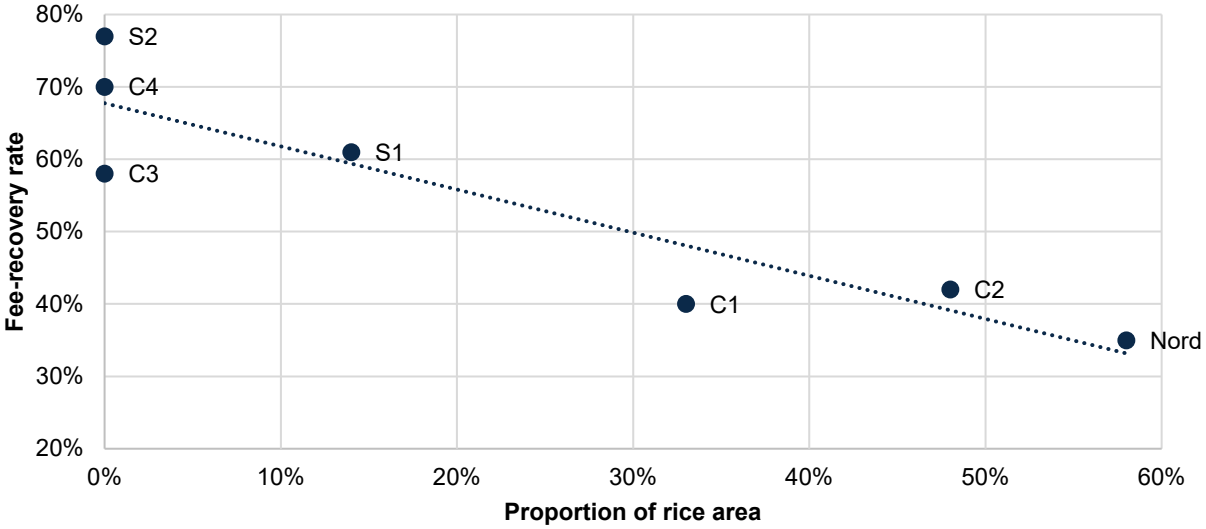
Sectors with larger proportions of rice plots have the lowest fee-recovery rates because rice is less profitable and rice plots have no canal valves. End-of-season recovery rates and long-term recovery rates are lower in sectors with a high proportion of rice plots (Table IV.2). The WUAs are unable to sanction nonpaying rice farmers because rice plots have no canal valves that would allow the WUAs to cut off the water supply. Thus, rice farmers have little incentive to pay the fees. In addition, WUA membership fees are disproportionately burdensome for rice farmers because rice is less profitable than other crops. In fact, the Di Project Due Diligence Report estimated that the operation and maintenance costs of irrigation are almost equivalent to the revenue for a farmer of a rice plot (MCA-BF 2008). Thus, rice farmers are less likely to pay the fees than polyculture farmers. As a result, the WUAs with a higher proportion of rice plots, such as those in the north of the perimeter, have the lowest fee-recovery rates. Data from the WUAs' financial reports support these qualitative findings, showing a direct inverse correlation between the rate of fees recovered by the end of the season and the proportion of rice area in the sector. Specifically, an increase of 30 percentage points in the proportion of rice area correlates with a decrease in end-of-season fee-recovery rates by 20 percentage points. With the highest proportion of rice plots, the North sector recovered only 26 percent of fees on time over the 2019 rainy season and the 2019–2020 dry season combined. At the same time, sectors with no rice plots (C3, C4, and S2) recovered more than twice that rate in the same period (Figure IV.5).

The seeds of the financial challenges for rice cultivation on the perimeter were planted at the outset of the project. Even though the Di Project Due Diligence Report (MCC 2008) showed that farmers who can only plant rice would not be able to pay per hectare fees equal to those of the polyculture farmers given their plots' limited revenue potential, the WUA fees were not adjusted for rice farmers. On the contrary, fees for rice plots are approximately 10,000 FCFA (US$ 18) higher than for polyculture plots on the perimeter and double that of rice plots on other perimeters in Burkina Faso (de Fraiture 2014). As a result, some owners have abandoned their land, lease it to renters with unclear responsibility for WUA

payments, or just do not pay the fees. Some WUAs now recognize that the fees are unrealistic for rice farmers. However, during discussions of possible adjustments to the pay structure, polyculture farmers (who make up most of the perimeter's population) did not agree to the proposed changes and the status quo fee structure remained unchanged. To cover fees owed, at least one WUA is considering seizure of the harvest equivalent of farmers' debts and two additional bags of rice. Some WUAs have resorted to publicly shaming nonpayers on rice plots by marking their plots with a symbol indicating that farmers have not paid their fees, however this approach has had limited success.

"The northern sector is mostly made up of rice plots of 2 hectares each. Many farmers try the same plot, they fail to make a profit and they leave, and therefore don't pay the fees. This is the real problem of the North. There are also other factors, such as the resident status of the farmer, and lack of valves, but the nature of the rice plot is the key. Rice plots are much more difficult to farm than maize or other crops." – AMVS leadership

Figure IV.5. Correlation of proportion of rice plot area in WUAs to fee-recovery rates at end of season

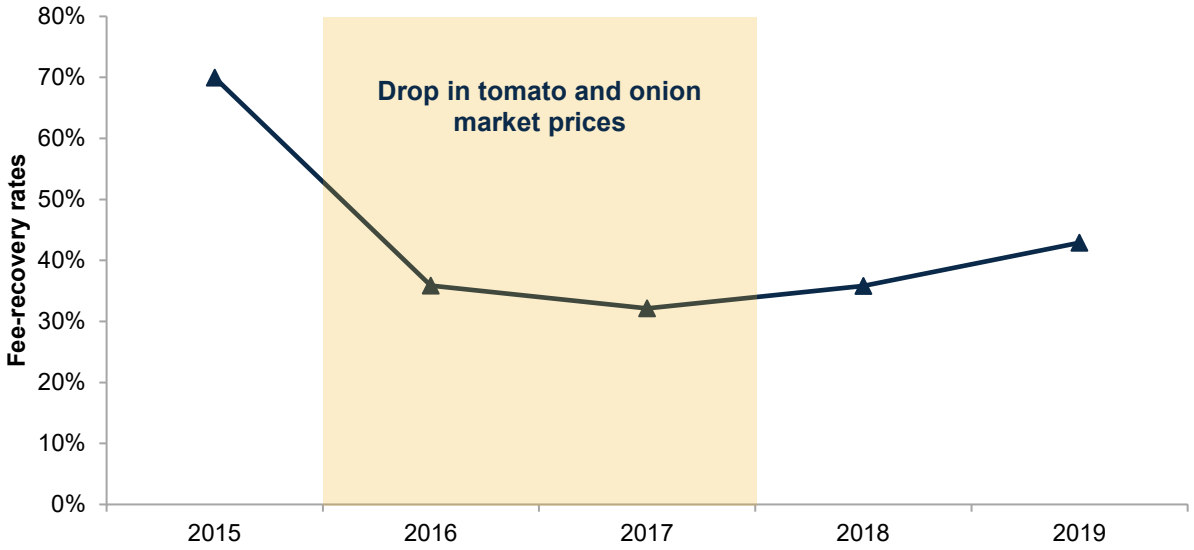


Source: WUA financial reports.

Notes: Fee-recovery rates shown for the rainyseason 2019 and the dry season 2019–2020. The rates include payments made only before the end of each season.

Most membership fee payments are late, negatively affecting the WUAs' cash flow and ability to pay their bills on time. Even though the WUA regulations stipulate that farmers must pay fees before the beginning of each season, many members who pay their fees are able to do so only at the end of the season, when they have made a profit selling the harvest. Moreover, many farmers can pay the season's fees only long after the season has ended; for example, only approximately 40 percent of farmers paid the fees before the end of the 2019 dry season and the 2019–2020 rainy season. Even fewer on-time payments were made before the end of the season in the years 2016 and 2017. These years were financially difficult for the farmers because of low market prices for tomatoes and onions, the two most profitable crops grown in the perimeter. The market prices for these key crops have since recovered, with end-of-season recovery rates recently trending up slightly (Figure IV.6).

Figure IV.6. End-of-season fee-recovery rates for all WUAs, by year

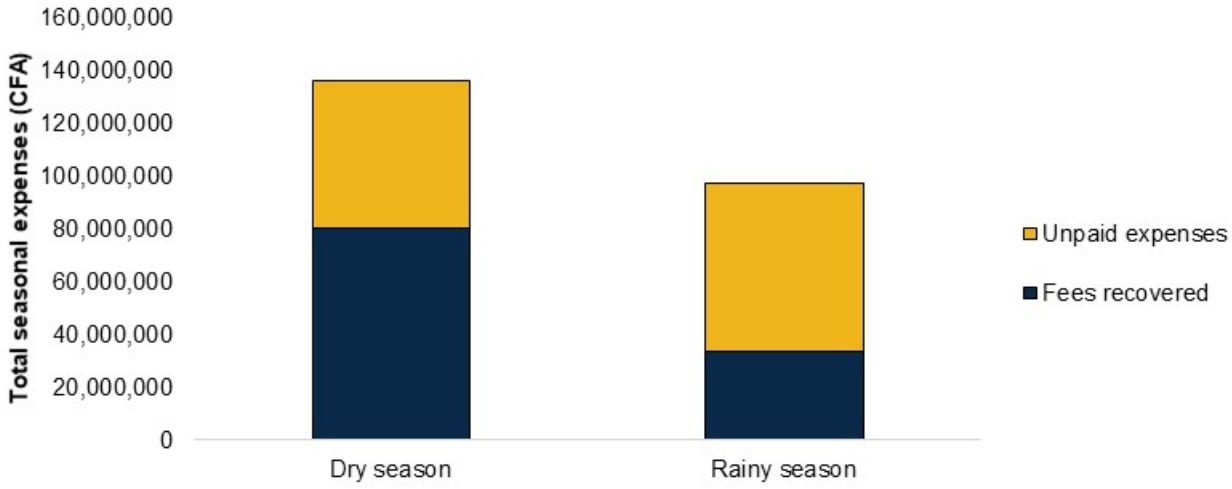


Source: WUA financial reports.

Notes: The rates combine the average rates for both seasons in each year for all WUAs. Dry seasons start in October and end in May and span two calendar years, with the year for the dry season annotated by the year in which the dry season began. For example, the dry season fee-recovery rates depicted in 2015 are for the dry season that started in 2015 and ended in 2016. The fee payment rates shown here include fees paid only by the end of each corresponding season.

Since the membership fees are the WUAs' only source of funds, the WUAs are not able to pay their operating expenses on time. The WUAs' financial reports revealed that most WUAs are paying their electricity bills for the previous season, along with some other expenses such as compensation of elected members. Overall, WUAs are paying only approximately half of their costs in each season (Figure IV.7). Compensation for elected members, *taxe d'ammenagement* to AMVS, and social security benefits for staff working at the pumping stations, such as guards and pumping technicians, are all among the WUAs' accumulating debts. In addition, the WUAs are contributing less to their savings than specified by their budgets.

Figure IV.7. Seasonal expenses for all WUAs, by season



Source: WUA financial reports.

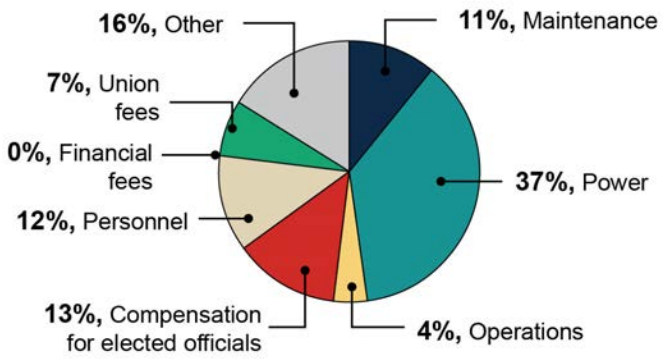
Notes: Seasonal expenses include debts from the previous season that were paid in this season. Dry season totals come from the 2019–2020 dry season, and the rainy season totals come from the 2019 rainy season. The fee payment rates shown here include fees paid only by the end of each corresponding season.

Recovery rates are lower during the rainy versus the dry season. During the dry season, farmers grow the most profitable crops, tomatoes and onions. On the other hand, during the rainy season, farmers on the perimeter grow staple crops such as maize and rice for sale as well for their own consumption, which does not generate the profits needed to pay membership fees. In addition, some farmers forgo paying the fees in the hope that rainwater alone will be enough to cultivate crops. As a result, rainy season fee-recovery rates are almost half those of the dry season (Figure IV.7). Although less irrigation is needed during the rainy season, the pump still operates during a dip in rainfall, especially at the beginning or end of the rainy season, and staff salaries and several operational expenses remain constant throughout the year.

Although end-of-season fee-recovery rates are low, the WUAs are more successful than neighboring perimeters in eventually collecting membership fee payments. The WUAs in the Di perimeter have higher fee payment rates compared to WUAs in neighboring perimeters. Cutting off the water supply for farmers who are behind on payments has proven an effective sanction for recovering fees. Most farmers start paying their fees when they receive a warning, before the water is cut off. If farmers continue to be delinquent on payments for several seasons, the WUAs may fine them. Eventually, some WUAs take possession of the plots of delinquent farmers and allow renters to farm those plots for two years if they pay the amount owned by the rightsholder. If the rightsholder can pay their debt, the rightsholder may retake possession of the plot after the two-year period expires.

Unaffordable electricity costs are detrimental to the WUAs' ability to maintain infrastructure. Electricity, which is essential for the ongoing operation of the pumping stations, is the greatest WUA expense, accounting for more than one-third of all expenses. The cost of electricity adversely affects the WUAs' ability to pay for other expenses, such as the purchase of replacement parts for broken infrastructure and elected officials' compensation. As a result, only 11 percent of the WUAs' budgets are spent on nonpower-related maintenance expenses, and most WUAs have delayed restocking replacement parts for maintenance during the 2019-2020 dry season (Figure IV.8). Most maintenance-related expenses go to hiring paid labor to clean the canals and drains in the place of farmer members. Several WUAs are exploring a switch to solar energy to power the pumping stations in a more cost-efficient matter, but they lack the funds needed to make the switch.

Figure IV.8. Annual expenses across all WUAs



Source: WUA financial reports.

Notes: This includes expenses from the last two seasons for which data are available: the 2019–2020 dry season and the 2019 rainy season. Power includes electricity and gas expenses; gas is used as a replacement for electricity when the power is out and represents a small portion of the power costs.

RQ3. What is an estimate of the remaining lifespan given current levels of maintenance?

Key findings

The state of disrepair of some of the infrastructure and financial challenges faced by the Di WUAs threaten the physical longevity of the entire irrigation network. Estimates of infrastructure longevity have decreased to 10 years for infrastructure built with earthen materials and 10 to 30 years for pumping stations and concrete components.

The state of disrepair of some of the infrastructure threatens the physical longevity of the entire irrigation network. Notably, dysfunctional drainage valves and clogged drains exacerbate flooding on the perimeter, which in turn threatens the integrity of the levee. Intensified flooding may also threaten the long-term fertility of the land in the perimeter, as chemical inputs accumulate in the soil to levels that affect crop productivity. The damaged access routes limit access to infrastructure in need of repair, further compromising maintenance work.

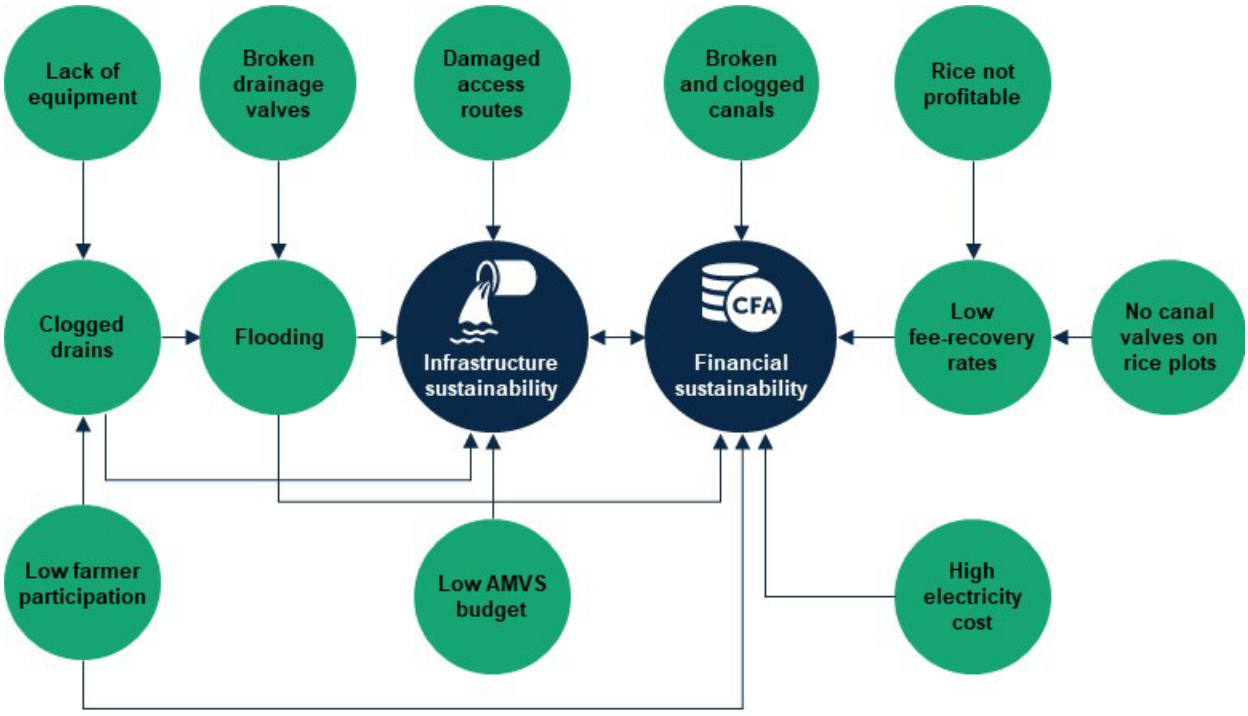
The WUAs of the Di perimeter face some financial sustainability challenges, which pose a major concern for the longevity of the infrastructure. The WUAs can collect only about half of the membership fees before the end of a given season, and a few WUAs have low final recovery rates even several years after the end of a season in large part because of the nature of rice plots. Late and low fee-recovery rates compromise the WUAs' financial ability. With fees their only source of funds, WUA budgets are further drained by high electricity costs. In addition, broken and clogged canals lower the efficiency with which water is pumped to farmers' plots; the greater the quantity of water lost on the way to the plots, the greater is the volume of electricity the WUAs need to pump the same amount water to the farmers. The WUAs hire laborers to make up for low farmer participation in basic infrastructure

maintenance such as cleaning canals and drains, a cost not foreseen at the design stage of the project. All combined, the various financial challenges are depleting the WUAs' savings faster than the WUAs are able to replenish them; the savings are crucial for making emergency repairs and performing infrastructure maintenance.

Infrastructure weaknesses and financial difficulties will likely compound in future years to threaten the perimeter's sustainability. Lack of financial resources has a large detrimental effect on the WUAs' ability to maintain and repair their vital irrigation infrastructure. The longer that infrastructure goes unmaintained and unrepaired, the more damage the system sustains and the more expensive it is to repair, as depicted in Figure IV.9. For example, clogged drains necessitate hired labor to clean them, which drains the WUA's budgets. Many WUA leaders also acknowledge that the current budget may suffice for the WUAs' O&M expenses at the moment, but they worry that the budget will fall short in the near future as infrastructure deteriorates at a faster pace with age and needs progressively more expensive repairs. Some WUA leaders reported that their current emergency savings are already too depleted to cover the cost of a significant maintenance emergency.

"At the moment, the savings are enough for the WUAs but they don't have to do emergency repairs frequently yet because the infrastructure is relatively new. This implies that the savings need to increase with time in order to keep up with increasing need for repairs as the infrastructure begins to break down more as it ages." – AMVS staff

Figure IV.9. Threats to sustainability of the Di perimeter



Estimated infrastructure longevity is slightly more pessimistic than it was two years ago; it depends mostly on maintenance and varies by infrastructure type. During the time of the interim evaluation, respondents estimated that infrastructure would last at least 25 years, the same as MCC's initial estimate. At that time, respondents even expressed optimism about expanding the irrigated area, and some expected

the infrastructure to function smoothly for decades without any breakdowns. Current estimates are less optimistic; the more fragile parts of the infrastructure—that is, the earthen components— are estimated to last 10 years or even less, and the more durable components such as the pumping stations and concrete canals are expected to last 10 to 30 years, given the current rate of membership payment rates and maintenance levels.[21]

"If you don't maintain a car, it gets ruined; an irrigated perimeter is the same when there are leaks, that's the beginning of the degradation. If we repair the issues, that improves the longevity of the perimeter, but if we don't, after a few years the perimeter won't be functional anymore." – APD Burkina (Interim evaluation KII 2018)

The longevity of infrastructure varies greatly by sector and depends on many factors. Overall, the Di perimeter faces several challenges to the sustainability of the irrigation network, both in terms of the longevity of the infrastructure and the financial sustainability of the WUAs that manage and maintain the network. However, the extent to which these challenges affect the perimeter varies by sector. As compared to other sectors, Sectors S1 and S2 have achieved a higher level of farmer participation in communal work and higher fee-recovery rates, resulting in healthier savings reserves that can be used to maintain the infrastructure. Meanwhile, the struggling sectors such as North and C2 may be in what Cutler and Zeckhauser (1998) refer to as a death spiral. High proportions of rice plots translate into both low fee-recovery rates even several years after the end of a season and limited farmer participation in maintenance. As a result, those sectors are unable to perform regular maintenance, causing infrastructure to deteriorate at a faster rate than in other sectors.

Table IV.2. Findings summary

Research question	Dimension	Findings
1. What is the current state of the infrastructure (main canals, roads, pumping stations) and functioning of the infrastructure?	Infrastructure	Deteriorating infrastructure causes more damage to the network by exacerbating flooding (clogged drains and broken valves) and impeding maintenance efforts (unusable access routes). Intensified flooding also threatens the long-term viability of the land in the perimeter, as chemical inputs accumulate in the soil. The WUAs lack support from AMVS, and the relationship between the WUAs and AMVS has worsened.
2. How well are the WUAs currently functioning with respect to (a) governance, (b) O&M, and (c) administrative and financial management?	Governance	The WUAs have the capacity to implement strong self-governance systems; all WUAs follow leadership protocols and maintain financial transparency.

[21] These current estimates are based on respondents' approximations. A third-party engineer was supposed to assess the infrastructure and provide an estimate, but due the spread of the COVID-19 pandemic and escalating security issues in the perimeter, the engineer was not able to do so.

Research question	Dimension	Findings
	O&M	The WUAs have appropriate routine maintenance systems for the pumping stations, but most sectors struggle to clean canals and drains given low farmer participation in communal work and the lack of appropriate tools. The damaged portions of the access routes have not been repaired, and the valves are beyond repair in many sectors. The North sector faces the most maintenance challenges, due to a higher proportion of land suitable only for rice cultivation, the sector's proximity to the river, and a large fraction of farmers who are not from the area.. The WUA union is effective in addressing and preventing some emergency breakdowns thanks to an inventory of repair parts.
	Financial management	The WUAs' financial sustainability is threatened by late fee payments in most sectors, low long-term fee-recovery rates in a few of the sectors, high electricity costs, low farmer participation in communal work, and leaky canals. WUAs lack effective means of payment enforcement; in the rice cultivation, in particular, WUAs cannot lock water valves for individual plots.
3. What is an estimate of the remaining lifespan given current levels of maintenance?	Infrastructure lifespan	From just a few years ago, estimates of infrastructure longevity have decreased to 10 years for infrastructure built with earthen materials (such as drains and small canals) and 10 to 30 years for pumping stations and concrete components (larger canals), but all estimates depend largely on maintenance.

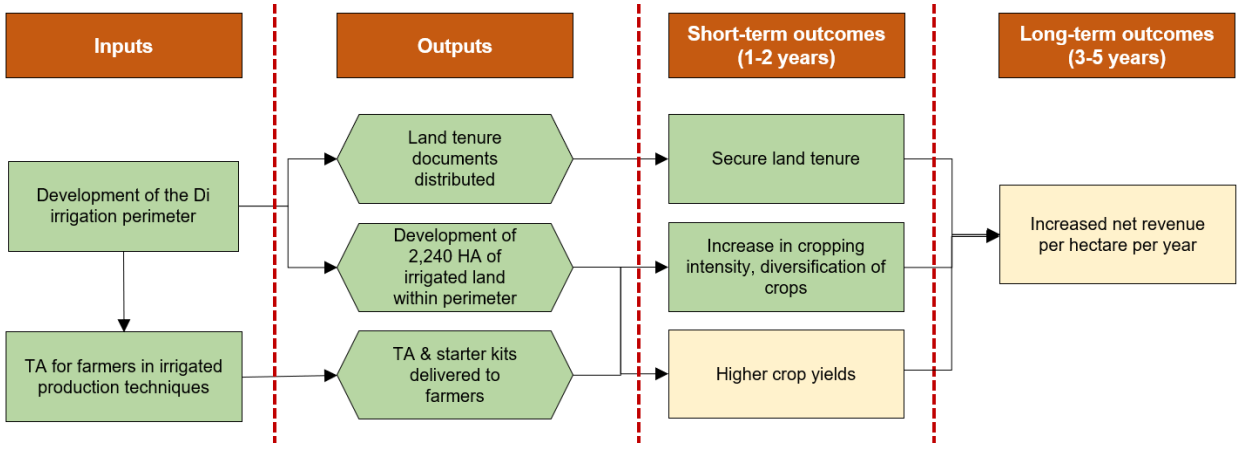
V. Summary and Implications

In the following section, we summarize the evaluation findings relative to the project's theory of change to provide learning related to future irrigation investments. We also summarize our learning about measurement and evaluation methodology with implications for evaluations of future investments of this type.

A. Project lessons

The Agriculture Development Project's objective was to support farmers so they could earn higher incomes from increased productivity and access to irrigation. The logic model for the Di perimeter is shown in Figure V.1. The figure shows logic model elements in solid green to indicate the steps of the Di perimeter program logic that our findings support and uses beige shading to indicate ambiguous findings.

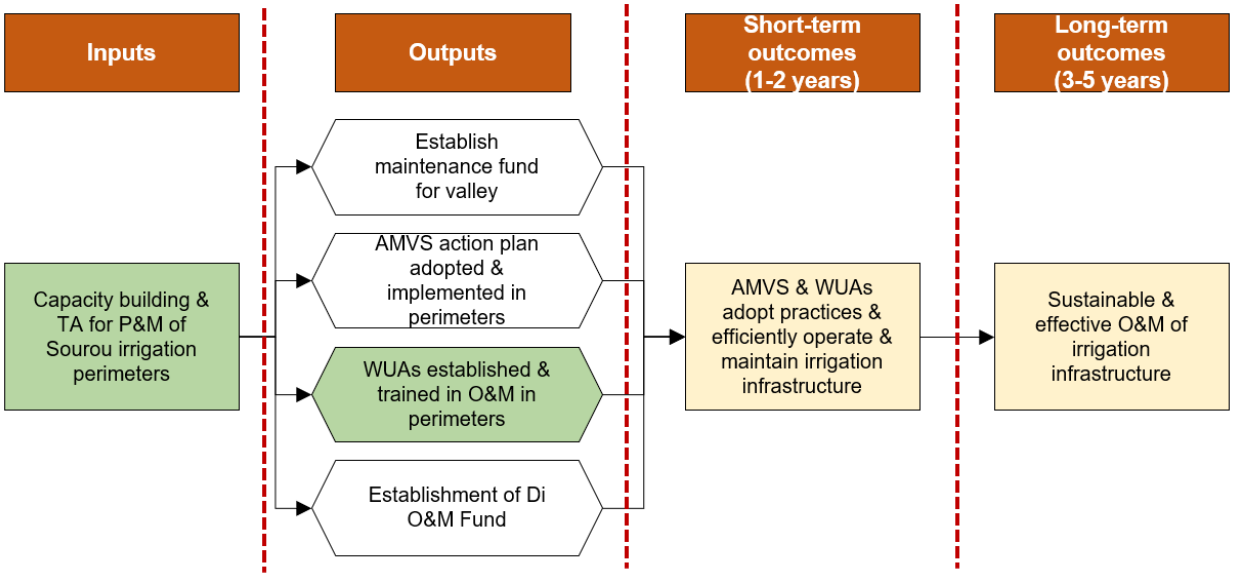
Figure V.1. Di perimeter program logic



In the interim report, we documented that the project provided the intended inputs and produced the intended program outputs. The interim report concluded that implementers successfully constructed the Di perimeter, the quality of infrastructure was high, and Di beneficiaries received the expected program benefits. In the interim report and this final report, we found that the project improved many of the intended short-term and medium-term outcomes, specifically related to improved land tenure, cropping intensity and, to a large extent, the adoption of the cropping patterns anticipated by the program. Because the program did not meet project targets on profits per hectare, and survey and crop-cut data provide contradictory information on whether yields increased, we shade these components in beige. Even though the project did not meet its profit targets, most PAPs—who as original owners of the land are a primary focus of the evaluation—report being better off than before the construction of the perimeter. In the absence of baseline information on agricultural information for three other groups of beneficiaries, Di neighbors and members of the women's and youth groups, we cannot estimate the change in agricultural incomes or outcomes due to the project. We can do so for Di Lottery beneficiaries, who constitute a control group for the lottery participants who did not receive land. We found strong impacts of receiving land on land tenure security, agricultural profits, agricultural income, and household income. Many of the increased agricultural outcomes and increased household incomes are due to farmers' ability to grow high-value cash crops, specifically onions and tomatoes, in the dry season due to the access to irrigation the perimeter provides.

The longevity of the benefits for PAPs, Di neighbors, women's groups, youth groups, and Di Lottery beneficiaries depends critically on the quality of operations and maintenance of the irrigation infrastructure. In Figure V.2, we relate our key findings from the evaluation of O&M on the perimeter to the O&M logic model. We focus this discussion on the findings from the final evaluation with respect to WUAs and WUA operations.

Figure V.2. Program logic for the Sourou O&M sub-activity



The capacity building and TA provided to the Di perimeters did establish and train water user associations (WUAs) in O&M. In terms of short- and medium-term outcomes, we found that the infrastructure made from concrete, such as primary canals and pumping stations, is in good shape and highly functional, but other components that were built using earthen materials such as access routes and drains have deteriorated and lost some functionality. Overall, the perimeter receives adequate levels of water, but some plots get flooded and others do not receive enough water. WUAs face challenges maintaining the infrastructure due to low farmer participation, lack of appropriate tools, and budget limitations. WUAs implement strong self-governance systems and effectively coordinate to hire specialized staff but they struggle with financial solvency; late fee payments and low long-term recovery rates, especially from farmers on rice plots, threaten their financial sustainability. As a result of the maintenance and financial challenges, the sustainability of the irrigation infrastructure on the Di perimeter is threatened and infrastructure longevity estimates have decreased to between 10 and 30 years. Combined with lower than expected profits per hectare, this leads to an estimated economic rate of return that is around zero or slightly negative. To guarantee the sustainability of the perimeter, water user fee recovery rates need to increase for WUAs to have the financial resources to improve maintenance and conduct repairs.

B. Measurement and methodological lessons

Our evaluation relied on a range of data collection and evaluation methodologies, and lessons from these different methodologies can inform future evaluations.

Different data collection methods yield substantially different results for key outcome measures in this setting. The estimates of area cultivated based on survey data are much lower than estimates from remote sensing data. Remote sensing-based approaches provide universal coverage over an area of

interest. These approaches are a promising solution for monitoring agricultural outcomes when faced with challenges like compositional changes to the sample resulting from participant out-migration or the entrance of new renters, as well as survey nonresponse. Due to security concerns followed by the COVID-19 pandemic, we had to switch to telephone surveys in the midst of data collection which resulted in an inability to follow renters or add farmers new to the perimeter to our sample. As a result, the survey estimates under-estimated area cultivated.

Crop-cut surveys provide a physical measurement of agricultural yields based on cutting and weighing random selections of harvested crop from fields, and estimated yields from crop-cut surveys also differ from survey-based findings. For all crops, total and per-hectare yield estimates from survey data were lower than estimates based on crop-cut measurements. The differences are so large for maize and onions that estimated yields based on crop cuts exceed project targets, while those based on survey information do not meet project targets.

Remote-sensing methods offer promising solutions to some challenges of survey data, but have their own limitations. Multiple and ideally sequential years of survey and crop-cut data collection will be essential as "ground-truthed data" to test the reliability of remote sensing based on sample predictions. For example, if remote-sensing algorithms are trained on data collected in 2019, the accuracy of algorithmic predictions for 2020 would require ground truth data for 2020. Remote sensing will not be able to answer many of the important questions that require a survey-based data collection approach, such as total household income, employment status, and level of food security.

Switching to COVID-19 compliant phone survey data collection required significant logistical adjustments, resources and time. The COVID-19 pandemic made a call center with many interviewers unsafe. Interviewer training could also no longer be conducted in person. Instead, we conducted training remotely using pre-recorded videos to concisely convey content while reducing bandwidth requirements. To allow for interaction and assessment of understanding, we complemented the pre-recorded materials with online meeting tools and group messaging services. To be able to ensure high quality work, we recorded a random selection of interviews that the supervisors would listen to give feedback to enumerators. Adapting the in-person questionnaire with several iterations to reduce survey length while also developing these training tools and the distributed call center procedures concurrently proved challenging but was ultimately successful, albeit with a significant delay.

Best practices for addressing limits to survey length for agricultural surveys conducted over the phone are lacking. The significant cuts required to reduce survey length also posed methodological challenges. We limited data collection to two plots, split—if households owned both—between a randomly sampled plot on the Di perimeter and one randomly sampled plot outside of the perimeter. Similarly, data collection on non-agricultural income was limited to a maximum of three household members. In order to construct total agricultural income and household income, we adopted simple and multiple imputation methods to predict agricultural profits on non-surveyed plots and to predict incomes for non-surveyed household members. A lack of prior research using this approach in agricultural evaluations mean that we could not follow established best practices. Future work should explore how best to apply simple and multiple imputation methods when designing agricultural evaluations that rely on survey data collection conducted via mobile phones.

A comparison of impact evaluation estimation methodologies shows that our randomized controlled trial (RCT) yielded larger point estimates than the regression discontinuity design (RDD), and only the point estimates from the RCT and an RDD variant were statistically significant. In this evaluation, we are able to estimate the impact of being a lottery winner by comparing agricultural and household outcomes of participants in the Di Lottery who won the lottery with outcomes of those who did not. This analysis uses the RCT toolbox. In addition, we are able to implement an RDD—a second impact evaluation methodology. In this design, we use the fact that lottery applicants were first graded on a scale of 0 to 100 according to a set of eligibility criteria. Only applicants with a score higher than 60 were admitted to the lottery. The RDD uses the threshold to compare lottery participants with scores slightly above the threshold (who won the lottery) with applicants with scores slightly below the threshold (who did not win the lottery). In many cases when an RCT is infeasible, an RDD is feasible if a program or benefit is assigned based on a cutoff in a continuous variable, such as income or test scores. In a methodological contribution of this report, we compare the RDD estimate with the RCT estimate. We find that the RDD treatment estimates at the cutoff for agricultural profit and income measures are about one-third lower than the RCT estimates and are not statistically significantly different from zero. However, an approach developed by Angrist and Rokkannen (2015) that extrapolates away from the cutoff provides robust estimates that are much closer to the RCT estimates, and is an approach that may be feasible in some contexts when an RCT is not.

References

Aarnoudse, Eefje, Alvar Closas, and Nicole Lefore. "Water User Associations: A Review of Approaches and Alternative Management Options for Sub-Saharan Africa." IWMI Working Paper 180. Colombo, Sri Lanka: International Water Management Institute (IWMI), 2018. doi: 10.5337/2018.210

Akudugu, Mamudu Abunga, Ben Vas Nyamadi, and Saa Dittoh. "Transforming smallholder agriculture in Africa through irrigation: an assessment of irrigation impact pathways in Ghana." International Conference of the African Association of Agricultural Economists, September 2016.

Ali, Daniel Ayalew, Klaus Deininger, and Markus Goldstein. "Environmental and Gender Impacts of Land Tenure Regularization in Africa: Pilot Evidence from Rwanda." *Journal of Development Economics*, vol. 110, 2014, pp. 262–275.

Angrist, Joshua D., and Miikka Rokkanen. "Wanna Get Away? Regression Discontinuity Estimation of Exam School Effects Away from the Cutoff." *Journal of the American Statistical Association*, vol. 110, no. 512, 2015, pp. 1331–1344.

Bardhan, P., and D. Mookherjee. "Land Reform and Farm Productivity in West Bengal." Palo Alto, CA: Stanford Center for International Development, 2007.

Besley, Timothy, and Maitreesh Ghatak. "Property Rights and Economic Development." In *Handbook of Development Economics, Vol. 5*, edited by Dani Rodrik and Mark Rosenzweig. Amsterdam: Elsevier, 2010.

Borkum, Evan, Anitha Sivasankaran, Elena Moroz, and Matt Sloan. "Evaluation of the Fruit Tree Productivity Project in Morocco: Final Report of Irrigation Activities." Washington, DC: Mathematica, February 2020.

Borkum, Evan, Jane Fortson, Irina Cheban, and Randall Blair. "Moldova Transition to High-Value Agriculture Project Evaluation: Interim Findings." Seattle, USA: Mathematica, 2018.

Brasselle, Anne-Sophie, Frédéric Gaspart, and Jean-Philippe Platteau. "Land Tenure Security and Investment Incentives: Puzzling Evidence from Burkina Faso." *Journal of Development Economics*, vol. 67, no. 2, 2002, pp. 373–418.

Coen, Thomas, Sarah M. Hughes, Matthew Ribar, William Valletta, Kristen Velyvis. "Evaluation of the Irrigation and Water Resource Management Project in Senegal: Interim Evaluation Report." Washington, DC: Mathematica July 2019.

Chauvin, N. D., F. Mulangu, and G. Porto. "Food Production and Consumption Trends in Sub-Saharan Africa: Prospects for the Transformation of the Agricultural Sector." Addis Ababa, Ethiopia: United Nations Development Programme, Regional Bureau for Africa, 2012. Available at http://www.undp.org/content/dam/rba/docs/Working%20Papers/Food%20Production%20and%20Consumption.pdf. Accessed September 22, 2016.

Cutler, David M., and Richard J. Zeckhauser. "Adverse Selection in Health Insurance." *Forum for Health Economics and Policy*, 1998, vol. 1, no. 2.

D'Agostino, Anthony Louis and Christopher Ksoll. "Results of Di Perimeter Exploratory Remote Sensing Analysis." Memo submitted to the Millennium Challenge Corporation, 2020.

de Fraiture, Charlotte, Gael Ndanga Kouali, Hilmy Sally, and Priva Kabre. "Pirates or Pioneers? Unplanned Irrigation Around Small Reservoirs in Burkina Faso." *Agricultural Water Management*, vol. 131, January 2014.

Deininger, Klaus, and Gershon Feder. "Land Registration, Governance, and Development: Evidence and Implications for Policy." *World Bank Research Observer*, vol. 24, no. 2, 2009, pp. 233–266.

DesJardins, Stephen and Brian McCall. "The Impact of Gates Millennium Scholars Program on the Retention, College Finance and Work-Related Choices, and Future Educational Aspirations of Low-Income Minority Students," Unpublished manuscript, University of Michigan, Center for the Study of Higher and Postsecondary Education, Ann Arbor, MI. 2008.

Dillon, Andrew. "Access to Irrigation and the Escape from Poverty: Evidence from Northern Mali." IFPRI discussion paper 00782. Washington, DC: International Food Policy Research Institute, 2008.

Dillon, Andrew. "The Effect of Irrigation on Poverty Reduction, Asset Accumulation, and Informal Insurance: Evidence from Northern Mali." World Development, vol. 39, no. 12, December 2011, pp. 2165–2175.

Dong, Yingying, and Arthur Lewbel. "Identifying the Effect of Changing the Policy Threshold in Regression Discontinuity Models." *Review of Economics and Statistics*, vol. 97, no. 5, 2015, pp. 1081–1092.

Food and Agriculture Organization of the United Nations (FAO). "AQUASTAT Main Database." 2016. Available at http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en. Accessed February 19, 2017.

Food and Agriculture Organization of the United Nations (FAO). "Country Fact Sheet: Burkina Faso." Rome, Italy: Food and Agriculture Organization of the United Nations, 2016. Available at http://www.fao.org/nr/water/aquastat/data/cf/readPdf.html?f=BFA-CF_eng.pdf. Accessed September 22, 2016.

Food and Agriculture Policy Decision Analysis (FAPDA). "Country Fact Sheet on Food and Agriculture Policy Trends: Burkina Faso." Rome, Italy: Food and Agriculture Organization of the United Nations, 2014. Available at http://www.fao.org/docrep/field/009/i3760e/i3760e.pdf. Accessed September 22, 2016.

Ghatak, M., and S. Roy. "Land Reform and Agricultural Productivity in India: A Review of the Evidence." *Oxford Review of Economic Policy*, vol. 23, no. 2, 2007, pp. 251–269.

Giordano, Mark, Regassa Namara, and Elisabeth Bassini. "The impacts of irrigation: A review of published evidence." Washington, DC: The World Bank, 2020.

Guido Imbens and Karthik Kalyanaraman. "Optimal Bandwidth Choice for the Regression Discontinuity Estimator." The Review of Economic Studies, vol. 79, no. 3, July 2012, pp. 933–959.

Huber, Martin. "Identifying Causal Mechanisms (Primarily) Based on Inverse Probability Weighting." Journal of Applied Econometrics, vol. 29, no. 6, June 2013, pp. 920–943.

Hussain, Intizar, Deeptha Wijerathna. "Irrigation and Income-Poverty Alleviation: A Comparative Analysis of Irrigation Systems in Developing Asia." International Water Management Institute (IWMI), February 2004.

Imai, Kosuke, Luke Keele, and Dustin Tingley. "A General Approach to Causal Mediation Analysis." Psychological Methods, vol. 15, no. 4, December 2010, pp. 309–334.Hussain, Intizar, Munir A. Hanjra. "Irrigation and poverty alleviation: review of the empirical evidence." *Irrigation and Drainage*, vol, 53, no. 1, 2004.

Kline, Patrick. "Oaxaca-Blinder as a Reweighting Estimator." American Economic Review: Papers and Proceedings, vol. 101, no. 3, 2011, pp. 532–537.

Ksoll, Christopher, Chantal Toledo, Seth Morgan, Anca Dumitrescu, and Kristen Velyvis. "Evaluation of the Burkina Faso Agriculture Development Project: Design Report." Washington, DC: Mathematica, June 2017.

Ksoll, Christopher, Randall Blair, Seth Morgan, and Kristine Bos. "Evaluation of the Burkina Faso Agriculture Development Project: Baseline Report." Washington, DC: Mathematica, April 2018.

Ksoll, Christopher, Randall Blair, Seth Morgan, Caroline Lauver, and Yiriyibin Bambio. "MCC Burkina Faso—Agriculture Development Project Interim Report." Washington, DC: Mathematica, July 2019.

Kuwornu, John, Eric Owusu, Eric. "Irrigation access and per capita consumption expenditure in farm households: Evidence from Ghana." *Journal of Development and Agricultural Economics*, vol. 4, no. 3, 2012.

Linkow, Benjamin. "Causes and Consequences of Perceived Land Tenure Insecurity: Survey Evidence from Burkina Faso." *Land Economics*, vol. 92, 2016, pp. 308–327.

Millennium Challenge Corporation (MCC). "Final Report: Di." Washington, DC: Millennium Challenge Corporation, 2008.

Millennium Challenge Corporation (MCC). "Burkina Faso Compact." Washington, DC: Millennium Challenge Corporation, 2016b. Available at https://www.mcc.gov/where-we-work/program/burkina-faso-compact. Accessed September 22, 2016.

Millennium Challenge Corporation (MCC). "Di Land Allocation (as of July 8, 2014)." Excel spreadsheet. Washington, DC: Millennium Challenge Corporation, 2016a.

Millennium Challenge Corporation (MCC). "Burkina Faso Agricultural Development Project, Di Irrigated Agriculture Closeout ERR." Washington, DC: MCC, 2017. Available at https://assets.mcc.gov/content/uploads/2017/04/mcc-err-burkina-di-irrigation-close.xls. Accessed April 26, 2017.

Ministère de l'Agriculture et des Aménagements Hydro-agricoles (MAAH). "Analyse de la compétivité de la filière riz local au Burkina Faso." Ouagadougou, Burkina Faso : MAAH, October 2009.

Ministère de l'Agriculture et des Aménagements Hydro-agricoles (MAAH). "Rapport de synthèse en productions végétales sur le périmètre irrigué de Di de 2014 à 2019." Sourou, Burkina Faso : MAAH, February 2020.

Muchara, B., G. Ortmann, E. Wale, and M. Mudhara. "Collective Action and Participation in Irrigation Water Management: A Case Study of Mooi River Irrigation Scheme in KwaZulu-Natal Province, South Africa." *Water SA,* vol. 40, no. 4, 2014.

Prindex. "Burkina Faso" 2020. Available at https://www.prindex.net/data/burkina-faso/. Accessed October 26, 2020.

Payne, Geoffrey, Alain Durand-Lasserve, and Carole Rakodi. "The Limits of Land Titling and Home Ownership." *Environment and Urbanization*, vol. 21, 2009, pp. 443–462.

Rasphone, Arounyadeth, Fumio Osanami, and Takumi Kondo. "The Irrigation Service Fees and Affordability After the Management Transfer: Empirical Evidence from Ban Vuen-Tonhen WUA in Savannakhet Province, Lao PDR." International Association of Agricultural Economists (IAAE), 2006 Annual Meeting, August 12–18, 2006, Queensland, Australia.

Sally, H., H. Lévite, and J. Cour. "Local Water Management of Small Reservoirs: Lessons from Two Case Studies in Burkina Faso." *Water Alternatives*, vol. 4, no. 3, 2011, pp. 365–382.

Sanfo, Safiétou, Bruno Barbier, Isabelle W.P. Dabiré, Paul L.G. Vlek, William M. Fonta, Boubacar Ibrahima, Boubacar Barry. "Rainfall Variability Adaptation Strategies: An Ex-ante Assessment of Supplemental Irrigation from Farm Ponds in Southern Burkina Faso." *Agricultural Systems*, vol. 152, 2017, pp. 80–89.

Sawadogo, Alidou, Louis Kouadio, Farid Traoré, Sander J. Zwart, Tim Hessels, Kemal Sulhi Gündoğdu. "Spatiotemporal Assessment of Irrigation Performance of the Kou Valley Irrigation Scheme in Burkina Faso Using Satellite Remote Sensing-Derived Indicators." *International Journal of Geo-Information*, 9, 2020, p. 484.

Senanayake, Nari, Aditi Mukherji, and Mark Giordano. "Re-visiting What We Know About Irrigation Management Transfer: A Review of the Evidence." *Agricultural Water Management,* vol. 149, 2015, pp. 175–186.

Shah, Tushaar. "Past, Present, and the Future of Canal Irrigation in India." In *India Infrastructure Report 2011–Water: Policy and Performance for Sustainable Development.* New Delhi: Oxford University Press, 2011.

Shah, Tushaar, Barbara Van Koppen, Douglas Merrey, Marna de Lange, and Madar Samad. "Institutional Alternatives in African Smallholder Irrigation: Lessons from International Experience with Irrigation Management Transfer." Colombo, Sri Lanka: International Water Management Institute (IWMI), 2002.

Tucker, J., and L. Yirgu. "Small-Scale Irrigation in the Ethiopian Highlands: What Potential for Poverty Reduction and Climate Adaptation?" Ripple briefing paper no. 3. Addis Ababa, Ethiopia: WaterAid Ethiopia, 2010. Available at http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6141.pdf. Accessed February 4, 2015.

Turiansky, Abbie. "Collective Action in Games as in Life: Experimental Evidence from Canal Cleaning in Haiti." Working Paper 57. Oakland, USA: Mathematica, 2019.

USAID Burkina Faso. "Fact Sheet: Agriculture and Food Security." Washington DC: USAID, 2015. Available at https://www.usaid.gov/sites/default/files/documents/1860/BF%20Fact%20Sheet%20-%20Food%20Security.pdf. Accessed September 22, 2016.

Venot, Jean-Philippe. "Rethinking Commons Management in Sub-Saharan West Africa: Public Authority and Participation in the Agricultural Water Sector." *Water International*, vol. 39, no. 4, 2014.

World Bank. "Burkina Faso Revue du Secteur: Support to Burkina Faso Land Policy ASA." June 25, 2020.

Appendix A

Additional Materials

This page has been left blank for double-sided copying.

A.1. Additional Tables and Figures

Table A.1. Interim survey sampling frame

Beneficiary category	Number of beneficiaries	Hectares owned in Di perimeter	Survey sample size	Crop-cutting sample size	Sampling strata
PAP	846	1,099	275	110	Gender, plot acreage, plot type; in some strata sampling proportional to size
Non-PAP from neighboring village	461	318	79	32	Gender, plot acreage, plot type
Di Lottery beneficiary	503	711	503	71	None
Women's groups	1725	90	30	20	None
Youth groups	846	16	30	20	None
Other: tree nursery, National research institute (INERA), Mixed groups	17*	13	0	0	
All Di beneficiaries	**4398**	**2,246** [a]	**917**	**253**	

Note: [a] Sum of the hectares owned by beneficiary groups exceed total land due to rounding error.

Table A.2. Number of yield measurement squares in the crop-cut survey, by crop.

	Dry season		Rainy season	
Crops	Plots with any measurement square (measured)	Number of measurement squares (measured)	Plots with any measurement square (placed)	Number of measurement squares (placed)
Tomatoes	147	284	9	9
Onions	149	340	0	0
Maize	45	76	237	461
Rice	78	170	71	127
Cowpeas	34	56	2	2
Soybeans	0	0	4	4
Total	**230**	**926**	**269**	**603**

Table A.3. Land access, crop cultivation, and agricultural practices for Di Lottery applicants and their households (rainy season)

Outcome	Treatment group mean	Control group mean	Estimated difference	*p*-value of difference
Cultivates any land on the Di perimeter (percentage)	82%	18%	63%	0.00
Total area cultivated-rainy season (hectares)	1.81	2.19	-0.38	0.34
Crops cultivated during rainy season (percentage)				
Tomatoes	1%	0%	0%	0.33
Onions	1%	1%	0%	0.88
Maize	80%	70%	10%	0.00
Rice	37%	22%	15%	0.00
Millet	11%	20%	-9%	0.00
Sorghum	7%	14%	-7%	0.00
Beans	4%	13%	-9%	0.00
Peanuts	7%	15%	-8%	0.00
Use of agricultural inputs during rainy season (percentage)				
Chemical fertilizer	96%	82%	14%	0.00
Organic fertilizer	42%	53%	-11%	0.00
Phytosanitary products	91%	78%	13%	0.00
Improved seeds	34%	27%	7%	0.01
Hired labor during dry season (any plot) (percentage)	59%	53%	6%	0.07
Number of different types of modern agricultural equipment used in the rainy season [a]	4.3	4.4	0.0	0.76
Cost of inputs per hectare (FCFA)				
Chemical fertilizer	51,724	50,932	791	0.90
Organic fertilizer	7,439	7,968	-529	0.81
Phytosanitary products	5,366	6,450	-1,084	0.22
Improved seeds	1,292	1,255	37	0.91
Hired labor	15,217	15,122	95	0.97
Sample size: all lottery participants	418	783		
Sample size: in-person survey respondents	162	336		

Source: Endline survey, 2020.

[a] Information for this indicator is only available for all plots for the in-person survey.

Table A.4. Program effects of winning the Di Lottery on land documentation

Dependent variable	Treatment	Control	*p*-value
Women			
Has any formal land documentation	92%	25%	<0.01
Has rural land possession certificate	7%	5%	0.53
Has land title	45%	10%	<0.01
Has lease document	38%	6%	<0.01
Has written contract with landowner	1%	1%	0.72
Has written notes from customary process (Procès Verbal de l'Arbre à Palabre)	1%	1%	0.93
Men			
Has any formal land documentation	86%	19%	<0.01
Has rural land possession certificate	6%	4%	0.20
Has land title	47%	9%	<0.01
Has lease document	35%	3%	<0.01
Has written contract with landowner	0%	0%	0.34
Has written notes from customary process (Procès Verbal de l'Arbre à Palabre)	5%	4%	0.45
Rice			
Has any formal land documentation	82%	20%	<0.01
Has rural land possession certificate	7%	4%	0.12
Has land title	43%	9%	<0.01
Has lease document	37%	4%	<0.01
Has written contract with landowner	1%	0%	0.55
Has written notes from customary process (Procès Verbal de l'Arbre à Palabre)	4%	5%	0.70
Polyculture			
Has any formal land documentation	89%	20%	<0.01
Has rural land possession certificate	7%	4%	0.05
Has land title	51%	9%	<0.01
Has lease document	33%	4%	<0.01
Has written contract with landowner	1%	0%	0.74
Has written notes from customary process (Procès Verbal de l'Arbre à Palabre)	7%	5%	0.17
Sample size plots	**449**	**783**	

Source: Endline (2020) Survey.

Note: Analysis estimates impact on land documentation for lottery winners for the Di perimeter plot with land documentation for plots not on the Di perimeter for lottery controls, accounting for preference strata.

A rural land possession certificate is a document granting its holder a long-term right to possess and use a plot of land; it provides formal legal recognition of a customary land right (*attestation de possession foncière rurale* in French).

Table A.5. Program effects of winning the Di Lottery on perceptions of land tenure security

Dependent variable	Treatment	Control	*p*-value
Women			
Short-term outcomes: Perception of land tenure security and transfer rights			
Worried about loss of land access in next 5 years: not at all	55%	60%	<0.01
Worried about loss of land access in next 5 years: a little	24%	29%	<0.01
Worried about loss of land access in next 5 years: a lot	21%	11%	<0.01
Perceived likelihood of loss of land access in next 5 years: not at all likely	81%	82%	<0.01
Perceived likelihood of loss of land access in next 5 years: a little	8%	11%	0.06
Perceived likelihood of loss of land access in next 5 years: very likely	11%	7%	.02
Most likely to take over if plot lost			
Family member (not spouse)	14%	23%	0.39
Government	23%	30%	0.06
Previous owner or their family	3%	18%	0.72
Owner (if plot is rented)	-3%	11%	0.71
WUA	29%	7%	0.03
Rights associated with the land			
Right to bequeath land (with or without external approval)	81%	76%	<0.01
Right to sell land (with or without external approval)	18%	20%	<0.01
Right to let land (with or without external approval)	78%	59%	<0.01
Not worried about losing land after divorce	80%	95%	<0.01
Not worried about losing land after spousal death	84%	94%	<0.01
Short-term outcome: Conflict			
Involved in land conflict	1%	1%	0.37
Short-term outcome: Land rental			
Rents out land in any season	9%	2%	0.01
Rents out land in dry season	8%	1%	0.01
Rents out land in rainy season	4%	1%	0.09
Short-term outcome: Access to credit			
Applied for a loan with bank or microfinance institution in past three years	24%	17%	<0.01
Used plot of land as collateral	17%	6%	0.26
Men			
Short-term outcomes: Perception of land tenure security and transfer rights			

Dependent variable	Treatment	Control	*p*-value
Worried about loss of land access in next 5 years: not at all	58%	58%	<0.01
Worried about loss of land access in next 5 years: a little	30%	28%	<0.01
Worried about loss of land access in next 5 years: a lot	12%	15%	<0.01
Perceived likelihood of loss of land access in next 5 years: not at all likely	84%	79%	<0.01
Perceived likelihood of loss of land access in next 5 years: a little	12%	11%	<0.01
Perceived likelihood of loss of land access in next 5 years: very likely	4%	11%	0.02
Most likely to take over if plot lost			
Family member (not spouse)	24%	30%	<0.01
Government	21%	11%	<0.01
Previous owner or their family	8%	26%	0.09
Owner (if plot is rented)	12%	11%	0.01
WUA	24%	1%	<0.01
Rights associated with the land			
Right to bequeath land (with or without external approval)	79%	81%	<0.01
Right to sell land (with or without external approval)	24%	26%	<0.01
Right to let land (with or without external approval)	74%	59%	<0.01
Not worried about losing land after divorce	91%	89%	<0.01
Not worried about losing land after spousal death	89%	87%	<0.01
Short-term outcome: Conflict			
Involved in land conflict	0%	3%	0.86
Short-term outcome: Land rental			
Rents out land in any season	16%	2%	<0.01
Rents out land in dry season	13%	2%	<0.01
Rents out land in rainy season	11%	1%	<0.01
Short-term outcome: Access to credit			
Applied for a loan with bank or microfinance institution in past three years	18%	13%	<0.01
Used plot of land as collateral	13%	1%	0.02
Polyculture			
Short-term outcomes: Perception of land tenure security and transfer rights			
Worried about loss of land access in next 5 years: not at all	55%	57%	<0.01
Worried about loss of land access in next 5 years: a little	30%	29%	<0.01
Worried about loss of land access in next 5 years: a lot	16%	13%	<0.01

Dependent variable	Treatment	Control	*p*-value
Perceived likelihood of loss of land access in next 5 years: not at all likely	83%	80%	<0.01
Perceived likelihood of loss of land access in next 5 years: a little	11%	11%	<0.01
Perceived likelihood of loss of land access in next 5 years: very likely	6%	9%	0.01
Most likely to take over if plot lost			
Family member (not spouse)	34%	33%	<0.01
Government	22%	14%	<0.01
Previous owner or their family	6%	20%	0.28
Owner (if plot is rented)	12%	11%	0.01
WUA	21%	2%	<0.01
Rights associated with the land			
Right to bequeath land (with or without external approval)	80%	78%	<0.01
Right to sell land (with or without external approval)	27%	23%	<0.01
Right to let land (with or without external approval)	75%	60%	<0.01
Not worried about losing land after divorce	83%	89%	<0.01
Not worried about losing land after spousal death	83%	89%	<0.01
Short-term outcome: Conflict			
Involved in land conflict	2%	3%	0.12
Short-term outcome: Land rental			
Rents out land in any season	12%	2%	<0.01
Rents out land in dry season	11%	1%	<0.01
Rents out land in rainy season	7%	1%	<0.01
Short-term outcome: Access to credit			
Applied for a loan with bank or microfinance institution in past three years	19%	13%	<0.01
Used plot of land as collateral	21%	2%	<0.01
Rice			
Short-term outcomes: Perception of land tenure security and transfer rights			
Worried about loss of land access in next 5 years: not at all	52%	59%	<0.01
Worried about loss of land access in next 5 years: a little		28%	<0.01
Worried about loss of land access in next 5 years: a lot	15%	14%	<0.01
Perceived likelihood of loss of land access in next 5 years: not at all likely	79%	80%	<0.01
Perceived likelihood of loss of land access in next 5 years: a little	12%	10%	<0.01
Perceived likelihood of loss of land access in next 5 years: very likely	9%	9%	<0.01
Most likely to take over if plot lost			

Dependent variable	Treatment	Control	*p*-value
Family member (not spouse)	18%	29%	0.02
Government	18%	13%	<0.01
Previous owner or their family	11%	24%	0.03
Owner (if plot is rented)	17%	11%	<0.01
WUA	24%	2%	<0.01
Rights associated with the land			
Right to bequeath land (with or without external approval)	75%	80%	<0.01
Right to sell land (with or without external approval)	18%	24%	<0.01
Right to let land (with or without external approval)	70%	59%	<0.01
Not worried about losing land after divorce	89%	89%	<0.01
Not worried about losing land after spousal death	87%	88%	<0.01
Short-term outcome: Conflict			
Involved in land conflict	1%	2%	0.10
Short-term outcome: Land rental			
Rents out land in any season	15%	2%	<0.01
Rents out land in dry season	11%	2%	<0.01
Rents out land in rainy season	12%	1%	<0.01
Short-term outcome: Access to credit			
Applied for a loan with bank or microfinance institution in past three years	24%	14%	<0.01
Used plot of land as collateral	4%	3%	0.28
Sample size plots	**540**	**1322**	

Table A.6. Program effects of winning the Di Lottery on long-term land outcomes

Dependent variable	Treatment	Control	*p*-value
Long-term outcome: Land investment			
Women			
Any land investment in past two years	12%	5%	0.01
Invested in land by planting trees	7%	2%	0.02
Invested in land by building a fence	0%	0%	0.00
Setting up an irrigation system	2%	0%	0.28
Undertaking landscaping	0%	0%	0.00
Value of land investment in the last two years (excluding unpaid household labor) (FCFA)	63,159	30,231	<0.01
Labor time invested into land (days)	-9.4	5.9	0.06
Men			
Any land investment in past two years	12%	7%	<0.01
Invested in land by planting trees	6%	2%	<0.01
Invested in land by building a fence	<1%	<1%	0.70
Setting up an irrigation system	<1%	<1%	0.11

Dependent variable	Treatment	Control	*p*-value
Undertaking landscaping	3%	<1%	<0.01
Value of land investment in the last two years (excluding unpaid household labor) (FCFA)	69,593	53,995	<0.01
Labor time invested into land (days)	2.76	12.30	0.59
Rice			
Any land investment in past two years	14%	7%	<0.01
Invested in land by planting trees	9%	2%	<0.01
Invested in land by building a fence	<1%	<1%	0.74
Setting up an irrigation system	<1%	0%	0.31
Undertaking landscaping	2%	<1%	0.02
Value of land investment in the last two years (excluding unpaid household labor) (FCFA)	35,062	46,231	0.05
Labor time invested into land (days)	2.39	12.01	0.60
Polyculture			
Any land investment in past two years	12%	7%	<0.01
Invested in land by planting trees	6%	2%	<0.01
Invested in land by building a fence	<1%	<1%	0.80
Setting up an irrigation system	1%	0%	0.14
Undertaking landscaping	2%	<1%	0.02
Value of land investment in the last two years (excluding unpaid household labor) (FCFA)	71,615	47,347	<0.01
Labor time invested into land (days)	5.83	11.87	0.29
Sample size plots	**537**	**1346**	

Source: Interim (2016) and Endline (2020) Surveys.

Note: Analysis estimates impact on land documentation for lottery winners for the Di perimeter plot with land documentation for plots not on the Di perimeter for lottery controls, accounting for preference strata.

Table A.7. Key inputs into close-out and evaluation-based CBA models

	Close-out CBA			Evaluation CBA		
	Profits/ha (1,000 FCFA)	Share of area planted	Total profits (1,000 FCFA / 1 M FCFA)	Profits/ha (1,000 FCFA)	Share of area planted	Total profits (1,000 FCFA / 1 M FCFA)
Dry season						
Tomato	1,630	0.04	136,764	219	0.20	92,708
Onions	2,427	0.81	4,204M	1,160	0.58	1,458M
Maize	68	0.02	3,199	2.3	0.00	-
Rice	157	0.10	34,658	189	0.22	88,708
Niebe	163	0.00	223	-	0.00	-
Other	110	0.02	5,446	-	0.00	-
Rainy season						
Tomato	1,630	0.00	579	-	0.00	-
Onions	2,427	0.09	463,894	-	0.00	-
Maize	68	0.83	120,405	2.3	0.79	4,051
Rice	157	0.07	23,614	258	0.21	118,048
Niebe	163	0.00	871	-	0.00	-
Other	110	0.01	2,013	-	0.00	-
O&M Costs			689M	NA		NA
Total profit			4,138M			1,761M

Source: MCC Closeout CBA (MCC 2017); Endline (2020) Surveys.

Note: Crop-specific profits per hectare and total profits for the evaluation CBA are calculated subtracting O&M costs.

Figure A.1 Crop choices on Di perimeter, by type of plot sample

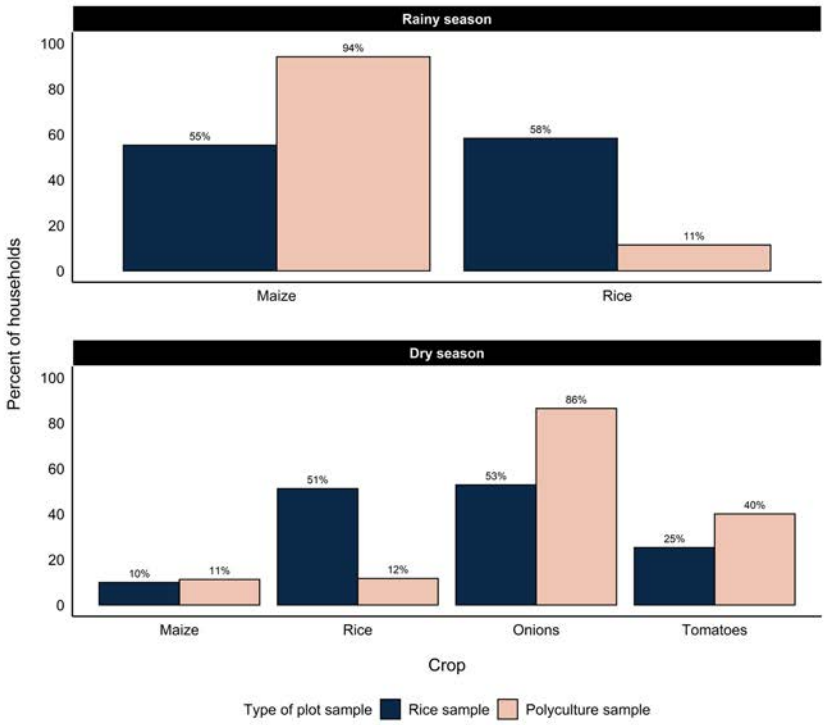
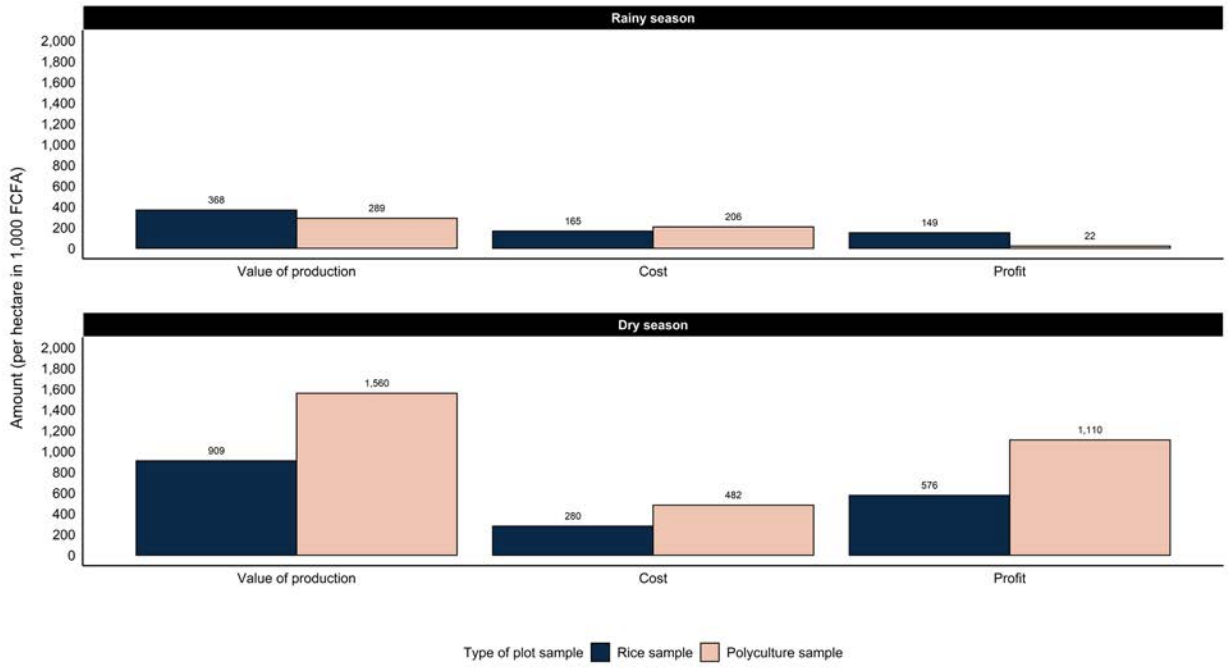


Figure A.2 Di perimeter agricultural outcomes, by type of plot sample (per hectare in 1,000 FCFA)



A.2. Remote sensing analysis – methodological information

Remotely sensed data collected by satellites offer the potential to conduct low-cost continuous monitoring of agricultural areas over large geographic scales. In contrast with survey instruments through which data can only be collected from cultivator respondents who complete the survey, remote sensing methods enable researchers to infer crop outcomes for all plots in a specified coverage area. Across the Di perimeter, we examined the capability of using remote sensing data to predict, (1) the area under cultivation ("cropland mask"), (2) the area cultivated with different types of crops ("crop type map"), and (3) crop-specific yields.

Generating model predictions for these three applications requires a combination of ground-truthed data and satellite data. A key input for these analyses is a dataset we constructed of GPS-derived outlines of agricultural plots, and 5 meter by 5 meter measurement squares from which crops were harvested and weighed as part of our crop-cutting data collection during the 2018/2019 agricultural campaign. This in-situ data contains information on a plot's cultivation status for the rainy and/or dry season, plot- and subplot-specific cropping decisions, and yield values.

We inputted this in-situ information to the Sen2-Agri platform which implements a series of image processing procedures and machine learning algorithms on all imagery collected by the Sentinel-2 satellites, which are part of an earth observation program run by the European Space Agency. All cloud-free imagery available over a season's window was used in the analysis, with an average of 15 images available for each plot in the rainy season and 17 images in the dry season. We used November 1, 2018, through April 30, 2019, as the dry season window and July 1, 2019, through December 30, 2019, as the rainy season window. For both the rainy and dry seasons, the Sen2-Agri platform produces cropland masks which are model-based predictions of the cropping status of all area in the Di perimeter. Conditional on identifying a section of land as agriculturally active, a subsequent crop type map data product classifies each pixel as belonging to one of the crop classes included in the in-situ data. Cropland

mask and crop type map data generation procedures withhold a portion of the in-situ data from the model development process, to be used in a testing process to validate the model. Model performance is based on maximizing predictive accuracy in the out-of-sample data.

Since the Sen2-Agri platform does not generate yield estimates, we rely on raw Sentinel-2 data available through Google Earth Engine as inputs for our yield prediction models. We compute multiple vegetation indices (VIs) from top-of-atmosphere reflectance values and perform crop-specific regression models to estimate the relationship between crop yields and vegetation index values averaged over each plot for which crop yield data is available. We consider both models that include season-total information (e.g., median value, max value) of a single vegetation index, as well as a saturated model that includes vegetation index values for all five VIs. Coefficients estimated from these yield response models are used in generating crop-specific, perimeter-wise estimates of agricultural output by multiplying them with the VI values for all pixels in the perimeter classified as a given crop in the Sen2-Agri generated crop type maps.

Further details on the methodology are available in D'Agostino and Ksoll (2020).

A.3. Land mediation analysis – additional methodological details

In Chapter III, we analyze linkages between steps along the land tenure causal chain using a methodology developed by Huber (2013). Imai et al. (2010) and Huber (2013) showed that it is possible to recover the effect of the mediator—an intermediate effect influenced by treatment—on outcomes through appropriate matching techniques combined with estimates from the RCT analysis as in Equation (1).

(1) $$y_i = \alpha + \beta Treatment_i + X_i + \theta_i + \varepsilon_i,$$

Huber (2013) developed a methodology to use propensity score matching by matching treatment and control group observations on the level of the mediator, conditional on observed covariates X. In a second stage, this propensity score can be used for inverse probability weighting to create treatment and control groups that have similar distributions with respect to the mediator. This allows the researcher to estimate the direct effect of treatment on outcomes, holding the level of the mediator constant.

Huber (2013) used the notation $\hat{\theta}(0)$ and notation $\hat{\theta}(1)$ to denote the direct effect when the mediator was held constant at the observed average in the control group and treatment group, respectively. The effect of the treatment that works through the mediator (the effect operating through land tenure security) is the difference between the impact and the estimated direct effect $\hat{\delta}(1) = \hat{\beta} - \hat{\theta}(1)$ and $\hat{\delta}(0) = \hat{\beta} - \hat{\theta}(0)$, where $\hat{\beta}$ is estimated as in Equation (1).

This methodology relies on several key assumptions:

1. There are no unobserved confounders jointly affecting treatment and the mediator. In our case, treatment was randomized, so this condition is met.
2. In addition to pre-treatment covariates, the analysis allows for the inclusion of post-treatment covariates that could be impacted by the treatment and could also affect the mediator. These could be interim measures of outcomes (for example agricultural activities, revenue, or income) that could potentially lead to higher interim measures of the land tenure security variables. We have included these in our model.

3. Conditional on treatment and observable covariates that the analysis controls for, there are no unobserved confounders jointly affecting the mediator and the outcome. In this case we want to be sure that there are no variables not controlled for that affect both interim perceptions of land tenure security and the long-term land investment outcomes. We control for a range of baseline and interim covariates to account for factors that potentially affect both the mediator and the outcome. However, we cannot be sure that we have included all relevant factors.

Appendix B

MCC Comments and Evaluator Responses

This page has been left blank for double-sided copying.

Table B.1. MCC Comments and Evaluator Responses

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
ES	M&E	N/A	General	Overall, this is a strong executive summary. It communicates the key points in a straight-forward manner.	Thank you.
ES	M&E	viii	Page viii, "…and several smaller activities"	This final evaluation does not cover most of the diversified agriculture activity. Please more accurately reflect what is not included in final eval. Could be in footnote.	Activities that are not covered are described in a footnote.
ES	LAE	ix	Pg ix, first paragraph: "USD$ 480.9 million"	Either use "USD" or "$", but not both.	Consistently used US$ throughout the report.
ES	M&E	x	Table ES.1. Analytic approaches for the ADP evaluation	Spell out PAP, ERR, O&M, and WUAs. Especially for the term PAP, I think it is best to not use the acronym as often as is used in the Executive summary. If you are not familiar with MCC practices the term is confusing.	Revised the text to introduce the reader better to the term, and used the acronym less often.
ES	M&E	x	Table ES.1. Analytic approaches for the ADP evaluation. "What is the total area planted?..."	I'm surprised this question doesn't use the remote sensing analysis. Does the "Performance evaluation using descriptive analysis" incorporate the remote sensing work?	We added remote sensing analysis because it is different from simple descriptive analysis.
ES	M&E	x	Table ES.1.	Formatting comment. Consider merging cells in the methodology column to reduce repetition and improve readability.	We've implemented this suggestion.
ES	M&E	x	Page x – xiii, General comment on evaluation findings	Consider specifying the magnitude when referring to quantities. For example, "Profits per hectare are lower than anticipated across all types of beneficiaries." By how much? Or, "…but some plots get flooded and others do not receive enough water due to errors in construction or damage." How many? The exact number does not always need to be provided, but a sense of magnitude is useful for the reader. 'Some' could mean 5% just like it could mean 40%.	In the Executive Summary, we provide magnitudes when possible to do in a precise way. The two examples you give are different. In the first example, the difference is not consistent across crops and so it is difficult to summarize. For the second case, our inability to conduct the planned irrigation visit means we are not able to provide very robust estimates of the magnitudes.
ES	LAE	x	Pg. x, third full paragraph: ". . . and the ability of the users to operate it	It would be easier to track by adding the word "on", as follows: ". . . and <u>on</u> the ability of the users to operate it."	Added.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
ES	M&E	xi	Comparison of data collection methods.	This bullet is under the findings, but it doesn't directly relate to the evaluation questions per se. I think it probably doesn't belong in this list, but I would still keep it in the Di Perimeter Evaluation Section. Can you also spend a sentence or two in this section identifying for the reader which methods are more reliable for which outcomes.	As suggested, we split the implications sections into two pieces, namely project learning and M&E learning, with the comparison of remote sensing, crop-cut data, and survey data falling into the latter.
ES	M&E	xi	Page x, "Comparison of Data Collection Methods"	If you keep this finding in the exec summary, consider placing it at the end. More generally, the variance in remote sensing, household survey, and crop cut estimates distract from the key findings. Are remote sensing and crop cut estimates more accurate? If so, why not just present those?	We've moved the finding of the discrepancy to a new section of the ES, the M&E Learning portion of ES.D (summary and implications).
ES	M&E	xii	The ERR is estimated to be between -0.0 and -2.19	Is the -0.0 a typo ?	Corrected
ES	M&E	xii	Economic rate of return.	What parameters are driving the ERR to be negative?	Added a comment about onion cultivation being less than anticipated.
ES	M&E	xii	Economic rate of return.	How does this ERR compare to the project's ex-ante or closeout ERR?	Added a comparison to the original and close-out ERRs.
ES	M&E	xii	General comment on **economic rate of return.**	The re-estimation of the ERR does not seem to have considered soil fertility issues raised in the interim evaluation.	We unfortunately do not have information on the degradation of soil fertility over time. Any soil issues that are currently present on the perimeter are, however, captured in the profit values. We include a comment in the main body of the text that future soil degradation would reduce the ERR further.
ES	M&E	xii	Economic rate of return. "… significantly below MCC's target of 10 percent."	The target was not 10% when this Compact was developed and signed. At the time, MCC's policy was to establish the hurdle rate by multiplying by 2 the average of the previous three years GDP growth rates. In addition, no hurdle rate was to be less than two times the average GDP of all countries. No hurdle rate was to exceed 15.0% either. According to investment-time documents, the hurdle rate for Burkina I was 12.5 or 12.6%.	Corrected here and in the main body of the text.
ES	M&E	xiii	Land cultivation and agricultural outcomes. "…but significantly less than they received on the perimeter."	"How much less? This seems to contradict the first finding on over 95 and 99 percent cultivation in the dry and rainy seasons.	Clarified to allude to the fact that they are not cultivating this land themselves.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
ES	M&E	xiii	Confusion about land tenure and documentation has increased since interim, with only one-third of beneficiaries understanding that they have emphyteutic leases and half incorrectly claiming to possess land titles.	What is an "emphyteutic lease"?	We've replaced that term with "lease document."
ES	M&E	xiii	**RD analysis.** The RDD treatment estimates at the cutoff are about one-third lower than the RCT estimates… extrapolates away from the cutoff seems more promising, as the estimated impacts are much closer to the RCT estimates."	I would imagine this would be pretty hard for someone that isn't familiar with econometrics to understand. I suggests putting this in more layperson terms or removing from the exec summary. This also does not directly relate to the evaluation questions so I would move it to a different part of this section if you choose to keep it in the exec summary.	We've moved it to the M&E Learning portion of ES.D (summary and implications).
ES	M&E	xiii	**RD analysis.** The RDD treatment estimates…"	Estimates of what outcomes?	Added "for agricultural profit and income measures."
ES	M&E	xiii	Page xiii, Quality of the O&M. "…due to the characteristics of their farmers"	Could you be more specific about the characteristics, perhaps by providing an example of a characteristic or mentioning the type of characteristic?	Added this.
ES	M&E	xiii	Page xiii – xv, Summary & Implications	Consider including a point on the use of remote sensing analysis? Are there any implications for future evaluations?	We have provided some additional content in the ES on the role of remote sensing in evaluation.
ES	M&E	xiv	**Di perimeter lifespan.** "Estimates of infrastructure longevity… between 10 and 30 years for pumping stations and concrete components (bigger canals)."	How do these lifespans compare to what was originally envisioned?	Added this.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Introduction	LAE	1	Pg. 1, second and third paragraphs	The second paragraph says land security is an issue in two different places, but the third paragraph is entirely dedicated to the same issue. Sounds kind of repetitive. May need some transition language at the top of the third paragraph.	The paragraphs have been revised to avoid repetition. The second paragraph focuses only on the negative consequences of variable and low rainfall, and the third paragraph addresses land security challenges.
Introduction	EA	1	Pg 1	How do the WMI, DA, and ARF activities map to the IWRM and DA "project areas" displayed in figure I.1?	The project area of the IWRM is also the project area of WMI. We have replaced IWRM with WMI in the graph.
Introduction	M&E	3	3	"Land tenure assistance" wording is odd and unclear what is meant. Suggest replacing with provided "leases and titles to secure land rights".	The text has been changed to: "providing lease documents and land titles".
Introduction	EA, M&E	6	Pg 6: "PAPs, women, though and non-PAPs received mostly polyculture plots"	Is there a typo in this sentence? "though"? Should this read "youth"?	Corrected.
Introduction	EA	6		Figure 1.3 is mislabeled? As presented it implies that women received only 4% of the land in Di and that none of the lottery winners, PAPs or non-PAPs were women. Instead of "women" and "youth" the labels in the figure should read "women groups" and "youth groups."	Corrected. In the remainder of the report, we also refer to "women's groups" instead of Di Women to clarify this point.
Introduction	M&E	7	Page 7, "The ERR analysis sets the post-project increase in agricultural profits…"	I'm confused by this sentence. Are you saying that the CBA set agricultural profits so that the ERR would equal exactly 10%? Or are you just giving the definition of an internal rate of return?	Revised for clarity, we are just defining IRR.
Introduction	EA	7	Pg 7: "The ERR was estimated to be 5.5 percent"	The closeout ERR published on MCC's external website, dated 03/23/2017, is 3.8% not 5.5%.	Corrected.
Introduction	M&E	7	Page 7, The ERR was estimated to be 5.5 percent.	Is this the closeout estimate? Could you also include the ERR at the time of IM or whatever the ERR was at the point the project was designed?	We updated the information on the ERR in this introduction section to include the original ERR (and the date at which it was calculated - April 2008) and the close-out ERR.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Introduction	M&E	7	7	"The analysis in the interim report concluded that the implementation of all activities was delayed but was generally completed by the end of the compact" Note that much of the expected training to lottery winners as well as provision of land leases/titles to Di were delayed and agreements made with the government to continue these post compact. They were eventually delivered but suggest say by "end of post compact period" instead of "by the end of the compact".	Revised to refer to end of post-compact period.
Introduction	EA	12	Pg 12: Land tenure security	The interim evaluation found that perceptions of land tenure security were considerably lower among Di leaseholders (lottery winners) relative to title holders (PAPs). Did this difference persist at endline?	In Section II.B.RQ3, we investigate differences in perception by beneficiary group and find that perceptions of land security do not vary substantially by type of beneficiary.
Introduction	M&E	14	Table I.1. Analytic approaches for the ADP evaluations	Was it possible to use any data to try to get at this question [on changes to prices]?	Instead of providing quantitative analysis of price data from the MIS system, we present qualitative evidence on perceptions in price changes drawn from the interim and final evaluations.
Introduction	M&E	14	Table I.1. Analytic approaches for the ADP evaluations	Please ensure table is identical to ES.1, including formatting changes suggested in comment [x].	We have reviewed the two tables for consistency, but do not think they should be identical, as they serve different purposes. Table ES.1 provides a broad summary of evaluation approaches according to MCC's performance and impact evaluation categorization. It is a summary of the information contained in Table I.1, but with less detail. Table I.1 is a concise way to present an overview of the evaluation approaches *and* data sources used to address specific research questions.
Introduction	M&E	15	15	No mention is made of the land interim surveys. Some of the land analysis was missing from the interim report due to an error by MPR in collecting this dataset. The agreement with MCC is that the land tenure data that was collected in the interim after the interim report would be included in the final results report here. As such, the data collection as well as results information should be included or it will be missing from the public sphere. Alternatively, MPR can include the land interim report as an annex.	We included a description of the land tenure retrieval data collection in Section I.C.2, footnote 6. We present the analysis from the interim land tenure retrieval memo in Tables III.4, III.5, and III.7 together with the final evaluation results (in the interim columns). Generally speaking, we discuss the interim analysis when it differs from the results of the final evaluation.
Introduction	M&E	16	Table I.2. Primary quantitative data collection overview, Crop cut survey	Please specify whether the 271 refers to plots or cropcuts.	The 271 refers to plots. We specify that in the report.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	LAE	18	Pg. 18, first para.: "In this chapter, we summarize the findings . . ."	Are the findings only being summarized, or are they being presented in full? This is the main final report, so I would think the latter.	We clarify that we are presenting findings.
Di Perimeter Evaluation	M&E	18	P18, Table II.1. Summary of Di perimeter sub-activity	Consider including the cost per hectare under funding.	We added this.
Di Perimeter Evaluation	M&E	18	Table II.1. Summary of Di perimeter sub-activity	Consider adding the exposure period to this table.	Added 2014 - present.
Di Perimeter Evaluation	EA	18	Pg 18 Table II.1: "Construction and resettlement completed in 2013"	Incorrect. The timeline on page 8 indicates that resettlement was not completed until March 2014.	We corrected this.
Di Perimeter Evaluation	M&E	19	RQ1 Key Findings	Can you add some nuance as to why we see such drastic difference across beneficiary types?	Edited to clarify that the differences are actually quite small. We do not have any evidence as to why these differences exist.
Di Perimeter Evaluation	EA	19	Pgs 19-20: Discussion of remote sensing.	Please explain how many different satellite images from different points in time were used in the remote sensing exercise. Was a single satellite image analyzed for each season, or were multiple images analyzed from different points in time (e.g., monthly, weekly)?	All images captured by the Sentinel-2 sensors during the seasons were analyzed in the cropland mask and crop type mapping analyses. This is roughly 10-15 images per pixel over a season, the exact number depending on pixel location and cloud cover. I'd have to dig into the EODC output further to get a firm number. As for the yield estimation, we also used all imagery that was not deemed too cloudy. The exact number of images is pixel-specific. This information has been included in the Remote Sensing Analysis Appendix A.2.
Di Perimeter Evaluation	EA	19	Pg 19: "The cropland mask generated for the 2018–2019 dry season and the 2019 rainy season…"	Why was the remote sensing exercise limited to the 2018-2019 dry season and the 2019 rainy season rather than extending back to 2014 or 2015? Given the very serious O&M problems discussed in Chapter IV, one might expect uncultivated area to increase over time. A time series analysis might capture changes in uncultivated area with greater accuracy.	Our remote sensing analysis was limited to the years for which we had training data from the crop-cut survey. It is unclear to what extent the algorithms trained on data for one year can be used to back-predict information in prior years. This is an area of research that NASA is actively pursuing, using survey and crop-cut data we collected for the Di perimeter. Given that Sentinel-2 data is available from June 2015 onwards, this would be the earliest that back prediction would be possible if algorithms were reliable.
Di Perimeter Evaluation	M&E	19	Pg 19 Satellite imagery	How does the high levels of cultivation in the rainy and dry season compare to the levels of cultivation before the project?	We note that, based on the baseline information in the CBA, the area cultivated during the rainy season is more than twice as large as at baseline and the area cultivated during the dry season constitutes a 20-fold increase.
Di Perimeter Evaluation	EA	19	Pg 19: "Overall, profits do not meet expected profits under the ERR"	I assume they mean the *closeout* ERR, in which case the text should be changed to read "…do not meet the expected profits under the closeout ERR estimated by MCC in 2017."	Corrected to add this clarification.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	M&E	19	RQ1 Key Findings	How do these improvements compare to what was expected in the logic, monitoring targets, and/or CBA? Essentially, these look impressive but is there a sense that they are high enough to justify the costs of the irrigation?	We added Appendix Table A.7, which compares ERR inputs from the evaluation CBA together with the corresponding values from the close-out CBA model. For yields, we already present those results.
Di Perimeter Evaluation	M&E	19	pg 19	The text mentions that dry season profits were 10 times that of rainy season profits but that profits were lower than expected by the ERR. Can you elaborate if profits increased relatively even if not to the level of ERR? As irrigated land was expected to provide the ability to grow more crops in dry season (cultivate more land as some of perimeter not planted in dry season), it would be helpful to understand the details a bit further.	Unfortunately, we don't have information on per hectare profits by season before the construction of the perimeter. However, the comparison with the dry season area cultivated at baseline that we include from the CBA model provides some information on the difference in irrigated land (and therefore likely profits). The CBA includes a baseline value of 110 hectares of land during the dry season.
Di Perimeter Evaluation	M&E	19	Land cultivation and agricultural outcomes. "Land on the perimeter is extensively farmed in both seasons with over 95 and 99 percent cultivation…. Profits do not meet expected profits under the ERR."	Can you add a couple of sentences about why profits are lower than expected and how much below the target needed to meet a 10% ERR?	We've added information in the summary box that this is driven entirely by lower onion profits and lower area cultivated for onions. As a test, we used the area cultivated and the profits for onions from the close-out CBA, and other values from the final evaluation. We calculate the same ERR (3.8%) as in the closeout model. In agreement with MCC during a subsequent discussion, we did not compute the increase needed to reach a target of 10% ERR.
Di Perimeter Evaluation	EA	20	Pg 20: "The cropland masks produce binary values at the level of a 10m-by-10m pixel,…"	Why was a 10m-by-10m resolution selected rather than a higher (more detailed) resolution? Was this just a cost issue, or were there other reasons for avoiding a more detailed resolution?	The 10-meter resolution is governed by the Sentinel-2 sensor. While there are proprietary satellites with higher resolution data available, they come at a cost premium and require preprocessing steps that make season-wide analyses more difficult. Sentinel-2 data, in contrast, has the benefits of being freely available and its imagery requires limited additional processing work.
Di Perimeter Evaluation	M&E	20	Pg 20	For the plots that are inactive in the dry season, do we know why? They seem clustered together somewhat.	Because we have complete information only on 19 inactive plots in our survey data, we are not sure. The qualitative interviews indicated that farmers sometimes leave a field inactive because they can't afford to cultivate it, and this is corroborated by the small number of in-person interviews. Other stakeholders noted the issues with levelling of the fields, which would be consistent with the observed clustering.
Di Perimeter Evaluation	EA	20	Pg 20: Plots vs Parcels	The paragraph at the top of page 20 refers to both "plots" and "parcels." Is there a difference between a plot and a parcel? If not, it would be less confusing to use a single term.	We revised to use plot consistently throughout the report.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	EA	20	P 20	Do figures II.1 and II.2 agree with respect to the share of the perimeter that is being cultivated? The text is somewhat confusing, and for example I think the discussion of the 10x10 pixel should be moved up to the discussion of figure II.1. What is figure II.2 showing that II.1 does not?	The output from Sentinel-2 is at the pixel-level. Because there will be some level of error, summarizing results at the plot-level allows for the possibility that one pixel was classified as non-agricultural, but the remaining pixels were. As a result, we would classify the parcel as being non-agricultural for that season. We added some clarity and edited so figures are directly below the text that refers to each figure.
Di Perimeter Evaluation	M&E	20	pg 20-21	Why is only remote sensing endline presented and not for historic period? 95% cultivation was not the case during dry season pre project as there were empty areas when no rain. Is there a reason the evaluation is not capturing the differences in cultivation pre/post project of the Di perimeter from the remote sensing and admin data?	The scope of the remote sensing for this evaluation was to pilot the use of the Sen2Agri platform, which requires ground-truthing data from the season to be investigated. We did not have such ground-truthing data for the pre-project period. In addition, this platform relies on Sentinel-2 satellites that entered into operation after construction of the Di perimeter. Instead, we have added several references to the best available information on the acreage cultivated in the pre-project period (based on the ERR and the atlas of achievements). We also highlight the large increase in total area cultivated across the two seasons (driven both by the increase in land under cultivation and the intensification due to the second season) in the report.
Di Perimeter Evaluation	M&E	21	P21, Table II.2. Total area cultivated on Di perimeter	If you present both household and remote sensing results in a single table, consider adding columns for the difference. But per comment [], be careful of not having difference estimates distract from the core findings. This comment applies to all tables where HH and RS estimates are shown.	We consider the different results from the two sources of information an important source of learning from the evaluation. As such, we think these results should remain in the main body of the text. To keep the tables easily readable, we present the information from both sources as opposed to the difference.
Di Perimeter Evaluation	EA	21	p 21	Top paragraph: "The key factor in these differences..." This sentence is not easy to penetrate, is the suggestion that land rentals were taking place and you were not able to learn enough about those? Also, in the next paragraph, it says "he cannot distinguish" and I am not sure it should.	Edited to clarify.
Di Perimeter Evaluation	M&E	21	Pg 21	Some of the discussion on pixels and Sentinel is a little technical. Maybe put it in language that is a bit easier to understand	We have expanded on this point and clarified to make it more accessible.
Di Perimeter Evaluation	M&E	22	P 22. "…Except for lottery beneficiaries who received rice plots, most farmers' reported crop choices are similar;"	Similar to what? To remote sensing estimates?	Edited to clarify that patterns of cultivation are similar across beneficiary groups.
Di Perimeter Evaluation	LAE	22	Pg. 22, very bottom	")" is needed	Edited.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	EA	22	Pg 22: "Only a small number of farmers cultivate corn, rice, and beans during the dry season"	Figure II.4 seems to indicate that around 20% of Di farmers cultivate rice in the dry season (15% of PAPs and 29% of lottery winners). This is consistent with Table II.3 which shows that rice accounts for 21.4% of the total cultivated area in the Di perimeter during the dry season. Is this a "small number"?	Smaller than the other crops; edited for clarity.
Di Perimeter Evaluation	EA	22	p 22	Please report the overall crop choices before the detailed description of crop choices by group. Also, Figure II.4 should have an 'overall' category, or a separate figure preceding it which shows what the overall choices were.	We added an "overall" category to the figure and edited the text accordingly.
Di Perimeter Evaluation	M&E	22	pg 22-23	Yes, beneficiaries were given either land for polycultural or rice growing. Rice growing areas would not support other crops mentioned here, nor was it expected. Beneficiaries were given the choice of poly or rice land. The majority chose poly and then leftovers of rice went to next in line beneficiaries. For Figure 2.4 crop choices, it would be helpful if can disaggregate further or create another chart showing distribution by the type of land the beneficiary received, as that is likely the key determining factor. (Also at the end of the page, you are missing a close parentheses)	We present information on crop choices disaggregated by type of plot as Appendix Figure A.1. We describe the main differences in the text. Edited the missing close parenthesis.
Di Perimeter Evaluation	M&E	23	P23, "the one exception was dry season maize… according to remote sensing estimates.	Is this because the remote sensing was detecting maize when it was actually a different crop?	This was because the crop type prediction algorithm likely misclassified what were true maize-growing areas as growing either tomatoes or onions. As a result, the predictions led to an underestimate of area under maize cultivation and overestimation of either tomatoes or onions, relative to our survey findings.
Di Perimeter Evaluation	M&E	23	P23, Figure II.4. Crop choices on Di perimeter, by type of beneficiary	Consider including MCC's projections as horizontal red lines in this figure.	We added MCC's projections from the ERR to Table II.3. We can't add these to Figure II.4, because this figure shows the share of farmers growing each crop in each season, while the ERR has projections for the total share of land they expected to be in each crop in each season. So they aren't comparable.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	EA	24	p 24	Is the Desiere and Joliffe paper merely a single example of survey under-reporting or is this a more widespread phenomenon? It would be helpful to know how strange the under-reporting here is. Also, in your professional opinion, is there any reason to doubt that the crop-cut estimates are more (or less) reliable than the survey estimates? Should the reader simply take the average of these two kinds of estimates or should they trust one more than the other?	We've added the following discussion to the report: There are numerous academic papers that document survey and crop-cut yield differences, with several papers finding survey reports exceeding crop-cut yields and others finding the opposite. Gourlay, Kilic, and Lobell (2019) show that in particular for small-holder plots, the survey reported yields are often larger on average than yields from crop cuts. Paliwal and Jain (2020) and Wahab (2019) on the other hand find crop-cut yields exceeding yields estimated from survey responses. Paliwal and Jain (2020) find that survey yields in their setting are 40% lower than crop-cut yields and conclude that self-reported yields cannot be used to train remote sensing algorithms. Wahab (2019) finds crop-cut yields that are more than three times larger than self-reported yields. This raises the question which results should be trusted: Several papers suggest that crop cuts outperform survey responses in measuring yields (for example Carletto et al. 2015), but there are several pieces of evidence that suggest this determination is not clear cut. In the setting documented in Wahab (2019), farmers adapt the area cultivated over the course of the season, reducing the effective plot area under cultivation as the season unfolds. However, the area on which the measurement square is placed is less likely to be abandoned. Along a similar line, Desiere and Joliffe (2018) note that crop cuts might be measuring potential yields, while the information on production contained in the surveys might measure actual harvests across a wider area.
Di Perimeter Evaluation	M&E	24	pg 24	Considering the differences in yields and that in fact the PAPs exceeded targets based on crop cuts vs didn't meet targets based on survey data, did Mathematica calculate the ERR based on crop cut data, which seems more accurate than farmer reporting? If not, suggest this is done as well. Namely we should be using the most reliable data source or at minimum presenting both.	The evaluation-based CBA model does not rely on survey or crop cut-based yields. It used farmers' reports on the value of sales from which we deduct costs to construct profits. As a result, the discrepancy between the two yield measures does not affect the ERR model.
Di Perimeter Evaluation	M&E	24	Pg 24 Difference between crop cuts and survey on yields	Do we know what accounts for such large differences in yields between the surveys and the crop cuts?	Please see our response to the comment in rows 43 and 44.
Di Perimeter Evaluation	EA	24	Pg 24, Table II.3 Total area cultivated on Di perimeter	The column totals for Remote Sensing add up to 100% but the column totals for Household Survey add up to considerably less than 100%. Is there a reason for this?	The survey allowed for respondents to report other crops, but we only report the key crops in this table, so the total is less than 100%. Added this as a note in the table to clarify.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	EA	25	Pg 25 Figure II.5: Comparison of farmer recall yields with crop-cutting yields.	MPR's crop-cutting survey finds rice yields on the Di perimeter ranging from 8.5 tons per hectare (dry season) to 8.9 tons per hectare (rainy season), nearly double the yields self-reported by Di farmers. These are outstanding world class yields as high as any country in the world. Japan achieves only 5 tons/ha, Bali and Java achieve less than 4 tons/ha. Is it possible that MPR is comparing apples with oranges? Did MPR's crop-cutting field staff measure the weight of paddy immediately after harvest, before the rice has been threshed, dried and milled? Rice loses at least half its weight in the drying and milling process. Perhaps farmers are self-reporting their *rice* yields while the crop-cutting survey is estimating *paddy* yields.	The weights used in our crop-cutting exercise were for rice that was dried but not hulled. We have applied a conversion factor provided by our local consultant in Burkina Faso to convert these figures into hulled weights so they are comparable with standard rice yield measures. Added this as a note in the table for clarity.
Di Perimeter Evaluation	M&E	25	Figure II.5.	Could you please include a note on why there is no target for tomatoes?	The indicator tracking table does not have a target for tomatoes; added this note to the figure.
Di Perimeter Evaluation	EA	25	Pg 25, final paragraph.	*"Survey estimates of total production are much lower than estimates that combine yields from the crop-cutting survey and estimates of area under cultivation by crop..."* Is something missing from this sentence? It is difficult to understand. What is the source of the "estimates of area under cultivation by crop"?	Edited for clarity.
Di Perimeter Evaluation	M&E	26	pg 26	Was MPR able to compare this data to the BERD/CERFODES data pre-project? Namely, before the project was dry season more profitable than rainy season? I believe it was the opposite so would be key to understand what these endline results mean in the bigger scheme of things.	Unfortunately, we don't have information on per hectare profits by season before the construction of the perimeter.
Di Perimeter Evaluation	M&E	26	P 26, "Agricultural outcomes vary somewhat by beneficiary type…"	There seems to be a disconnect between the headline and the graph in terms of which sub-groups have the lowest and highest profits. [Please make sure any edits are also reflected in executive summary, as needed]	We have clarified the text: this statement is true when looking at yearly profits that add up both seasons.
Di Perimeter Evaluation	M&E	26	Pg 26 Table II.4	This table has an estimate of the remote sensing with crop cut but the narrative doesn't seem to explain it.	Provided this information.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	EA	26	Pg 26, Table II.4: Total production on Di perimeter.	This table is confusing. Additional explanatory text would be helpful. For example, what is the difference between "crop-cut survey" and "remote sensing crop-cut survey"? A crop cut survey provides an estimate of yield, not of production. To estimate production a crop-cut survey must be augmented by information on cropped area.	See the answer to the comment in the line immediately above.
Di Perimeter Evaluation	M&E	26	Pg 26 Table II.4	How do the costs and value of production compare to the targets?	We include a table in the appendix that shows costs and profits from the evaluation as well as from the CBA models.
Di Perimeter Evaluation	M&E	26	Pg 26 "Agricultural outcomes vary somewhat by beneficiary type, with Di PAP households earning the lowest profits per hectare and Di neighbors and women achieving the highest."	Do we know why there is this difference in profits across beneficiary types?	We do not have evidence as to why this is. We can hypothesize that these plots are probably cultivated more intensively since they are small plots of land and women do not in general have access to irrigated plots of land.
Di Perimeter Evaluation	EA	26	p 26	It would be helpful to know what agricultural costs consist of (e.g., are labor costs counted?), and similarly for ag revenues. Also, it's not clear how ag profits/ha are derived/calculated and in particular which kinds of yield estimates (crop cut vs survey) are being used. Both types would be interesting to see displayed. Ag profits/ha are a key outcome and warrant more of this type of description. Also, if ag profits/ha in table II.5 are in fact based on survey-reported yields, it would be interesting to see an analog based on the crop cut-reported yields (perhaps using a survey-crop cut adjustment factor for those HHs whose crops were not cut). Finally, the text reports that dry season ag profits/ha exceed 1.1M FCFA, but the table lists that value as 1.05M.	We include information on the costs in Table II.5. Agricultural profits are not based on survey yields but rather value of sales (plus own consumption) minus costs. We corrected the statement that the profits/ha exceeded 1.1M FCFA.
Di Perimeter Evaluation	M&E	26	pg 26	Can table 2.5 (and maybe figure 2.6) be disaggregated by poly and rice plots?	We added rows to Table II.5 to break down costs, value, and profit by type of plot, and added some text to describe the findings.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	M&E	26	pg 26	Notes women and neighbors higher profits--it seems so were sales/rentals . Does sales/rentals include those who rented/bought land from Di beneficiaries? If so, that makes sense re production and shows land markets working--namely land goes to those who most effectively utilize land.	Sales and rentals are those respondents who rented or bought land before the interim survey and who are still cultivating the land now. However, we were not able to interview new renters and buyers who were not part of the interim survey. We clarify this in the text. Because the renters and buyers are not representative of all renters and buyers but a selected sample, we do not feel confident in making such a strong statement.
Di Perimeter Evaluation	EA	27	Pg 27, Figure II.6: PAPs earn lower profits than lottery winners?	PAPs received mostly polyculture plots whereas lottery winners received a high proportion of their Di land as rice plots. Since polyculture land can be used to grow high value crops such as onions and tomatoes, while rice land produces less valuable crops, one would expect logically that PAPs would have higher profits per hectare from their Di holdings than lottery winners. Figure II.6 shows the opposite. Is there an explanation for this counter-intuitive finding?	This may be due to the fact that (a) Di Lottery beneficiaries are particularly good farmers (they were selected on that basis) and (b) poor-performing Di Lottery beneficiaries may have left the perimeter and so are not included in this average.
Di Perimeter Evaluation	EA	27	p 27	In the face of all the results disaggregated by beneficiary type, I find myself wondering whether we should expect differences across groups. For example, is there any reason to think that lottery winners would experience different outcomes than PAPs or women? If so, it would be helpful to outline the thinking earlier in the text.	We add an explanation into the text that we cannot assess why different beneficiaries have different outcomes, given that they vary along multiple dimensions.
Di Perimeter Evaluation	M&E	27	Pg 27	Figure 2.6--does Di women throughout results include just those with veg parcels or also female headed households in the Di PAP and Di lottery households?	We now use the term women's groups throughout to clarify that these are only members of the women's groups.
Di Perimeter Evaluation	M&E	27	pg 27	bottom of page-remove duplicate FCFA	Corrected.
Di Perimeter Evaluation	M&E	28	P 28, RQ2, "PAPs agricultural profits and household incomes increased since the interim survey."	By how much? Please give a sense of the magnitude of the increase.	Added this.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	M&E	28	Pg 28 "**Agricultural profits and household incomes increased between interim and endline."**	You say in this section that agricultural prices account for the changes in the profits from interim to endline. Do these prices also affect the total agricultural income as well as agricultural profits? Is there a sense that both of these levels of income are within a standard range for profits/income in any given year? Is it likely that the higher income level from endline will persist?	We first clarify that the price increase is one reason for the increase in incomes and profits for which we can provide evidence. We do not know if this is the only reason, however. Yes, the price increases would affect all three indicators. In the section on prices we do provide stakeholder perceptions that prices rebounded from what they considered were very low levels at interim. We do not have evidence beyond those perceptions on what normal prices might be.
Di Perimeter Evaluation	M&E	28	pg 28	with 3/4 of PAPs noting higher profits after the project in interim and 9 out of 10 in the endline, it seems that the survey responses on yields/profits might be underestimating results.	We don't think that transformational impacts on individuals and low economic return are contradictory. Our evaluation highlights that profits and incomes of beneficiaries rose (substantially) for the different groups of beneficiaries. However, they did not rise enough to meet project targets, which were set to justify a 89M USD investment.
Di Perimeter Evaluation	M&E	29	P. 29, Table II.9.	Consider including interim results in this table .	In the interim survey, we only collected information on land tenure outcomes for Di PAPs and Di Lottery beneficiaries. As such, the comparison between endline and interim data would not be pertinent and would be confusing in this table.
Di Perimeter Evaluation	M&E	29	Pg 29. "At the same time, 96 percent of PAPs reported reduced food insecurity in the interim survey; this share declined to 91 percent by endline."	Do we know why perceptions of food insecurity decreased? Or do you feel that the statistical significance is too low to make claims about this with a p value of .07?	We do not have any additional information on why PAPs' perception of food security fell between the two surveys.
Di Perimeter Evaluation	M&E	29	pg 29	Do we know whether the rental market increased/decreased since prior to the project based on recall data or whether significant difference with control at endline for lottery? The key point of interest isn't difference with interim but difference from prior to project where we collected recall data on land transactions which people usually recall correctly.	Due to lack of baseline information, we are not able to compare to the pre-project situation. In the interim survey, we did not collect recall information given the length of the survey instrument. We provide rigorous assessment of the difference in rental and sales between Di Lottery beneficiaries and controls in Section III.B.2

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	M&E	31	pg 31	The findings are hard to follow. Can MPR clarify the text related to credit and investment. Specifically how did loans change prior and post project not just interim vs endline. Does 22% reflect those who took loan in total or only in the short period between interim and endline? Is the 22% from PAPs or from lottery or other? 22% (1 in 5) taking a loan is quite high-see comparison with controls for Di Lottery. 14% used land as collateral, but even if not used as collateral, is a title required to access a formal loan? In many places banks require a title to the land/property as a condition but the collateral is still income of some sort. Similarly for investments it notes in 2 years that 10% of farmers made land investments. What about in the interim--namely what was the trend before/after project not interim vs final. I believe we had asked for historic data so could compare even though didn't have formal baseline. Also need to clarify what "long-term land investments means" vs " annual investments in agricultural inputs". The expectation was not that farmers would invest only in property but also agriculture. Namely tenure security would drive all sorts of investments--rentals/sales, property and agricultural.	Your comment raises several issues. 1) Comparison to the pre-construction period. We cannot compare beneficiaries to a pre-situation, as there is no baseline nor is there historic data pre-project. 2) We clarified the text to state the 22 percent is the percentage of Di perimeter households who took a loan since the interim survey. One in ten has made land investments in the past two years. We now state the rates as opposed to qualifying them as high or low. 3) A title is not required to take out a loan. 4) The interim analysis is not comparable to the final analysis in terms of land investments since in the interim survey this information was only collected for PAPs, not other beneficiaries. Unfortunately, there is no historical data on land investments, as noted above. 5) We added a definition to the text to specify that we use "land investments" to refer to investments in the agricultural land with a long-term payoff; and agricultural investments when we describe input decisions whose benefits last a shorter time. We show in Table III.3 that winning the lottery led to substantially higher agricultural investments, in Table III.5 to more land rental, and in Table III.7 to higher land investments. The mediation analysis in RQ2, Section III.B tries to disentangle to what extent this is due to land tenure security. 6) We are not clear what the reference to property means, as all of the land on the perimeter is agricultural land.
Di Perimeter Evaluation	M&E	32	P32	The ex-ante ERR should preferably be included in the analysis.	Added a comparison between the original and close-out ERRs in the description of the text.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	M&E	32	Pg 32. "Agricultural profits subtract the cost of inputs from the value of total production. The main costs are (1) labor costs for land preparation, weeding, and harvesting; (2) the costs of fertilizer, seeds, and pesticides; (3) post-harvest and marketing costs; and (4) contributions to the WUAs. The calculation assumes that the amounts of inputs differ across crops and dry and rainy seasons but that input prices remain constant across years and seasons."	Did the closeout model estimate economic prices for these inputs and outputs or did they simply use the prices in the market?	We used market prices due to a lack of evidence of overall market distortions (see below). The exceptions are subsidies to improved seeds. Because it is a small part of overall costs, its inclusion would have small negative effects on the ERR.
Di Perimeter Evaluation	M&E	33	Pg. 33 "Model does not incorporate distortions "	If the model does not take into account distortions then this is not an ERR, but rather an IRR. This is a fatal flaw if the evaluation based CBA does not at least attempt to correct for major market distortions. If there are inputs and outputs that are highly protected – perhaps fertilizer, rice, water, etc. these must have conversion factors applied to correct for distortions. If we don't have that, we are missing a critical piece of whether the economy as a whole is better off or just the individual PAPs. I'm guessing that the current internal rate of return is negative because in most scenarios the project costs swamp the benefits to the farmers. However, we should also be aware if there are major distortions that also make these profits bloated or lower than they should be and what affect that has on the entire economy.	See the answer to the comment in the line immediately above.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	M&E	33	Pg 33	Does either model take into account the opportunity cost of family consumption. If most of the benefit in the rainy season is accounted for in consumption rather than sales this could be missing a large benefit. Are maintenance costs (or lack thereof) incorporated into the evaluation based CBA?	We estimate the value of family consumption and include that in the value of production. Maintenance costs are also included through water user fee payments.
Di Perimeter Evaluation	M&E	33	Pg 33 "No spillovers from the additional production outside the perimeter"	Is there any evidence that the project actually affected market prices? If they did somehow affect prices, why?	We present qualitative evidence on perceptions in price changes from the interim and final evaluations. This includes stakeholders' opinion that the perimeter led to lower prices.
Di Perimeter Evaluation	LAE	33	Pg. 33, just above Table II.10	Delete "paste a"	Corrected.
Di Perimeter Evaluation	M&E	33	Pg 33 "These costs do not include costs incurred by the post-compact entity APD after the close of the compact."	Are these costs included in the evaluation based CBA model?	No, these costs are not included.
Di Perimeter Evaluation	M&E	34	Pg 34 "We do not update the close-out CBA model's estimates on agricultural outcomes in the absence of the project because we do not have access to better information, as the baseline data do not include information on production of crops before the project."	Are saying here you aren't updating the counterfactual? How can that be if we have an impact evaluation for some of the beneficiaries. It seems more than reasonable that you would need a model broken down by beneficiary types when the outcomes are so different between the different kinds of beneficiaries. And particularly for PAPs, isn't there counterfactual data from the Di Lottery evaluation?	That is correct. We are not updating the ERR counterfactual with control group outcomes because they serve different purposes. The ERR counterfactual represents the (probable) production and profits from the land on which the Di perimeter was built if the perimeter had not been built. The Di Lottery control group serves a different purpose: their incomes serve as counterfactual for the incomes Di Lottery beneficiaries would have received if they had not won the lottery and been able to access land and other project benefits.
Di Perimeter Evaluation	M&E	34	Pg 34. Table II.11 "Future profits are the same as those from the final evaluation"	What is the evidence that supports this assumption? Is there something about the trend between midline and endline that supports this higher level of profits?	We are limited in terms of the values we can include in the ERR, given that we only collected two rounds of data. We use the final evaluation data because (a) the information on area cultivated is available from remote sensing and (b) this is the more recent information, which is important if farmers adopt and perfect agricultural technologies over the medium term.
Di Perimeter Evaluation	EA	34	p 34	Again, it's not clear what estimated ag profits/ha are based on, and in particular whether they utilize survey- or crop cut-based estimates of yields.	Our profits per hectare do not rely on yield estimates, but rather take sales of crops from a plot (plus the estimated value of own production minus costs) and divide that by the plot size.
Di Perimeter Evaluation	M&E	34	P34, Table II.11.	Consider integrating interim evaluation findings on soil fertility in the evaluation-based CBA assumptions.	We do not have information on how soil fertility will evolve over the course of the perimeter lifespan. To the extent that soil fertility has already suffered, these effects would be reflected in the final evaluation profits.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter Evaluation	M&E	34	Pg 34 Table II.11 "Given that the remaining lifespan estimates vary quite widely from 10 years to 30 years, we assume a remaining lifespan of 18 years as our benchmark and vary the lifespan around that in sensitivity analyses."	What is the evidence around using 10 years and 30 years? Given the current state of the infrastructure, are these 3 point estimates (10, 18, and 30) in the reasonable range? Is 18 actually the most likely given the maintenance of the perimeter and what you have learned around sustainability?	All lifespan estimates we present in the evaluation are based on interviews with irrigation engineers familiar with the Di perimeter infrastructure and yet, as you note, this is a wide interval. Because the insecurity and the COVID-19 pandemic prevented our own irrigation engineer from visiting the sites, we are not able to provide a less noisy estimate from the final evaluation. We therefore present the minimum and maximum values from the final evaluation. In addition, we note that the interim assessment conducted two years ago placed the remaining lifespan between at least 20 and 25 years-or between 18 and 23 years from now on--which is consistent with the ERR assumption on lifespan at 18 years.
Di Perimeter Evaluation	M&E	34	Pg. 34 "Overall, the undiscounted benefits are slightly exceeded by the undiscounted costs."	This is using the survey, I assume?	This compares the survey profits with construction costs and counterfactual profits.
Di Perimeter Evaluation	EA	34	Pg 34, ERR recalculation.	What is the source of the **crop yield** information used in MPR's ERR recalculation? Are crop yields estimated from the crop-cutting survey, from farmer recall, remote sensing, or something else?	Our profits per hectare do not rely on yield estimates, but rather take sales of crops from a plot (plus the estimated value of own production minus costs) and divide that by the plot size.
Di Perimeter	M&E	34	pg 34	MPR mentions reestimating ERR by both surveys and remote sensing data. Were crop cuts used and if not why?	We do not use crop-cut information to calculate profits. Instead, we use the area cultivated by crop from the remote sensing analysis and then use the profits per hectare by crop from the survey.
Di Perimeter Evaluation	EA	35	Pg 35, explanation of lower ERR in MPR's recalculation compared to MCC's closeout ERR.	*"This is due to a lower cultivation area for this crop[onions] that remains the most profitable on a per-hectare basis,* ***as well as lower yields****… As shown in Figure II.6,* ***estimated yields from the crop cut survey are about 40 percent lower****…"* [emphasis added] The yield statement is incorrect. Estimated onion yields in MPR's crop-cutting survey are in fact 14% higher than the estimated onion yields used in MCC's closeout ERR. MPR's crop-cutting survey estimates onion yields at 30.7 tons per hectare while MCC's closeout ERR used an onion yield estimate of 26.9 tons per hectare. However, MPR is correct that their lower ERR estimate is likely due to a much lower estimate of total cultivated area in the most profitable crop – onions.	Corrected.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Perimeter	M&E	36	pg 36	MPR noted credit taking is low but 1 in 5 people taking credit in a 2 year time frame seems high. What are you considering a normal amount of credit/loans? When compare with controls from Di lottery it appears higher.	When we compare it with the Di Lottery controls in the interim survey, it is lower, while it is higher than in the final evaluation. We agree that the classification into high or low here is somewhat arbitrary. In the revision, we present the percentage of respondents who take out credit.
Di Lottery Evaluation	M&E	N/A	Overall	It would be helpful to include interim and endline results in all the tables so folks can see the trajectory.	We reference the interim findings when they provide context for the final results or suggest a significant change.
Di Lottery Evaluation	M&E	N/A	overall	Were changes in off-farm labor measured? Any differences?	The analysis of off-farm labor does not address a research question and was not conducted.
Di Lottery Evaluation	M&E	38	pg 38	The summary of results on Ag cultivation/production has a negative connotation and appears to miss some outcomes. Yes, farmers increased cultivation of land by half a hectare instead of the 1 hectare provided, but when compare against the less than half a hectare cultivated by controls, they more than doubled their land cultivation. Similarly, you had 50%-100% increases in cultivation in various crops.	We have referenced the analysis in the Di perimeter chapter and the O&M chapter on land rental/sales. We unfortunately don't know what the outcomes are for the "missing land" but we do know it is cultivated. That is a missing link that the interruption of the in-person survey due to COVID-19 caused.
Di Lottery Evaluation	EA	38	P 38	"Winning the lottery has a significant impact on amount of land cultivated, but lottery winners cultivate significantly less land on the perimeter than they received"--What is happening, are lottery winners leaving substantial shares of their lottery-won land uncultivated (or renting it out)? Please clarify.	We clarify that this is land they are not cultivating themselves.
Di Lottery Evaluation	M&E	39	Pg 39 Table III.3	What is the 1,096 for the Lottery Participants in the table? This doesn't sum to the total, nor does it represent a difference.	Corrected.
Di Lottery Evaluation	EA	39	P 39	Please display what treatment and control group ag profits per ha were.	We do not present these indicators, as the research question for the Di Lottery is to estimate the impacts of the lottery on agricultural profits overall. To provide profits per hectare requires disaggregating overall profits by season and by location of the plot. This is outside the scope of this revision.
Di Lottery Evaluation	M&E	40	Pg 40 Figure III.1	Why are the figures for female farmers statistically insignificant? Is this an issue with sample size or is it likely that the changes are not meaningfully different than zero?	This is due to a much smaller sample size.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Lottery Evaluation	M&E	42	P42, Table III.4.	20% of control have formal land documentation. Is there qualitative data that could help interpret this data point? Should we interpret this as there being expansion of land formalization in nearby areas?	Much of this is explained by the fact that some control-group farmers ended up having land on the perimeter. 44% of the control-group farmers who claim to have formal land documentation have land on the perimeter, compared with only 15% of those who don't have land documentation. Without control-group farmers having land on the perimeter, the share would be similar to the 9% we observe with land documentation at interim. We do not know of other land formalization programs, but it is possible that such programs could explain some of the other control-group farmers who have land documentation. We include this information in a footnote.
Di Lottery Evaluation	M&E	42	pg 42-43	The project gave titles/leases and as such the key factor to discuss here is not whether formal documentation but rather the difference in treatment/control with titles/leases. Considering this, the figure is much larger than 4 times. 85 vs 3% in interim and 84 vs 13% in the endline. Also, the growth in general around control groups having any sort of formal land documentation may point to some benefits of the Rural Land Governance Project or legal reforms made by the government for households to obtain land rights. As for women, our understanding was no women had formal title to land prior to the project.	We discuss results for an expansive definition of land documentation and for land titles/leases in particular.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Lottery Evaluation	M&E	42	pg 42-44	Unclear that capturing the nuances in the framing of perception of tenure. First, need to flag interim results which were that there was a 7pp difference in control vs treatments with about 1 in 5 worried a lot that they would lose land in treatments vs closer to 1 in 3 or over 1 in 4 for controls. Similarly you had treatments at 63% not worried at all in interim vs 52% for controls (significant). Then in endline, interestingly these numbers basically evened out between control/treatment showing that there were decreases in tenure security perceptions by treatment and increases by controls. Regardless, having 1 in 7 significantly worried about loss of land is not a small/insignificant number as framed. I think overall Prindex has been noting 1 in 5 do not feel secure globally. number. Then, when it comes to whether linked with investment, the questions revolves around whether those who were more secure were those who more likely to invest (correlations) and also keeping in mind their tenure security perceptions when they took out the loans which likely coincided with interim not endline.	You raise two comments: 1) Interpretation of the levels of worry of land loss in the interim and final data collection, and comparison with Prindex. We have edited and expanded the text in this section to highlight that one-seventh of farmers feeling land-insecure is still a significant number, and to compare our results with those in the Prindex report for Burkina Faso. Because Burkina Faso is a country with one of the highest levels of land tenure insecurity in the world, both control and treatment group perceptions of land tenure security appear low by national standards (even though it might appear high from the outside). 2) Link with investment. In the mediation analysis, which links land tenure security with land investment, we use measures of land tenure security from the interim survey, as you correctly point out. The description of our use of interim land tenure security measures is later in the chapter, right before Figure III.3.
Di Lottery Evaluation	M&E	43	pg 43-44	Interesting re perception of tenure vs men. Can you include (move up from annex) the related tables disaggregated by gender?	We moved key indicators for which the treatment effect differs between men and women from the appendix into the main body of the text, into a new table (Table III.6).
Di Lottery Evaluation	M&E	45	pg 45	Can you clarify what is meant by: "Polyculture farmers were more likely than rice farmers to think the owner or renter may ask them to leave or that a family member may take over their plot"? Didn't MPR interview the owner? Or perhaps this means that polycultural land was rented out and this was the renter responding? How can a renter ask them to leave?	Corrected, this should read "owner or former owner".

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Lottery Evaluation	M&E	45	pg 45-46	The descriptions sometimes are before and other times after the related chart. Can the report make consistent even if that means breaking up the charts? For example, at first it seemed the details on letting land and significant differences in rentals and loans were not there but then realized it was just below the related chart.	Edited text to be before this table.
Di Lottery Evaluation	M&E	46	pg 46	The bold and summaries seem a bit negative compared to results. The report notes that the project increased farmers investment in land but that it is a small/low number. However, it was a doubling of investment compared to control in both interim and endline and 1 in 10 and 1 in 8 making investments over 2 year timeframes compared to other studies does not seem like a small number. More importantly, I am not clear why "land investment" vs ag inputs is separately analyzed as usually these are combined. You do see property investments like fencing or roofs analyzed separately from land investments which include agricultural inputs and trees (like in Benin RCT trees/perennials were included together) . There was no expectation to see changes in "land scaping" or "fencing".	Your comment raises several issues. We have edited these summary statements to ensure they accurately portray the more detailed findings, and to focus more clearly on longer-term investments. We define land investments as long-term investments in the land from which a farmer will benefit for several seasons. Agricultural investments are made to increase the yields and profits for a single season. We include different types of land investments as it would bias results if we excluded investments common in non-perimeter land.
Di Lottery Evaluation	M&E	49	pg 49	Mediation analysis is interesting! Though I'm not sure there was ever a claim that land tenure on its own without the other support (ag/infra) would increase investments. Rather the combined investments were necessary to lead to key outcomes. Could the report also show correlations of the variables? Are people who feel more secure via the mediators listed also the same people who invested and let land in both treatment and controls? Are those who feel secure also the same as those who said they had title/lease?	"We clarify in the text that land tenure security does not appear to be the sole driver of long-term investment in the land. If we had found effects operating through the land tenure channel on its own, it would be interesting to dig deeper into these correlations. Since that is not the case, we do not think it is promising to assess these correlations. "

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Lottery Evaluation	M&E	54	pg 54	"Land tenure security does not appear to be the driver of long-term investment in agricultural land." Suggest adding the word "sole driver" as it is a set of investments but not the only one necessary-correct?	We added this wording.
Di Operations and Maintenance	M&E	55	P55	Great visualization. Quaternary should connect to farms? Consider showing division between AMVS and WUA O&M responsibilities.	We have adjusted the figure to display WUA/AMVS responsibilities and connect the farmer plots to the canals
Di Operations and Maintenance	EA	55	Chapter IV, Di O&M	This chapter is the most interesting and useful part of the entire evaluation. It should be reproduced as a standalone document and distributed to any MCC staff still working on irrigation projects, and to MCC's water & irrigation group.	Thank you! This is great to hear.
Di Operations and Maintenance	M&E	58	P58, valves	You state the valves on rice plots are missing entirely. Do you know why this is? Was the expectation these would be part of infrastructure package?	Edited for clarity that these are not missing from an original design, but just that the canals do not have valves for rice plots. There was not an expectation among WUA staff that rice plots have valves, but the fact that they are missing is seen as flawed, given that the valves on the polyculture plots are very useful to WUA management. Some WUAs have begun installing valves on rice plots themselves.
Di Operations and Maintenance	M&E	65	P65, last paragraph	"operating fees on time". I think it would be more accurate to say operating expenses.	Agreed, fees have been changed to expenses.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Operations and Maintenance	EA	66	Pg 66: "On the other hand, during the rainy season, farmers grow crops such as corn and rice, primarily for their own consumption"	What is the source of MPR's assertion that most of the rice grown in the Di perimeter is for the farmers own consumption? This is very unlikely. According to Table II.3 annual rice production from the perimeter is at least 8,000 tons. Per capita annual rice consumption cannot exceed 300 kgs (Myanmar has the highest per capita rice consumption in the world at 195/kg/year). There are at most 543 rice farmers in Di (assuming 30% of the 1,810 farmers who received plots of land within Di grow rice). Assuming average family size of 15 people, average annual consumption per family cannot exceed 4.5 tons (300 x 15 = 4,500 kg). 543 x 4.5 = 2,444 tons of rice consumed by Di rice farmers per year leaving at least 5,556 tons to be sold. These consumption estimates are extreme upper limits. Per capita rice consumption by Di households is probably less than 200 kilograms/year.	We will correct this assertion to state "farmers on the perimeter grow staple crops such as corn and rice for sales and their own consumption." Also, our measurements of rice yields are of dried paddy. The weights used in our crop-cutting exercise were for rice that was dried but not hulled. We have corrected these numbers, applying a conversion factor provided by our local consultant in Burkina Faso to convert these figures into hulled weights so they are comparable with standard rice yield measures. We corrected these numbers and added these details as a note in the table for clarity.

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Operations and Maintenance	EA	66	66	In responding to MPR's assertion that Di farmers grow rice "primarily for their own consumption, and thus do not generate the profits needed to pay membership fees" I assumed that the yield and production numbers in their report were expressed in terms of milled rice. I made this assumption partly because MPR does not explain, anywhere in their report, whether they are measuring rice production in terms of paddy, unhusked rice or milled rice. Assuming that they are measuring production in terms of unhusked rice, it is still clear that production greatly exceeds consumption. Di farmers were allocated rice land in either one hectare or two hectare plots. According to MPR's crop-cutting survey a one hectare rice plot will produce 8.9 tons in the rainy season plus 8.5 tons in the dry season for a total annual production of 17.4 tons. Using a standard 65% conversion ratio this amounts to production of 11.3 tons of milled rice per year. A farmer allocated two hectares of rice land would produce 22.6 tons of milled rice per year. Average family size is around 12 persons. Assuming annual per capita rice consumption of 150 kilograms (a more realistic estimate than in my previous comment), average annual consumption of milled rice for a Di family would be 12 x 150 = 1,800 kgs/year. The one hectare rice farmer would therefore have 11.3 - 1.8 = 9.5 tons of surplus milled rice for sale each year and the two hectare rice farmer would have 22.6 - 1.8 = 20.8 tons of surplus milled rice to sell each year. Even assuming average annual rice consumption of 300 kilograms per capita, the family of a one hectare Di rice farmer could consume at most one-third of their annual rice production, leaving two thirds for sale. MPR should explain the source of their assertion that most rice grown in the Di irrigation perimeter is for own consumption.	Thank you for this detailed calculation. We have made corrections to the text and the tables (see above).

Section	Reviewer division	Page number	Page or Paragraph Reference	Comment	Evaluator response
Di Operations and Maintenance	M&E	67	P67, RQ3, Key finding	It's not immediately clear whether the decrease in infrastructure longevity is referring to interim evaluation estimates or MCC's initial estimates. It would be useful to compare against MCC's estimates.	The report now also compares to MCC's ERR estimate of 25 years, and also presents the estimates from the interim evaluation.
Conclusion	M&E	70	P 70	Please include a conclusion to the report. Can be similar to the one in the exec summary.	Included a conclusion to the report.

Appendix C

Stakeholder Comments and Evaluator Responses

This page has been left blank for double-sided copying.

Table C.1. Stakeholder workshop comments

no.	Reviewer	Comment	Evaluator response
1	Maire de Gassan	Il était important de faire un résumé du rapport méthodologique dans ce document afin que toute personne qui vient à lire le rapport, puisse le comprendre.	In this final report, we only briefly reference the evaluation design in order to keep the report to a reasonable length; the final report is meant to focus on the findings, while the evaluation methodology is laid out in great detail in the Evaluation Design Report.
2	Maire de Gassan	Les aspects adverses comme les pôles d'attraction que peuvent engendrer ces aménagements ne ressortent pas dans le rapport. Il est important les faire ressortir.	This was outside the scope of the evaluation activities of the final evaluation.
3	Maire de Gassan	Le consultant s'est plus étalé sur ce qui n'a pas été bon dans le projet. Ce qui fait que les leçons à tirer, les bonnes pratiques et les success stories ne sont pas mises en exergue.	In the interim report, we state that the program outputs are considered of good quality. Additionally, we have now added some references to the high quality of program outputs in the final report in several places. We also report successes like income increases in the final evaluation report.
4	Maire de Gassan	Les perspectives et les recommandations ne ressortent pas dans le rapport. Il convient de les mentionner dans le rapport.	Offering recommendations is outside the scope of this final evaluation. The goal of this final evaluation is to assess the long-term outcomes; it is not designed to gather the types of inputs from stakeholders that are necessary for making such recommendations. The survey instruments that were reviewed by MCC were not designed to capture this, either. We hope that the challenges highlighted in the report provide stakeholders a foundation for starting discussion to make improvements.
5	Maire de Gassan	Quelle est la taille de l'échantillon et quel est le pourcentage de cet échantillon par rapport à la population ?	The sample sizes were chosen using power calculations to ensure statistically significant results. This process is outlined in the annexes in further detail.
6	Maire de Gassan	Quel est le taux des drains qui sont bouchés ?	We had planned to conduct an infrastructure assessment in which an irrigation engineer would conduct an in situ assessment of the perimeter infrastructure including the drains. Due to the insecurity and COVID-19, we were not able to do that.
7	Maire de Gassan	Qu'est-ce qu'on fait des ouvrages en souffrance dans le périmètre de Di ? Quelles mesures par rapport à la longévité réduite des investissements ?	The report highlights a clear need for better maintenance; however, making recommendations on financing maintenance is outside the purview of the research team.
8	Maire de Di	Encouragement et remerciements à l'AMVS qui malgré les ressources limitées œuvre à trouver des solutions pour le maintien des ouvrages en bon état.	NA
9	Maire de Di	Ecrire Di au lieu de Dî pour le nom de la commune dans le rapport.	We consistently write Di.
10	Maire de Di	Contrairement aux dires du Consultant, des aménagements étaient faits sur le périmètre de Di avant le début du PDA mais ils n'étaient pas aussi modernes	Some parts of this area were indeed manually irrigated or using small pumps. We discuss this in the interim report when assessing issues of compensation. However, there was no large-scale infrastructure on the land on which the Di perimeter was developed before the implementation of the ADP.
11	DGEP	Félicite la Primature et le MCC pour avoir pris l'initiative de mener une étude d'impact, une chose rare pour nos projets.	NA
12	DGEP	Absence de mention sur les difficultés rencontrées dans la conduite de cette évaluation. En faire cas pourront peut-être justifiées la taille de l'échantillon qui sont des éléments d'atténuation.	The research team had some challenges in the process of transferring the endline survey from in-person to phone mode. We had to cut down the questionnaire significantly, and the enumerator team was retrained remotely to conduct the surveys over the phone from home, rather than in-person. This type of training was new for the research team and for the enumerators and took some iterations of materials and approaches. We have included information on this in the text.
13	DGEP	Classer les acronymes par ordre alphabétique.	We've ordered the references alphabetically.

no.	Reviewer	Comment	Evaluator response
14	DGEP	Revoir le dernier paragraphe des remerciements qui semble être le même que la note de bas de page au niveau du résumé.	This text is so important for MCC that we want to include it both in the Acknowledgments as well as in the Executive Summary.
15	ICDE	Rapport très technique et moins opérationnel.	Thank you for the relevant comments. Kindly note that, due to time and resource limitations, the evaluation could not expand the analysis to include operational questions. Rather the report focused on a few key questions in order to retain depth and scientific rigour.
16	ICDE	Relire le document et consacrer un pan pour souligner le rôle important du CATG dans l'accompagnement des OUEA.	The important role of CATG was outlined in the interim report. Since the final report focused on the endline outcomes when CATG was no longer operating in the area, in this report CATG is mentioned only as an actor in Table II.1, which outlines the project activities, and in footnote 6, which specifies post-compact activities.
17	ICDE	Omission d'auditionner les coopératives agricoles installées dans la zone de Di afin de mieux faire une analyse comparative entre les bénéficiaires du projet et ces coopératives et aussi de cerner les effets induits.	This was outside the scope of the evaluation activities of the final evaluation.
18	ICDE	Omission de citer le rôle de ECOBANK et de l'interviewer pour son accompagnement aux acteurs dans le volet accès aux crédits.	Assessing the different actors involved in credit provision to farmers post-compact was outside the scope of this final evaluation.
19	ICDE	Mener une réflexion nationale sur la question de la tarification de l'électricité en zone rurale quand on sait qu'elle représente près de 47% des charge d'exploitation.	NA
20	ICDE	L'évaluation aurait pu s'intéresser sur une comparaison entre les cultures du périmètre de Gassan et celles de Di.	The interim report compared WUAs on Di and in the Niassan perimeters. An analysis of cultivation patterns on the Di perimeter and the Niassan perimeters is outside the scope of the project.
21	ICDE	Quelles sont les solutions que le Cabinet propose pour sauver les infrastructures de Di ?	See response for comment #7, row 8 in this tab.
22	ICDE	Il serait souhaitable d'avoir une étude similaire sur le périmètre dans le long terme.	A long-term study of outcomes on the Di perimeter would be interesting. It is up to MCC to decide whether this kind of study should be pursued.
23	DPAAH/Sourou EAC-Di	Les 10 ans de durée de vie des infrastructures en terre court à partir de 2020 ou à partir de 2014 ?	The remaining lifespan duration is starting from 2020.
24	DPAAH/Sourou EAC-Di	Y a-t-il une différence entre taux de rendement économique et taux de rentabilité économique utilisés dans le rapport ?	In this report, both terms are used interchangeably.
25	DPAAH/Sourou EAC-Di	Quelles sont les mesures à prendre pour que le taux de rendement économique soit rentable ?	The evaluation identified reasons why the ERR is lower than the close-out ERR (lower cultivation area for onions, lower profits, road access). Developing concrete recommendations is outside the scope of this report.
26	DPAAH/Sourou EAC-Di	Recommandations et suggestions absentes dans le rapport	Developing recommendations is outside the scope of this report.
27	Président de l'Union des OUEA de Di	La difficulté majeure que rencontre les OUEA est le problème d'électricité. Bien qu'il existe le courant électrique dans la zone, les coupures intempestives poussent les OUEA à faire recours aux groupes électrogènes et cela augmente leurs charges.	We have added a note about the importance of unreliable power supply and the need for gas-powered generator substitutions as the drivers of high electricity costs in the Executive Summary.
28	Président de l'Union des OUEA de Di	Remerciement au CATG qui les a permis de maîtriser les appareils informatiques.	NA
29	Président de l'Union des OUEA de Di	La digue principale est en dégradation accélérée et si rien n'est fait pour la sauver, les dégâts seront énormes.	We mention in the report in Chapter IV that the levee is damaged and threatened by dysfunctional drainage valves and clogged drains, which exacerbate flooding on the perimeter.

no.	Reviewer	Comment	Evaluator response
30	Président de l'Union des OUEA de Di	L'autre difficulté que rencontre les OUEA, c'est la mévente de la production. L'absence de voies d'accès aux périmètres pourrait expliquer cette mévente.	The report notes poor road access to the Di perimeter as an important factor affecting farmers' outcomes in Chapter II, under RQ4.
31	Président de l'Union des OUEA de Di	Invite la Primature à se pencher sur leurs doléances.	NA
32	DRAAH Cascades	Avec la survenance de l'insécurité qui a interrompu les enquêtes terrain, y a-t-il eu une réadaptation du questionnaire dans son administration par voie téléphonique ?	The questionnaire was shortened by more than half, and certain questions were rephrased to be better suited for the phone mode.
33	Agence de l'eau du Mouhoun	Il serait intéressant de faire une comparaison entre les groupes qui ont gagné à la loterie et ceux qui n'en ont pas bénéficié.	This comparison is the basis for the evaluation design for the Di Lottery RCT conducted in Chapter III.
34	Agence de l'eau du Mouhoun	Quelle est la quantité d'eau qui a servi à l'irrigation pendant la saison sèche ? l'eau est – elle utilisée de façon efficiente ?	We had planned to conduct an infrastructure assessment in which an irrigation engineer would conduct an in situ assessment of the perimeter and efficiency of water usage. Due to the challenges posed by insecurity and COVID-19, we were not able to conduct this infrastructure assessment.
35	Agence de l'eau du Mouhoun	Y a-t-il des informations en ce qui concerne le respect des cahiers de charge ? si oui, les faire ressortir dans le présent rapport.	An analysis of adherence to the perimeter by-laws was outside the scope of our work.
36	Agence de l'eau du Mouhoun	Absence de suggestions eu égard aux résultats de l'évaluation.	See response to comment #62, row 63 in MCC comments tab.
37	Agence de l'eau du Mouhoun	Est-ce que le carré des rendements utilisé dans le rapport est le meilleur outil d'estimation pour ce type d'étude ?	See response to comment #42, row 43 in MCC comments tab.
38	Agence de l'eau du Mouhoun	Quelle appréciation le consultant fait des données du carré des rendements et celles issues des enquêtes ? Quelle est la meilleure approche ?	See response to comment #42, row 43 in MCC comments tab.
39		L'intérêt d'un tel rapport serait de voir si les résultats obtenus sont duplicables dans d'autres zones.	The scope of the evaluation is just to understand what the effects of this project were. Indeed, more research on this topic in neighboring areas would be interesting but is outside the scope of this evaluation.
40		Il serait les propositions à l'issue de l'évaluation devant permettre de sauver les infrastructures en souffrance pour plus de durabilité.	See response to comment #91 (row 37 in this tab).
41	AMVS	C'est la méconnaissance des droits et du cahier des charges qui fait que les gens louent leurs terres. La peur des sanctions fait que les gens ne garantissent pas leur terre pour avoir accès aux crédits.	We describe differing stakeholder views on land rentals in the land tenure section.
42	AMVS	Mettre l'accent sur le désenclavement de la zone.	The report notes poor road access to the Di perimeter as an important factor affecting farmers' outcomes in Chapter II, under RQ4.
43	AMVS	Les écarts entre les données satellitaires et les enquêtes terrains pourront s'expliquer si d'aventure il y a eu un décalage sur le temps d'observation. L'enquête terrain et la prise des données satellitaires ont elle été fait à la même période ?	Yes, both methods were conducted using the same period of time.
44	AMVS	Préciser que les PAP ont reçu des titres fonciers et les autres des baux emphytéotiques.	Table II.1 provides information that PAPs received titles for land received as compensation and leases for additional land. All other beneficiaries received leases.
45	AMVS	Faire ressortir le taux de croissance entre l'évaluation intérimaire et l'évaluation finale.	We calculate the growth rate and showed this in the lottery chapter.

no.	Reviewer	Comment	Evaluator response
46	AMVS	Mettre l'accent sur les bonnes pratiques.	The report includes both successful practices and challenges. For example, in the summary of research question 2, we note that WUAs have strong governance and financial transparency. We also note that the southern WUAs are performing maintenance well.
47	AMVS	Quelle est la représentativité de l'échantillon ? La représentativité de l'échantillon de l'étude doit être mis en exergue dans le rapport pour éviter toute suspicion.	For the quantitative survey, we now include information at the beginning of Chapter I, Section C.2 about the sample, noting that it was a stratified random sample of the population that is representative. We also reference the sampling design in the interim report. The qualitative data collection includes all WUAs and thus is comprehensive.
48	AMVS	Pourquoi n'avoir pas mener une étude comparative avec d'autres infrastructures de la même zone de Di ?	Although this is an interesting suggestion, it is outside the scope of this evaluation.
49	DGDR-PM	L'impact du projet sur l'environnement ne ressort pas dans le rapport.	MCC conducts environment and social projection analyses for all of their projects, which is separate from this evaluation.
50	DGDR-PM	Est-ce que les infrastructures en souffrance dans ledit projet peuvent être pris en compte dans le second compact en cours de démarrage ?	NA. These are comments for MCC , not the evaluator.
51	DGDR-PM	Est-ce que dans le second compact on peut prendre en compte l'énergie agricole ?	NA. These are comments for MCC , not the evaluator.
52	DGDR-PM	Quel est l'impact de la crise sécuritaire et de la Covid-19 dans le déroulement des activités du périmètre ?	This question is outside the scope of our evaluation. However, the reference period for the evaluation was the dry season of 2018/2019 and the rainy season of 2020 during which COVID-19 did not affect operations. We add that as a comment.
53	MCC	Il serait intéressant de formuler des recommandations fortes pour sauver les drains et canaux en dégradation accélérée.	It's clear the perimeter needs more maintenance, which can be achieved through higher payment rates. We state this in the Executive Summary and hope the report will serve as the basis for starting discussion about how to improve the situation, but it is outside our scope to state what measures to implement to make these resources available.
54	MCC	Remarque : il n'y a pas eu assez d'éléments du rapport qui traitent de l'accès aux crédits et les techniques de gestion du secteur agricole et de l'élevage.	The report discusses access to credit in Chapter III. Evaluating the larger management of the agricultural sector and livestock sector is outside the scope of this evaluation.
55	MCC	Quel est l'impact de l'insécurité sur le projet ?	See response to comment #107 (line 54 in this tab).
56	SG-PM	Rappeler les grandes conclusions du rapport méthodologique dans le présent rapport d'évaluation finale.	In this report, we mention that the methodological details are provided in the Evaluation Design Report. In Section I.C, we specify that the research methodology presented here only pertains to the final evaluation report.
57	SG-PM	Prendre en compte tous les acteurs en clarifiant leurs rôles dans la mise en œuvre du projet. Notamment, les acteurs commerciaux pour éviter que le non écoulement décourage certains intervenants.	We describe the project in more detail in the Evaluation Design Report. The analysis of other project actors was outside the scope of this final evaluation report.
58	SG-PM	Comment s'est fait le déguerpissement-réinstallation ? y a-t-il eu des résistances ? quel est la moyenne des superficies de dédommagement ? est-ce que ce modèle est duplicable ailleurs ?	These are relevant questions that we addressed in the interim report, which focused on the implementation of the project activities, including land and compensation issues.
59	SG-PM	Suggestion : regrouper les acteurs pour réfléchir sur la tarification de l'électricité dans le domaine de l'agriculture.	NA. This comment is addressed to the Government of Burkina Faso.

Table C.2. Stakeholder report comments

Section	Reviewer	Page number (French)	Comment	Evaluator response
N/A	Primature	N/A	Observation générale : Document à justifier	Mathematica uses a common template for each document that allows for efficient updates and a uniform look.
N/A	Primature	N/A	Orthographe : Ou**a**ttara au lieu de Outtara	Corrected.
ES	Primature	xv	« En réponse, le Millennium Challenge Corporation (MCC) a investi dans le Projet de Développement Agricole (PDA) dans le cadre du Compact du Burkina Faso, un montant de 480,9 millions de dollars, qui a été mis en œuvre de 2009 à 2014 par le Millennium Challenge Account - Burkina Faso (MCA-BF), en partenariat avec le Gouvernement du Burkina Faso ». Besoin de reformulation du paragraphe car les 480,9 millions de dollars est le montant total du Compact investi dans les 4 projets dont le PDA. Proposition : « En réponse, le Millennium Challenge Corporation (MCC) a investi dans le Projet de Développement Agricole (PDA) dans le cadre du Compact du Burkina Faso, un montant de 480,9 millions de dollars, qui a été mis en œuvre de 2009 à 2014 par le Millennium Challenge Account - Burkina Faso (MCA-BF), en partenariat avec le Gouvernement du Burkina Faso ». le montant de 141,9 millions de dollars a été injecté dans seulement le PDA.	Corrected.
ES	Primature	xxii	Concernant la figure ES1, il est fait cas des éléments en blanc devant représenter les résultats qui ne sont pas conformes à la logique du programme, parce qu'il n'y a pas d'effet observés ou que l'effet va à l'encontre de la logique du programme. Mais il n'y a de représentation en couleur blanche sur le graphique. Partie à revoir	We have taken out the note about white shading since this figure does not display any findings that were not supported by our evaluation.
ES	Primature	xviii	Le MCC a investi 89 millions de dollars dans la construction du périmètre de Dî, un périmètre agricole de 2 246 hectares situé sur la rive est du fleuve ~~de la rivière~~ Sourou.	Corrected.
ES	Primature	xix	Xix au lieu de xxiv	Page xxiv is page 24, which comes right after page 23 (xxiii), so we believe this roman numeral is correct.
ES	Primature	xxiv	La phrase *« les OUEA mettent en place des systèmes d'auto-gouvernance solides, ont des difficultés avec la solvabilité financière » pose une difficulté de compréhension. Proposition si cela ne dénature pas l'idée : les OUEA mettent en place des systèmes d'auto-gouvernance solides, mais ont des difficultés avec la solvabilité financière.*	We have clarified this.

Section	Reviewer	Page number (French)	Comment	Evaluator response
ES	Primature	xix	Les conclusions montrent que la durabilité des infrastructures sont menacées en raison de problèmes d'entretien et de difficultés financières, alors la question : les entités étatiques doivent-elles jouer un rôle pour cette durabilité. Si oui, arrivent-elles à jouer ce rôle et convenablement ? parce que l'évaluation fait des difficultés rencontrées par les OUA qui peuvent compromettre la durabilité des investissements, je ne sens pas suffisamment l'appréciation sur le rôle de l'Etat sur ce volet, notamment l'AMVS.	The role of the state and AMVS is outside of our research questions/evaluation. Additionally, it is noted in Chapter IV that the AMVS has limited resources, so they are not able to fully support the OUEAs as intended. Our interim report also discusses the challenges that AMVS faced with implementing their post-compact tasks.
Introduction	Primature	16	Proposition de formulation : « ….mais il a été interrompu avant la fin de la collecte des données en raison de l'insécurité accrue dans la région de la boucle du Mouhoun où la collecte des données en personne était mise en œuvre. ~~Bien qu'aucun membre du personnel n'ait été blessé, l'insécurité dans la région a créé un~~ le risque était devenu trop important pour que les répondants et les équipe de collecte des données puissent poursuivre le travail en toute sécurité.	We have clarified that no member of the evaluation team was injured.
Introduction	Primature	20	Paragraphe-principales conclusions-: Il serait intéressant de mettre en exergue les informations chiffrés (issues des enquêtes) attestant les conclusions.	We have added the numbers to the ES.
Chapter II	Primature	20	Deux chiffres différents sont mentionnés pour le niveau d'exploitation des terres en saison sèche : 95% et 96%. Chiffre à harmoniser	Edited for clarity.
Chapter II	Primature	20	Il serait incessant que les difficultés rencontrées dans le cadre de cette évaluation puissent être relevées distinctement et les évoquées dans certaines conclusions de l'étude du fait que ce sont des biais qui peuvent limiter la portée des résultats de l'analyse. Ce qui permet de ce fait d'atténuer certaines conclusions.	We added a note in the data collection section about the possible biases introduced by the necessary switch to a phone survey and the resulting reduction in the sample and in the plots of land included in the survey.
ES	DRAAH-BMH	xviii	« En termes d'identification des cultures, l'enquête sous-estime la superficie cultivée en riz, tandis que l'analyse par télédétection a du mal à identifier le maïs en saison sèche ». Pourquoi l'enquête sous-estime la superficie cultivée en riz ? (Environ 25% des superficies du périmètre sont destinées à la riziculture). Cependant, c'est la deuxième spéculation la plus importante en termes de superficie aussi bien en saison sèche qu'en saison pluvieuse. Pourquoi les superficies cultivées en maïs en saison sèche par ménage pourraient être difficilement identifiable par télédétections ?	We are not able to state why the algorithm performs poorly for maize, given that we used a routine that we could not adapt to investigate further.
ES	DRAAH-BMH	xviii	« Pour toutes les cultures, les estimations de rendement total et par hectare tirées des données de l'enquête sont nettement inférieures aux estimations basées sur les mesures par carrées de rendement ». Evidement que les enquêtés (producteurs) le plus souvent et dans la plupart de cas, ne prennent pas en compte plusieurs paramètres pour évaluer les rendements de leurs parcelles (les dons, la consommation, les pertes post-récoltes ne sont souvent pas comptabilisés). Donc la pose des carrés de rendements donne des résultats fiables et concrets.	We added literature on the source of these discrepancies and note that crop cuts and survey reports have issues.

Section	Reviewer	Page number (French)	Comment	Evaluator response
ES	DRAAH-BMH	xviii	Est-ce « Taux de Rentabilité Economique » ou « Taux de Rendement Économique » ou les deux expressions s'équivalent ?	In this report, both terms are interchangeable. We now consistently use the expression "Taux de rentabilité économique" in the final version of the report.
ES	DRAAH-BMH	xix	Le sigle ECR (Essai Contrôlé Randomisé) absent des acronymes.	We reorganized the list of acronyms in the French report to be in alphabetical order.
ES	DRAAH-BMH	xx	« Les bénéfices agricoles ont augmenté d'environ 460 000 FCFA par an (environ 840 USD), soit une augmentation de près de soixante-quinze pour cent par rapport aux bénéfices agricoles des non-bénéficiaires ». Qu'elle est la situation de référence en termes de bénéfices agricoles ?	This section is based on the lottery that assigned land randomly to some farmers, so the counterfactual is the control group farmers who did not receive land on the Di perimeter.
ES	DRAAH-BMH	xxi	« Les OUEA et l'AMVS n'ont pas la capacité requise pour réparer les parties endommagées des voies d'accès, les canaux fissurés et les vannes endommagées ». Vu l'état de dégradation très avancé de certaines parties du périmètre, il est très impérieux de travailler à avoir les capacités requises pour leur entretien.	This point is very relevant. We hope that this report will be useful for starting conversations related to improving capacity for repairs and maintenance, in terms of both human resources and funding.
Chapter II	DRAAH-BMH	23	« La superficie cultivée pendant la saison sèche telle qu'elle a été estimée par l'analyse de la télédétection (2340 hectares) est environ 4 % plus grande que la taille du périmètre (2 246 hectares) » Mieux expliquer cette partie ?	Edited for clarity.
Chapter II	DRAAH-BMH	24	« Cependant, il y a une certaine culture de maïs et d'oignons sur les parcelles de riz pendant les saisons des pluies et les saisons sèches, ce qui correspond aux preuves anecdotiques… » Ceci est un des facteurs aggravant le degré des inondations. La zone rizicole par exemple est située le long du fleuve avec des sols hydromorphes facilement inondables et qui ne répondent pas forcement à tout type de culture mais conseiller pour la riziculture.	Thank you for this comment. We note that if polyculture crops are planted on the rice plots-which some farmers do- the consequences of flooding can be severe. The flooding issue, however, also affects plots meant to cultivate polyculture crops.
Chapter II	DRAAH-BMH	32	« …environ 85 % estiment qu'il est très peu probable qu'ils perdent l'accès à leurs terres au cours des cinq prochaines années » S'agit-il de 85% des 75% ayant affirmé avoir des documents fonciers ou s'agit-il de 85% de l'ensemble des agriculteurs interrogés ? Quelles sont les raisons qui expliquent cette probabilité des perdre l'accès à leurs terres dans 5 ans ?	Edited for clarity: this is 85% overall, not 85% of the previous 75%. The reasons why they might lose their land are detailed in the main text: the most common reasons are fear that the government, the WUAs, or a family member might take over their land.
Chapter II	DRAAH-BMH	34	« En ce qui concerne les droits associés au périmètre de Dî, tous les ménages ne sont pas pleinement conscients de leurs droits de transfert de terres » Il est donc nécessaire et urgent que ces derniers soient pleinement informés de leurs droits sur le foncier à travers des sensibilisations.	Yes, we hope the report is the starting point for this type of further discussion/action.
Chapter II	DRAAH-BMH	24	« Planter du maïs » revoir l'expression	Edited in the French report.
Chapter II	DRAAH-BMH	26	La faiblesse des rendements obtenus par enquête par rapport à ceux obtenus par pose de carré de rendements s'expliquerait par plusieurs raisons (la non-prise en compte de la part destinée aux dons, à la consommation, aux pertes post-récoltes …). Tandis que les carrés de rendement donnent des résultats visibles et concrets.	We cite a body of literature that provides evidence on why the two sources of data might provide different estimates. The survey did collect information about crop production, crop sales, and post-harvest losses. We infer the value of the harvest destined for gifts and self-consumption.
Chapter II	DRAAH-BMH	28	Il serait très intéressant de faire le TRE par spéculation ou par zone de culture (riziculture et polyculture) et déterminer la spéculation ou la zone de culture qui enregistrerait le TRE très faible.	We include a table in the appendix that shows profits per hectare by crop for the close-out ERR and the evaluation re-estimated ERR.

Section	Reviewer	Page number (French)	Comment	Evaluator response
Chapter II	DRAAH-BMH	29	La faiblesse des bénéfices obtenus en saison sèche comparativement à ceux obtenus en saison humide s'expliquerait par les coûts de production très élevés de l'eau en saison sèche (redevance en eau plus élevée,).	Although the water fees are indeed slightly higher in the dry season, dry season crops are of much higher value on average so profits are much higher in the dry season.
Chapter II	DRAAH-BMH	39	« Le TRE est nul dû à la valeur faible de production d'oignon » qu'est-ce qui expliquerait cette nullité ? Faudra-t-il augmenter les superficies emblavées en oignon ou augmenter les superficies ?	Our data and analysis do not let us predict how profits would change if we changed the amount of area under production in onions, since (1) we do not know whether farmers currently cultivating other crops would obtain similar profits, and (2) we do not know if more farmers cultivating onions would have any impact on onion prices.
Chapter II	DRAAH-BMH	40	« Les rendements obtenus par carré de rendement dépassent les objectifs du projet tandis que ceux obtenus par enquêtes restent en deçà des objectifs. » Partant de ces deux types de rendement (par carré de rendement et par enquête), quelle est celui qui a servi de calcul du TRE ?	The basis for the ERR is the information on agricultural sales that households provided, not the yields from the survey or the crop cuts. By using sales, we are safeguarding against the issues with the yield data.
Chapter IV. O&M	DRAAH-BMH	66	« La redevance en eau collectée auprès des producteurs sert à l'OUEA d'entretenir les infrastructures d'irrigation et pour payer une redevance à l'AMVS » S'agit d'une taxe d'aménagement ou s'agit-il d'une redevance qui doit entrer également dans l'entretien des infrastructures ? Il serait important que les responsables d'OUEA expliquent aux agriculteurs qui payent cette taxe, son importance dans l'entretien des infrastructures d'irrigation ainsi que les responsabilités de l'AMVS dans cet entretien des infrastructures d'irrigation. Nous pensons qu'il faut faire un travail de sensibilisation sur le terrain afin que les agriculteurs comprennent leurs responsabilités et celle également de l'AMVS qui doit s'occuper de l'entretien des infrastructures qui sont entre le fleuve et la station de pompage (Chenal, digue de protection…).	We have corrected the term of the payment to AMVS to be a "taxe d'amenagement." We hope the report serves to start a discussion on the importance of paying water user fees and the importance for WUAs and AMVS to complete important maintenance.
Chapter IV. O&M	DRAAH-BMH	68	« Au début, le drain principal avait une profondeur de 1,2 mètre, maintenant il n'a plus que 50 cm. Le problème du drain principal est aggravé par la détérioration des voies d'accès le long du drain » Qu'est-ce qui est à l'origine de la détérioration des voies d'accès ? Peut-on citer la divagation des animaux sur le périmètre pendant les mois d'avril et de Mai, l'accès incontrôlé de tout type de tracteurs sur le périmètre qui contribue à détériorer les voies d'accès surtout les voies d'accès tertiaires qui séparent deux Unité Autonome d'irrigation. Toutes ces pratiques ne sont-elles pas à l'origine de l'aggravation de la détérioration des drains quaternaires, ce qui augmente le phénomène des inondations.	In Chapter IV, table IV.1, we explain the root causes of the road degradation; the roads are damaged due to a number of reasons, including cattle herding.
Chapter IV. O&M	DRAAH-BMH	70	Si les retards de paiement des frais et les faibles taux de recouvrement des frais à long terme, ainsi que les coûts élevés de l'électricité, la faible participation des agriculteurs aux travaux communaux et les fuites des canaux, menacent la solvabilité financière et la trésorerie des OUEA, nous pensons que c'est à elles (OUEA) de prendre leurs responsabilités afin que le payement de la redevance en eau et le taux de recouvrement soient effectués à temps par les agriculteurs à travers l'application stricte des testes régissant le fonctionnement du périmètre.	In Section ES.D (summary and implications), we clearly note the importance of water user fee payments and maintenance for the sustainability of the perimeter. It is outside the scope of the evaluation to make detailed recommendations on roles and responsibilities of the different parties.

Section	Reviewer	Page number (French)	Comment	Evaluator response
Chapter IV. O&M	DRAAH-BMH	70	NB : Comme suggestion : il aurait été intéressant de formuler des recommandations à l'ensemble des acteurs de mise en œuvre du projet pour améliorer le TRE pour les années à venir.	This is outside the scope of this evaluation.
N/A	DRAAH- CASCADES	Tout le document	Texte non justifié	Mathematica uses a common template for each document that allows for efficient updates and a uniform look.
ES	DRAAH- CASCADES	xxiii	Figure ES.2. Logique de programme pour la sous-activité O&M de Sourou : Certaines écritures dans les formes sont cachées. Redimensionner les formes pour permettre la lecture des contenus.	We addressed this.
ES	AMVS	xvii	Quel est l'impact du gain à la loterie de Di sur les pratiques agricoles.....Ceci sous-entend l'impact de l'aménagement sur les populations ? sinon l'impact de la loterie pourrait être la transparence dans l'attribution des terres du périmètre aux exploitants.	We clarify that this is the impact on the agricultural practices of lottery winners.
ES	AMVS	xviii	Les PAP déplacées par la construction du périmètre ont reçu une compensation financière pour les récoltes perdues, les terres sur le périmètre avec des titres des baux officiels... Le bail étant également un titre, la précision peut être utile en disant : avec des titres fonciers et des baux emphytéotiques	We clarified this.
ES	AMVS	xviii	La logique du programme du périmètre de Di prévoyait qu'un accès accrue aux terres irriguées, un régime foncier formalisé et une capacité technique renforcée suite à la formation pourraient augmenter l'intensité de culture des PAP et les aider à diversifier.... pas seulement les PAP mais tous les bénéficiaires y compris les gagnants de la loterie.	We clarify that the program logic applies to all beneficiaries.
ES	AMVS	xviii	Les bénéfices agricoles et les revenus des ménages des PAP tels qu'estimés à partir de nos enquêtes, ont augmenté entre l'évaluation intermédiaire et l'évaluation finale.. bien vrai que c'est un résumé, mais il serait intéressant de donner le taux de croissance des revenus entre l'évaluation intermédiaire et l'évaluation finale.	We have added this calculation in Section II.B.RQ2.
ES	AMVS	xix	Environ 7% des agriculteurs ont loué des terres en 2019. Comme dans l'enquête intermédiaire, peu d'agriculteurs ont demandé un crédit et utilisé des terres comme garantie pour obtenir un crédit... Cette situation s'expliquerait non seulement par la méconnaissance des droits conférés par les titres fonciers, mais aussi des dispositions du cahier spécifique de charges (article 75) qui considèrent la mise en location des terres des périmètres aménagés de la Vallée du Sourou, comme faute passible au retrait de la parcelle.	In the interim report, we noted that different stakeholders have different views on beneficiaries' legal right to rent out land. The leasehold documents provide a source of nuance on this issue. They specify that the permission to rent out land is granted, unless the Ministry of Finance objects in writing within a month of receiving a written notification of the intent to rent out land. We include this information and the fact that there are differing views of stakeholders in a footnote.
ES	AMVS	xx	Les bénéficiaires de la loterie sont plus préoccupés par la perte de leurs terres au profit d'institutions officielles, tels que le gouvernement et les OUEA.... En effet, sur l'ensemble des périmètres irrigués de la Vallée, la possession d'un titre foncier ne déroge pas au respect des règles et conditions d'exploitation édictées par le cahier de charges. La préoccupation serait beaucoup plus en relation avec le non-respect des règles et conditions d'utilisation de l'eau agricole notamment le paiement de la redevance eau, la discipline etc.	The fear of government expropriation is common in Burkina Faso as a whole, where three-fifths of those who feel insecure cite government expropriation as a source of their feeling of insecurity (Prindex 2020). Relative to those high levels, Di perimeter beneficiaries are comparatively less worried about government expropriation.

Section	Reviewer	Page number (French)	Comment	Evaluator response
ES	AMVS	xx	Les bénéficiaires de la loterie de Di ont plus de quatre fois plus de chance que les non-bénéficiaires d'avoir des documents fonciers officiels. *Ecrire : Les bénéficiaires de la loterie de Di ont quatre fois plus de chance que les non-bénéficiaires d'avoir des documents fonciers officiels.*	Edited.
ES	AMVS	xx	Cela est dû à quoi? est-ce que c'est la procédure d'obtention au niveau des non-bénéficiaires qui est 0compliquée ou bien le SFR de Dî qui est rendu opérationnel par le MCA-Burkina ne fonctionne pas? Autrement est-ce que l'enquête a touché cette structure pour comprendre la procédure de formalisation et de remise des documents de possession foncière dans la commune de Dî?	We describe these potential hypotheses in Chapter II, Section B, RQ2.
ES	AMVS	xx	La confusion concernant le régime foncier et la documentation s'est accrue depuis lors, un tiers seulement des bénéficiaires comprenant qu'ils ont des baux emphytéotiques et la moitié *affirmant à tort qu'ils possèdent des titres fonciers.* Les PAP effectivement ont obtenu des titres fonciers suite la compensation terre- terre et les bénéficiaires de la loterie, des baux emphytéotiques.	Clarified in the Di perimeter summary in the ES. Is also clear in Table II.1.
ES	AMVS	xxi	Les OUEA ont la capacité de mettre en œuvre des systèmes d'auto-gouvernance solide ; toutes les OUEA suivent des protocoles de leadership en respectant une gouvernance démocratique par le renouvellement au tiers du comité de gestion chaque année et en maintenant une transparence financière.	We added the information on democratic governance to the summary.
ES	AMVS	xxi	La viabilité financière des OUEA est menacée par les retards de paiement des redevances dans la plupart des secteurs,.....ainsi que les fuites des canaux. En effet, contrairement à la logique de paiement des redevances eau en début de campagne, les exploitants ne paient qu'en fin de campagne généralement après la vente des produits. Cette situation oblige les OUEA à préfinancer les activités et de poursuivre vainement certains pour le remboursement. Elles ne disposent pas cependant d'un moyen de coercition efficace qui puisse contraindre les gens à payer. Le système de fermeture des arroseurs n'étant pas possible surtout dans la zone rizicole.	We provided the information on the lack of enforcement means in the ES.
ES	AMVS	xxiv	Les OUEA mettent en place un système auto-gouvernance solide et emploi du personnel d'appui (comptable gestionnaire, électronicienne, ect.),	Added information on the cooperative staff utilization to the ES.
ES	AMVS	xxiv	Les estimations de la longévité des infrastructures sont tombées entre 10 et 30 ans. Quelle est la durée de vie normale de ces infrastructures?	We have added the project assumption of 25 years to Section ES.C.3.
Introduction	AMVS	1	Mon souhait est de regrouper les idées. Ecrire : *Malgré son rôle prépondérant dans l'économie du pays, le secteur agricole se caractérise par une faible productivité des cultures et du bétail (USAID BURKINA FASO 2015). La faible productivité agricole contribue à l'extrême pauvreté au BURKINA FASO, qui est l'un des pays les plus pauvres du monde avec un PIB par habitant de 634 dollars (FAPDA2014). Le BURKINA FASO est également un importateur net de denrées alimentaires (Chauvin et al 2012).*	We revised this section as you suggested.

Section	Reviewer	Page number (French)	Comment	Evaluator response
Introduction	AMVS	1	Selon la Banque mondiale, l'insécurité foncière au Burkina Faso pourrait réduire les terres agricoles de 15% au cours des 10 prochaines années et nuire à la productivité agricole. Mettez la référence du document en question et l'année entre parenthèse à l'instar des autres références citées.	Mathematica uses a common template for each document that allows for efficient updates and a uniform look.
Introduction	AMVS	2	2246ha et 2240ha : quelle est la vraie superficie ?	It is 2,246 hectares of land. The project planned to have 2,240 hectares, but ended up with additional cultivation area.
Chapter II	AMVS	22	Le secteur clé de ces différences est que l'enquête finale ne pas expliquer le manque d'informations sur les cultures associées à la location et à la vente de terre qui a eu lieu entre les enquêtes intermédiaires et finales.	We have revised the text to clarify this.
Chapter II	AMVS	22	L'estimation de la superficie basée sur la base des données de l'enquête.....les enquêtes intermédiaires et finales. Noter que tous les agriculteurs ne respectent pas correctement le calendrier cultural. En saison pluvieuse certains traînent pour laisser la parcelle vide afin de pouvoir planter l'oignon précoce à partir de septembre. Si l'enquête terrain et l'imagerie satellitaires ne sont pas réalisées au même moment, il est fort probable qu'il y ait cette différence.	We re-assessed the data to investigate whether this possible hypothesis could explain the discrepancy. We don't think that it can; the remote sensing analysis identifies a higher level of onion cultivation than the survey information.
Chapter II	AMVS	22	La question : Y-a-t-il pas un coefficient pour corriger la marge d'erreur entre les données satellitaires et les données de l'enquête terrain?	Because we don't know what the true value is, we cannot provide a correction factor.
Chapter II	AMVS	34	La probabilité perçue de perdre des terres au cours de cinq prochaines années est un peu plus élevée chez ceux qui ont loué ou acheté des terres.	Yes, that is correct.
Chapter II	AMVS	34	Quel est le coût de la location des terres par campagne sur le périmètre de Dî? Si ces coûts sont intéressant, et qu'on n'y prend pas garde, on peut assister éventuellement à une véritable spéculation qui va augmenter les charges de production et finalement rendre le périmètre inexploitable.	The median per hectare rent in the survey is 120,000 FCFA for renters and 140,000 for landlords.

Mathematica

Princeton, NJ • Ann Arbor, MI • Cambridge, MA
Chicago, IL • Oakland, CA • Seattle, WA
Tucson, AZ • Woodlawn, MD • Washington, DC

EDI Global, a Mathematica Company

Bukoba, Tanzania • High Wycombe, United Kingdom

mathematica.org