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REPORT

Evaluation of the Irrigation and Water Resource Management Project in Senegal: Interim Evaluation Report

July 29, 2019

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LIST OF ACRONYMS

AIDEP	Projet Agriculture Irriguée et Développement Economique des territoires ruraux de Podor
ANSD	Agence Nationale de la Statistique et de la Démographie
CAPI	Computer-assisted personal interviewing
CATI	Computer-assisted telephone interviewing
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station
COGEMAP	Conseils en Gestion, Études et Management des Projets et Programmes
CNCAS	Caisse Nationale de Crédit Agricole du Sénégal
CR	Communautés Rurales
DAM	Direction Autonome de la Maintenance
DC	Domain Commissions
ERR	Economic rate of return
FoMAED	Fonds de Maintenance des Adducteurs et Emissaires de Drainage
FCFA	Franc CFA where CFA stands for Communauté financière africaine
GIE	Groupement d'Intérêt Économique
GPF	Groupement de Promotion Féminine
IWRM	Irrigation and Water Resource Management
LTSA	Land Tenure and Security Activity
MCA	Millennium Challenge Account [Senegal]
MCC	Millennium Challenge Corporation
OMVS	Organisation pour la mise en valeur du fleuve Sénégal
PDIDAS	Projet de Developpement Inclusif et Durable de L'Agribusiness au Senegal
POAS	Plans d'Occupation et d'Affectation des Sols
SAED	Société Nationale d'Aménagement et d'Exploitation des Terres du Delta
SIF	System d'Informations Foncières
SV	Section Villageois
SRV	Senegal River Valley
WUA	Water User Association
ZC	Zone Commissions

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ACKNOWLEDGEMENTS

We greatly appreciate the support of the many people whose efforts contributed to this report. We especially thank our monitoring and evaluation colleagues at the Millennium Challenge Corporation (MCC) for their input and support throughout the evaluation: Julian Glucroft, Ishani Desai, Jack Molyneux and Sarah Lane. We thank the many MCC and external reviewers whose input on the draft version of this report has led to deeper analyses and more interesting and clear reporting of results; Alain Diouf, Jennifer Lisher, Kent Elbow, Bob Fishbein, Tim Mooney, Kari Nelson (formerly of MCC) and Cynthia Berning. We likewise thank the participants in two presentations of the draft report in Senegal for their comments and questions on the report, which provided additional context for our analyses; these include participants from DAPSA, MAER/DBRLA, SENEVAL, CREA, SAED Direction Generale, SAED de Dagana, SAED de Ross-Béthio, USACS, Ibrahim Fall, and Ibrahim Niane and a number of community leaders from the communes in which the IWRM was implemented in the Delta and Podor Activity areas.

Also in Senegal, we are grateful for the unwavering dedication and knowledge that our research coordinator, Ahmadou Kandji, continues to provide to the evaluation and to his irreplaceable help coordinating, documenting and following up on our field visits. We thank COGEMAP, which led the qualitative data collection and are particularly grateful for the leadership provided by Houlata Bah, and the insights and analysis carried out by Aminata Niang. Their strong team contributed greatly to the quality of this report. We appreciate the hard work and dedication of the staff of CRDES who collected the survey data for this midline evaluation. We also thank Mamadou Assane Niang of USACS and Sidiki Diop, former director of monitoring and evaluation for MCA-Senegal, as well as the rest of the post-compact team for their support and assistance during several visits to Senegal and for their organization of stakeholder feedback on the draft version of this report.

Our colleagues at Mathematica provided valuable support for the data collection and analysis. We are especially grateful to Elena Moroz and Abbie Turiansky who programmed the survey instruments, to Kathryn Cronquist for cleaning and processing the survey data, to Linda Molinari for code reviewing the analytical work, Anu Rangarajan for her guidance on the technical approach, Chris Ksoll for providing feedback on our agricultural findings, and Amanda Beatty for providing valuable feedback on the survey instruments. We thank Evan Borkum, who carefully reviewed the draft report and provided analytical support and clear recommendations for new or improved analyses. Jonah Deutsch advised on the mediation analysis and reviewed the results. Sheena Flowers and Shantal James produced the report. Effie Metropoulos, Maria Myers, and Betty Teller edited the report.

We would be remiss to omit recognizing the great efforts of former Mathematica colleagues including Aravind Moorthy, who led the midline evaluation design, co-led the land tenure case study team and whose dedication to thorough documentation has permitted the team to carry forward his rigorous design after he left the evaluation sector, Anca Dumitrescu who co-supervised follow-up data collection, Claire Hou and Claire Bobst who re-cleaned the baseline data, and Katie Naeve, who led the evaluability assessment.

We also received important contributions from Harounan Kazianga, who helped interpret some of our agricultural findings, El Hadji Ibrahim Thiam, our hydrological engineer who verified post-compact irrigation infrastructure maintenance, and Bougouma Mbaye Fall, who led our translation team with support from Dara Bernstein at Mathematica.

Most importantly, we gratefully acknowledge the community leaders, farmers, household members, and government officials that participated in the surveys and qualitative data collection and hope that the results provide information useful for improving programming and policies that affect their lives.

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. This evaluation reflects the independent assessment of its authors who have no potential conflicts of interest, to their knowledge, in evaluating the IWRM Project. The evaluation is funded by the Millennium Challenge Corporation, a U.S. government agency.

EXECUTIVE SUMMARY

The Senegal River Valley (SRV) produces 80 percent of the rice in Senegal (Sylla 2015). However, with improved irrigation infrastructure and other investments, the SRV has the potential to significantly increase domestic rice production. Such increased production has the potential to improve food security, contribute to broad economic gains and reduce poverty in Senegal (Matsumoto-Izadifar 2009).

Activities covered by this evaluation

The Delta Activity rehabilitated the existing irrigation and drainage infrastructure in the SRV delta, in the departments of Dagana and St. Louis.

The Podor Activity constructed a new irrigated agricultural perimeter at Ngalenka, in the department of Podor.

The Land Tenure Security Activity (LTSA) mapped land across nine communes in the St. Louis, Dagana, and Podor departments, and supported the creation of a comprehensive land occupancy and use inventory; developed an inclusive process for allocating land that prioritized customary claimants, women, and landless farmers; allocated parcels and formalized land rights through the provision of titles; and trained local officials to better administer land rights.

To improve agricultural productivity and the competitiveness of the agricultural sector in the SRV, in 2010 the Millennium Challenge Corporation (MCC) invested in a five-year compact with the government of Senegal. The Senegal Compact invested in two projects: the Integrated Water Resource Management (IWRM) Project, and the Roads Rehabilitation Project.

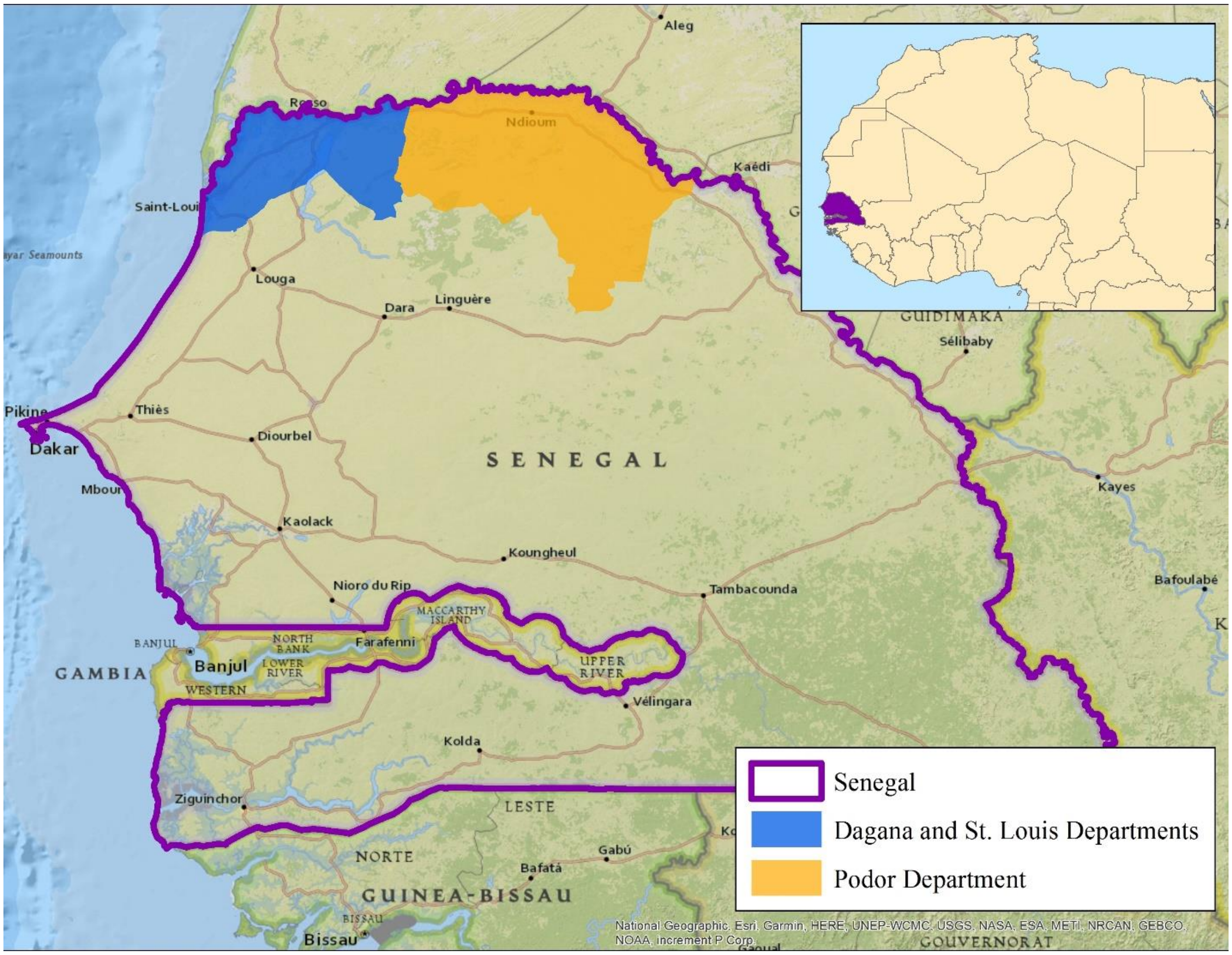
This report presents findings from an evaluation of the IWRM Project in the first three years after the compact closed in September 2015. We use a matched comparison design to evaluate the impact of the Delta Activity on water use, agricultural production, household income, land security, and land conflicts. For the Podor Activity, we use a pre-post design to assess changes in the same outcomes

We combine this quantitative analysis with qualitative data collected from beneficiaries and other stakeholders to understand the mechanisms of implementation and perspectives on sustainability in both the Delta and Podor Activity areas. Finally, to understand implementation of the Land Tenure Security Activity (LTSA) and whether its principles have been sustained since the end of the compact, we conducted a qualitative case study of land institutions and of community perceptions on their functioning in four communes, assessing implementation in both the Delta and Podor Activity areas.

A. Activities and timeline

The **Delta Activity** was implemented in the largely flat and arable delta of the SRV, in the departments of St. Louis and Dagana. By increasing available irrigable land through rehabilitating existing irrigation and drainage infrastructure, the activity was designed to increase the area of land cultivated in the SRV. It was also designed to increase crop intensity, which is the amount of cultivated crop area divided by the amount of crop area that could be cultivated, including through repeat cropping of the same area.

Figure ES.1. IWRM Project areas



When the compact closed in September 2015, the Delta Activity had built 17 water control structures and 37 kilometers of new canals; rehabilitated 181.3 kilometers of canals, 8 kilometers of protection dikes, and 39.8 kilometers of drainage canals; and created 1,519 temporary jobs (MCC 2015). The project recovered or increased the total area of agricultural land with improved irrigation infrastructure from 11,800 hectares to 38,391 hectares (MCC 2015a). Water flow in the Lampsar Canal increased from 20m^3 (MCC 2009a) to 65m^3 per second and the project implemented a new and effective drainage system (USACS 2018a).

The **Podor Activity** was designed to install new irrigation and drainage infrastructure in the Ngalenka basin. Ngalenka is an area in the Podor Department south of the departmental capital town of Podor. It was chosen for its large farming population and sufficient water resources, which suggested a high potential for rice production.

At the end of the compact, the activity had constructed a new irrigated perimeter including 7.7 kilometers of protection dikes, 24 kilometers of primary and secondary canals, 14 kilometers of access trails, and two pumping stations, creating 450 hectares of irrigated land. During July 2014, the first growing season since the irrigation infrastructure was built, 53 farmer groups

(GIEs), consisting of over 2,200 individuals and including 13 women's groups (commonly referred to as "*les groupements de promotion feminine*," or GPFs) cultivated rice (MCC 2015a; MCC 2015b). Each GIE created a water user association (WUA) to manage access to water and maintenance of irrigation infrastructure for their sections of the perimeter and contributed to the creation of higher-level WUAs, often referred to as water unions, to ensure the maintenance of the primary and secondary canals. Thus, there are 53 GIEs and 7 WUAs that represent them.

The **LTSA** was designed to support the creation and implementation of fair, efficient, and transparent processes for allocating land, as well as to offer equitable access to newly irrigated perimeters and strengthen local land governance. Its geographic scope encompassed the project areas of both the Delta and the Podor Activities. Because improved irrigation under the project was expected to lead to more land conflicts as the land became more productive, the LTSA was designed to deter or reduce conflict, ensure protection of landholder rights, and improve the investment climate in the project area.

The LTSA had two phases. From 2010 to 2012, it undertook an inventory of existing occupation patterns, land use, and property rights claims in the area of IWRM irrigation investments. During this first phase, the activity documented land rights claims and mapped over 60,000 hectares of farmland across the Delta and Podor Activity areas, which included nine communes. Phase I also included research to reveal for public discussion the land access challenges for all users of natural resources, including those of different ethnic groups, families, and clans; landless farmers; herders; women; and youth.

Phase II of the LTSA, 2012–2015, included five key tasks: (1) clarification and formalization of land rights in the nine communes in the LTSA intervention area and allocation of land and delivery of land titles in Ngalenka following the allocation procedures and principles developed during Phase I; (2) completion and application of land management and planning tools (POAS) and the Charter for Irrigation Development for the Senegal River Valley, two tools meant to provide a more transparent land formalization mechanism; (3) training of local administrators to increase the capacity for local land governance, including land management, planning, and allocation; (4) establishment of geospatial databases for land rights and land use at the local government level; and (5) adoption of improved land registries, allocation procedures manuals, and conflict resolution processes at the local government level.

During the course of the project, 8,655 farmers, GIEs, or corporate entities in the intervention area received land use rights titles covering 15,246 hectares of land (MCC 2015c). This exceeded the project goal of 3,440 hectares by 443 percent. The number includes both farmers in Ngalenka, who received newly allocated land and titles through the GIEs, as well as others who sought to formalize their land titles in other project areas (Elbow 2016). In addition, 5,018 stakeholders were trained in the use of land tenure security tools, including registries, procedures manuals, and databases. In Ngalenka, the LTSA facilitated the official delivery of land use titles to the 53 GIEs[1] and helped the groups obtain loans needed to buy seeds, fertilizers, and pesticides.

[1] As mentioned, 13 of these GIEs were women's groups, also known as GPFs.

B. Research Questions and Methodology

Table ES.1 lists the research questions this evaluation attempts to answer through impact and performance evaluations using quantitative and qualitative methods.

Table ES.1. IWRM Project research questions

Research question
Use and availability of water
Have there been changes in the sources of water used for agricultural production?
How has water availability changed, and have barriers or costs to accessing irrigation been reduced? Has the water supply become more reliable?
Has the amount of irrigated land increased?
Has the role of WUAs changed and how do they impact the use and availability of water?
Agricultural production
Have there been changes in the amount of land used for agricultural production? Is land being used for production in different seasons than before?
Has crop production improved? Have production methods, including the choice of inputs, changed? Have there been changes to the types of crops produced?
What factors are contributing to or constraining changes in agriculture inputs and production? Why are households changing or not changing agriculture production decisions, and how do those reasons vary depending on crop type, growing season, or income level?
How have changes differed by gender and among different income levels?
Household income
Have household income levels changed, including changes in components of household income, and has income shifted between agricultural and nonagricultural sources?
Do farmers perceive an improvement in their living standards?
Have agricultural profits changed?
Land formalization and conflicts
Have perceptions of land tenure security changed? Is there increased confidence in the land tenure system? If so, why?
Has the extent of land formalization changed? Is there greater awareness of the process for formalizing land?
Has demand changed for formalized land rights and are the costs of formalizing land rights perceived as reasonable?
Has the number or severity of land conflicts reduced? Has the type or nature of land conflicts changed?
How has the IWRM Project affected women's access to land and irrigation? How has it affected the landless?
How have changes in land security perceptions, formalization, conflict, or conflict management affected investments on land?
What have been the constraints or barriers to land access? Do these differ depending on gender, income levels, or age?
Land administration and governance
Have local government agencies become more effective at land management, including land allocation, land formalization, and conflict resolution? Is there greater confidence in the efficacy of these institutions?
Do institutions receive adequate support to carry out their functions?

Research question
Sustainability
What are the prospects for the sustainability of project activities post-compact?
What impacts did the project have outside of project areas?
Who benefitted from each IWRM activity? Where and when did each activity occur?

Primary quantitative data collection for this evaluation occurred at baseline between May 2012 and March 2013 and at follow-up between May 2017 and March 2018. Each round of surveys contained three waves, each of which focused on the most recently completed agricultural season: the cold season (November to February), the hot season (March to June), and the rainy season (June to October). The hot season is the primary rice growing season in the SRV. We waited to collect data until two agricultural season cycles after the end of the compact in order to allow sufficient time for impacts to materialize on agriculture production. We note that the baseline data was collected after the start of LTSA Phase I activities.

Our qualitative data support the quantitative data and provide answers to research questions which cannot be appropriately answered by surveys. Our qualitative methods included focus group discussions and interviews with members of GIEs and GPFs, and key informant interviews with *Société Nationale d'Aménagement et d'Exploitation des Terres du Delta* (SAED) headquarters staff and field engineers, leaders of WUAs, and individual community members in the areas affected by the IWRM interventions who did not belong to a GIE or a GPF. These interviews took place in late 2017 and early 2018 and included a mixture of women, landless residents, herders, and previously landless farmers.

To assess the effects of the LTSA project on land institutions, in December 2017 we carried out an in-depth case study of land institutions in four communes that received the LTSA.

C. Key findings in the Delta project area: the Delta Activity and the LTSA

For the Delta Activity, overall, we find that the project met or exceeded all output targets for building and refurbishing irrigation infrastructure—including water control structures, canals, protective dikes, and drains—resulting in a large amount of potentially irrigated land. And while we find a significant increase in land under production for the main growing season in our matched-comparison group analysis, the total amount of land under production as reported by SAED is lower than MCC's targeted amount and what is assumed for its Economic Rate of Return (ERR) analysis (USACS 2018a).

In terms of agricultural production, we find that the project significantly expanded rice production in the main growing season. More farmers cultivated rice, cultivated rice on a larger area of land, and harvested more kilograms of rice per hectare of land relative to the comparison group. However, many farmers decided not to cultivate during the cold and rainy seasons and did not farm market vegetable crops like tomatoes and onions as anticipated in the project's ERR and program logic. As a result, SAED reported that cropping intensity was only 75 percent in 2017, well below the project's target of 150 percent. Prior studies have found that cropping intensity is a key factor for increasing agricultural economic returns. While we find a significant increase in agricultural profit, particularly in the hot season, that change appears largely driven by the increase in the amount of land under production and is offset by an overall decrease in off-farm revenue. An increase in cropping intensity, if it were to occur, may provide more widespread economic benefits to treatment households.

The LTSA increased land formalization in the four communes in the Delta Activity area that received this intervention. However, lack of funding post-compact has hampered the ability of local institutions to implement the principles and policies of the LTSA, and land management practices differ across communes. We now present more detailed key findings from the Delta Activity area.

- **Farmers increased their land under production.** The IWRM Project led to a statistically significant increase in land under production of 0.56 hectares on average during the main agricultural season. This is an increase of 80 percent over the comparison group mean. Almost all this land was irrigated and used to cultivate rice. These increases were significant irrespective of the household's economic status or whether the household was headed by a male or female.
- **Agricultural profit increased for all three farming seasons combined.** The increase in agriculture profit appears mainly driven by an increase in land under production. While this increase is significant, it is partially balanced by a trade-off between off-farm earnings and farming.
- **Farmers are spending more money on agricultural inputs, but they are not spending more money on a per-hectare basis.** Farmers are spending more money on agricultural inputs, but they also increased their land under production. As a result, even though they are increasing their inputs and receiving greater profits, we find no changes in *per-hectare* agriculture investment or revenue during the main growing season.
- **Rice farming drove most of the changes in total agriculture production investment and revenue.** Rice farming was a primary focus of the IWRM Project. During the main growing season, the project led to an 11 percent increase in the number of households that cultivated rice, the average area of land dedicated to rice production increased by 91 percent from 0.64 to 1.22 hectares, and yields increased by 940 kg/ha on average.
- **Farmers produced more rice at the expense of cultivating other crops.** The project also intended that households would expand vegetable farming during the secondary farming seasons (cold and rainy seasons), but we did not find evidence that this took place.
- **Farmers shifted resources to focus on the main farming season.** As a result of the IWRM Project, households have shifted the allocation of their resources to focus more on farming in the main growing season, resulting in higher agriculture profits in that season.
- **Farmers choose crops largely based on the availability of water and agricultural inputs.** In our qualitative data, farmers reported that after the project ended, farm credit banks made it easier for them to get seed and fertilizer inputs. However, farmers also said that these inputs were costing them more money than previously, because they had more land under production and had to pay more for the mechanized irrigation needed to access water in parts of the new irrigation system.

- **The IWRM Project increased farmers' satisfaction with water availability in the Delta intervention area, though this varied depending on farmer distance to the water source.** Qualitative data reveal that almost all the beneficiaries we interviewed appreciated the increased availability of water from the project. They considered it a major driver of improved agriculture in the Delta, including their ability to cultivate year-round. However, farmers farther from the water sources and canals reported less satisfaction than those closer, who have easier access.
- **MCA helped WUAs formalize.** MCA helped WUAs restructure, obtain permits of association, and establish offices; MCA also worked to strengthen the WUAs' technical capacities. The function of WUAs is to help communities sustain the irrigation infrastructure in concert with SAED. However, WUA leaders we spoke with asserted they lack material means for maintenance to ensure the operation of the infrastructure and a good supply of water.
- **The IWRM Project led to positive impacts in land formalization, which also contributed to some positive changes in agricultural production.** More households in the Delta Activity area know the process they have to follow to receive a land title, and more households applied for and received land use titles at the commune level. The increase in land titling contributed to the increase in land under production in the hot season. We do not find any project impacts on reducing land conflicts and there was no increase in conflicts; however, there were few conflicts reported in the baseline data.
- **The LTSA aided local land institutions to develop principles and policies for land use and land allocation.** Commune land officials implemented the policies with the assistance of the implementation team during the compact but have not been able to fully implement land formalization activities since compact close due to lack of funds to physically inspect the lands. Communes report a large backlog of applications. Land management practices differ considerably by commune.
- **SAED has carried out maintenance on the irrigation works, and has plans to continue to do so.** The post-compact entity reports some slowing of maintenance and follow-up activities, which are largely in the hands of SAED. However, budgetary shortfalls at SAED combined with under-resourced WUAs may threaten the sustainability of the project.

D. Key findings in the Podor project area: the Podor Activity and the LTSA

For the Podor project area, we find that MCC achieved its output and short-term outcome targets by successfully constructing a new irrigated perimeter with 450 hectares of cultivable land. However, the project had mixed success in achieving its medium and longer-term outcomes. We find that the project supported improved land access as households targeted by the intervention for land within the perimeter reported greater access to land and, during the hot season, were more likely to farm relative to baseline. The project was successful at expanding rice production among beneficiary households thanks to the new irrigation system. Rice yields and revenue increased from baseline for the intervention group during the main growing season. However, problems with the new perimeter prevented farmers from cultivating in the cold and rainy seasons, leading to a reduction in agricultural production in these seasons compared to baseline and a significant drop in cultivating market vegetable crops.

While the project supported improved land access for households targeted by the intervention for land within the perimeter, the project also struggled with achieving sustainable outcomes for land tenure security. The Land Information System (*System d'Informations Foncières* or SIF) database is not in full use in most commune land offices and is not routinely updated due to limited human capacity and available resources. And while the intervention increased demand for land formalization, there remains a substantial backlog of tenure applications at the land bureaus. We now present more detailed key findings from the Podor Activity area.

- **The project was successful at increasing rice production during the main agriculture season**. Relative to baseline, we see increases in the intervention group in the percentage of households cultivating rice, the area of rice cultivated, rice investment costs, rice revenue, and rice yield. Among all intervention households, average area of rice cultivated increased by 43 percent.
- **More households harvested crops in the hot season at follow-up than at baseline.** The land within the irrigated perimeter may have reduced the rate of crop failure—a key objective of the project.
- **The project did not increase overall agricultural profit**. Despite the improvement in rice production in the main growing season, there is no statistically significant change in overall agriculture profit in this season. Households tended to consume a large portion of the rice they harvested. In the cold season, there is also an overall decline in agricultural profit relative to baseline, as well as a decline in off-farm earnings.
- **There was no change in the percentage of households who farmed land in the hot season, or in land under production in Podor among intervention households.** Although more households had access to farm land, there was not a commensurate increase in the share of households that farmed land in the hot season. We find no significant change in the average amount of land under production for intervention households during the hot season. Households may be prioritizing production on the Ngalenka perimeter land due to its better water access, so are changing the land on which they farm instead of farming on more land. We find a decline in land under production during the cold season, which is likely due to the perimeter not being irrigated during this season, because few producer groups planned to farm and the costs are too high to irrigate only a small portion of the perimeter.
- **The IWRM Project was successful in providing land to previously landless households.** The project was successful in providing farm land to some households that did not have access to farm land before the project. Among the intervention group, access to farm land increased by 15 percent in the cold season and 24 percent in the hot season. Both results are significant increases from the baseline value.
- **Improvements in land use were highest among female-headed households and the poorest households**. Those groups saw significant increases in reporting that they farmed land and the amount of land under production in the hot season. There were no changes in these measures among male-headed households or less-poor households.
- **Women and landless residents received land within the Ngalenka perimeter.** This was viewed as a very positive element of the project. **However, many were challenged by the small size of plots allocated to them, which inhibits substantial profits**. Others reported the unsuitability of their Ngalenka perimeter plots for rice cultivation as a disappointment

with the project's outcomes. Some women's groups have not been able to cultivate their preferred market garden crops, as the costs for inputs, especially electricity to run the perimeter's pumps, exceed any potential profit for the small land area that would be cultivated.

- **Accessibility of irrigation water in the main growing season increased with the completion of the Ngalenka perimeter.** However, the IWRM project did not increase the percentage of farmers who used irrigation as their water source. This is because most farmers already irrigated their fields from local waterways.
- **Water user associations in Ngalenka received training and appear to be functioning, although farmers' opinions on their effectiveness were mixed.** Some leaders of WUAs perceived improvement in their role in managing fee collection and assisting with maintenance. Other interviewees saw WUAs as less active than they should be, and saw the role of SAED as remaining dominant.
- **The LTSA increased demand for land formalization, but funding for land agencies is not adequate to keep up with demand.** LTSA outreach and education, as well as the new land grants provided to GIEs and GPFs in the Ngalenka perimeter created strong demand for formalization in Podor but lack of funding for the land bureaus has led to a backlog of applications.
- **Land allocation in Podor continues to consist of formalizing customary claims.** Project outreach and education activities were designed to improve access to land for women, landless and disadvantaged groups. While the Ngalenka project successfully delivered titles to groups including women and landless, customary land tenure is otherwise dominant in the LTSA project area in the department of Podor, thus land allocation consists of formalizing customary claims. Post-compact, this continues to create barriers to land access for those without customary claims, such as women and landless residents.
- **The SIF database is not in full use in most commune land offices and is not routinely updated**. Lack of human and material resources limit its use.
- **The percentage of plots with a land title did not change.** Among households with land in the Ngalenka perimeter, we examined the percentage of plots that are titled for each household and find that on average, one-quarter of plots have a land title both before and after the intervention. Since the land allocation that was part of the LTSA and the Podor Activity delivered titles to the cooperatives rather than to individuals, households may not perceive the land as titled to them.
- **Decisions about investment in the perimeter do not appear related to land security or concerns about conflict**. Rather, farmers cultivate when the likelihood of a good harvest is highest. In other words, farmers decide to cultivate in the hot season when water flow can be well regulated, when credit is available, and when other communal actors with land in the perimeter, with advice from the local agricultural extension agent, decide to cultivate. Among the intervention group, we find no significant correlation between a change in concern about losing land with changes in agriculture investment per hectare or revenue per hectare.

E. Next steps/future analysis

The findings reported here help build the limited evidence base for agricultural interventions in West Africa, but also highlight questions for further research. We find that the IWRM Project has met a number of its objectives in the first years after the compact, particularly those focused on making water more available for farming in the Delta Activity area and providing land to underrepresented groups in the Podor Activity area. These early evaluation results also highlight some outcomes that have not been attained, particularly increases in cropping intensity that prior studies have suggested is a necessary condition for improvements in households income (Connor et al. 2008; Kuwornu and Owusu 2012). Understanding why households are cultivating in some farming seasons but not others and which crops they are choosing to harvest will require further examination of farmers' economic behavior, and identification of barriers such as access to markets and market conditions or access to credit.

In terms of changes to land tenure security, we found that although the LTSA led to high demand for formalization and allocation of land, and the POAS is generally known and in some use, local land institutions are overburdened with land requests and require more funding and resources to manage the titling process. As the application backlog grows, it will be important to continue examining how titling, as well as perceived tenure security in the absence of documentation, affects farmers' decisions to invest in their land, and to monitor whether land conflict becomes more or less common. In the coming years, it will be important to assess whether the processes for land titling are sustainable without external donor intervention.

For the next and final phase of our evaluation of the IWRM Project, we will revisit the medium and long term outcomes to observe changes at four-plus years post compact and we will calculate the Economic Rate of Return (ERR) of the IWRM project. We will carry out a final round of data collection in early 2020 and present a final evaluation report in November 2020. The final evaluation report will allow us to further explore questions from our interim evaluation, such as:

- Are farmers satisfied with water flow and drainage in the irrigation systems, even when their plots are farther from the source than before the IWRM? Has SAED been able to maintain and repair the irrigation infrastructure?
- Are households continuing to concentrate on rice production and are they achieving the same yield gains we found in the interim report?
- Have increases in rice production had an effect on other parts of the agricultural value chain such as local markets?
- Have farmers increased their cropping intensity by farming more in the cold and rainy seasons, particularly by cultivating market vegetable crops? What factors are promoting or inhibiting changes to cropping intensity?
- How has the IWRM project affected on-farm and off-farm household labor allocation and ultimately income four years after the compact closed?
- Has demand for formalization continued and have land agencies successfully processed and registered these requests? Have the number of land conflicts changed?

- Is there a change in land security or perception of land tenure security and does it affect agricultural investment?
- Have the irrigation and land tenure interventions influenced new irrigation, land security and land allocation projects in the area? Has the GoS continued to support the sustainability of these activities?

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I. INTRODUCTION

Agriculture in Senegal plays a central role in the livelihood of millions, directly employing more than half of the country's population in 2017 (ILO 2018). However, the agricultural sector accounted for only 15 percent of Senegal's gross domestic product in 2017 (World Bank 2018), and the country is unable to meet its consumption needs. Senegal continues to import nearly two-thirds of its primary staple—rice—making the country vulnerable to price shocks on the world market (Sylla 2015). In addition, rural poverty, subsistence farming practices, environmental damage, and recurring natural disasters hamper agricultural production, leaving two million people undernourished and 17 percent of all households food insecure (WFP 2018).

The Senegal River Valley (SRV) produces 80 percent of the rice in Senegal (Sylla 2015). With improved irrigation infrastructure, water delivery, and drainage; appropriate inputs such as seeds and fertilizer; and better harvesting and transportation practices, the SRV has the potential to significantly increase domestic rice production, improve food security, and contribute to broad economic gains and reduce poverty in Senegal (Matsumoto-Izadifar 2009). However, in 2015 less than half of Senegal's arable land was irrigated, and rain-fed agriculture continued to dominate in the SRV despite increasingly unpredictable and unreliable rainfall. Recurrent droughts and occasional flooding have led to declining yields as soils have degraded and eroded.

Issues of land governance have also plagued Senegal's agricultural sector. Unclear and informal property rights, poor record keeping on land tenure, and a lack of capacity to govern land rights and manage conflict have all been problems in the SRV (Diouf et al. 2015). Such a lack of formal land tenure can inhibit investment, create conflict, and reduce productivity (Goldstein and Udry 2008). Despite Senegal's decentralization policies, which are designed to divert authority to local governments in an attempt to improve land governance, the system has been plagued by insufficient financial resources and poor application and understanding of the law (Diouf et al. 2015).

To harness the potential of agriculture in Senegal by helping the country overcome its agricultural challenges, to improve agricultural productivity and encourage the competitiveness of the agricultural sector in the SRV, and to increase rural employment and incomes, the Millennium Challenge Corporation (MCC) invested in a five-year Compact with the Government of Senegal, which began on September 23, 2010. Two projects made up the Compact: The Roads Rehabilitation Project and the Irrigation and Water Resource Management (IWRM) Project. This report presents interim findings from Mathematica's evaluation of the IWRM Project.

The IWRM Project included three activities in the SRV: (1) the Delta Activity, (2) the Podor Activity, and (3) the Land Tenure and Security Activity (LTSA). A fourth planned activity, the Social Safeguard Activity, was not implemented. The Delta Activity rehabilitated the existing irrigation and drainage infrastructure in the SRV Delta, in the Departments of Dagana and St. Louis. The Podor Activity constructed a new perimeter of irrigation infrastructure at Ngalenka, in the Department of Podor. Across the St. Louis, Dagana, and Podor Departments, the LTSA supported the creation of a comprehensive land occupancy and use inventory; developed an inclusive process for allocating land that prioritized customary claimants, women, and landless farmers; allocated parcels and formalized land rights through the provision of titles; and trained local officials to better administer land rights. The LTSA was administered in coordination with the irrigation improvements: all areas in which irrigation improvements took place also had access to the LTSA. Project activities were completed and the five-year Compact closed on September 23, 2015.

This report presents interim findings from Mathematica's evaluation of the IWRM's three activities to determine their impact on use and availability of water, agriculture production, household income, land administration and governance, and land security and conflicts. The findings come from data collected in 2017 and early 2018, two years after the end of the compact. When data were collected, land titles had been distributed for four years (beginning in 2013), new irrigation infrastructure in Delta had been operational for two years (beginning in 2015), and the new irrigated perimeter in Podor had been operational for three years (beginning in 2014). We answer research questions on implementation, project outcomes, and sustainability using a mixed-methods evaluation that deploys both quantitative and qualitative evaluation methods. Because the IWRM program operated differently in two distinct regions of the SRV, we use separate evaluation approaches for the Delta and Podor project areas. For the Delta Activity, we use a matched comparison group design to conduct an impact analysis and estimate the causal effects of IWRM Project activities. For the Podor Activity, we estimate project changes using a quantitative pre-post design. We also use qualitative approaches to answer several research questions, specifically the questions involving the LTSA. When applicable, we integrate both quantitative and qualitative approaches to triangulate the effects of the IWRM Project.

The rest of the report is structured as follows. In Chapter II, we introduce the Compact, the IWRM Project, and the project activities; and describe the program logic. In Chapter III, we review the existing literature on (1) irrigation infrastructure and (2) interventions to improve land tenure security and administration, discuss the gaps in the literature, and describe how the IWRM Project evaluation could fill those gaps. In Chapter IV, we present the design of the evaluation, including both the overall methodology and the differences in our approaches to Delta and Podor districts. In Chapter V, we present the quantitative and qualitative findings of the evaluation for the Delta Activity and for the LTSA activities in the Delta area. We present the findings for the Podor Activity and the LTSA activities in the Podor area in Chapter VI. In Chapter VII, we link our key findings for the LTSA back to the project logic model. Chapter VIII concludes the report.

II. OVERVIEW OF THE COMPACT AND THE PROJECT

This section provides an overview of the Senegal Compact, the IWRM Project, and the specific activities that Mathematica evaluated as part of the interim study. This section addresses our research question on where and when each activity occurred.

A. Overview of the Compact

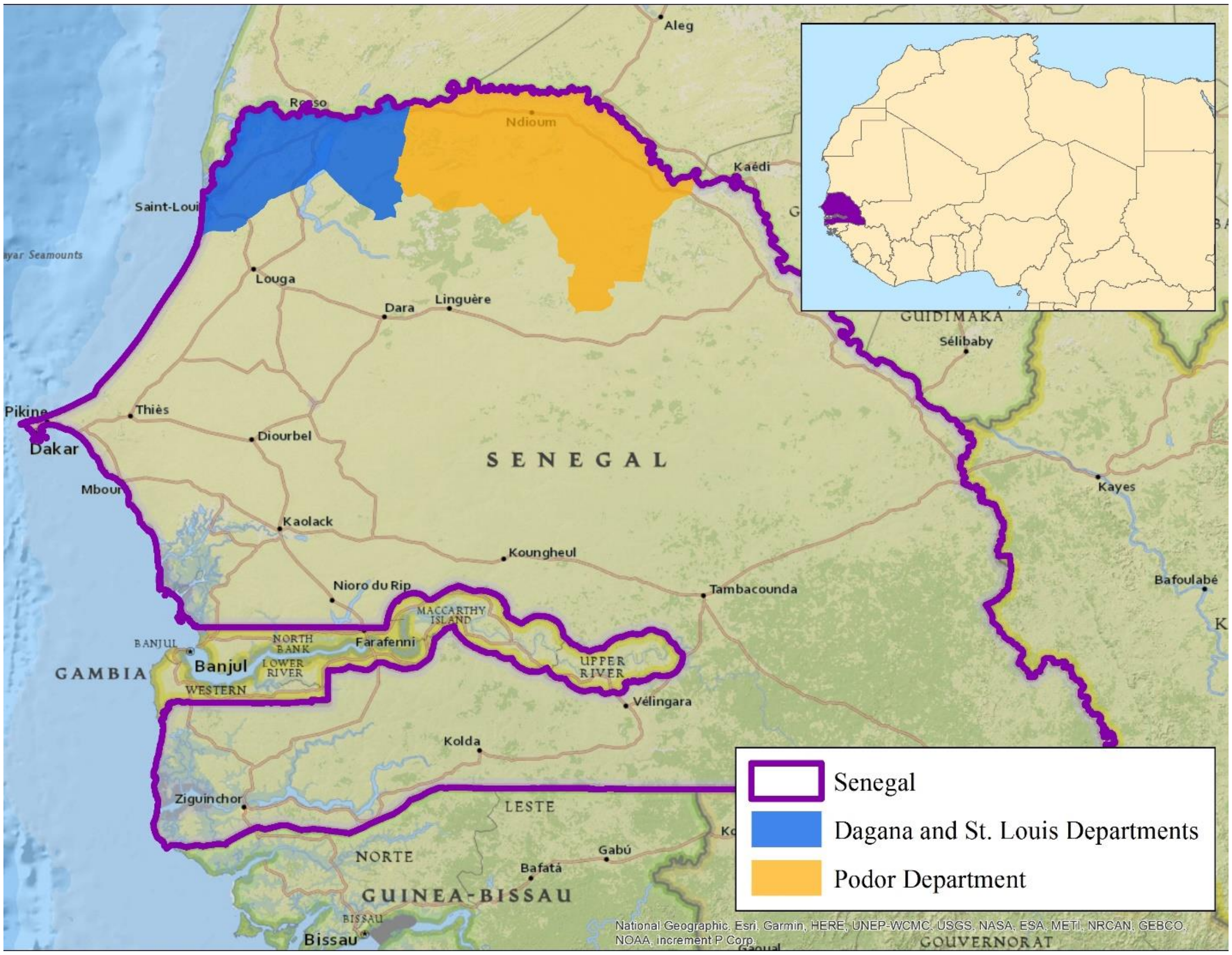
On September 16, 2009, MCC signed a $540 million compact with the Republic of Senegal. This compact, which entered into force on September 23, 2010, had as its goal to "enable improved agricultural productivity and to expand access to markets and services through critical infrastructure investments in the roads and irrigation sectors" (MCC 2009b). The compact consisted of two separate projects: The Roads Rehabilitation Project and the IWRM Project. The Roads Rehabilitation Project was designed to reduce transportation time and costs by improving two main highways, thereby expanding access to markets and services. The IWRM Project, the subject of our evaluation, was designed to improve the quality and availability of irrigation in agriculture-dependent areas of northern Senegal, and thereby increase productivity in the country's agricultural sector.

B. Overview of the IWRM Project

The Senegal River forms the eastern and northern border of Senegal; in the west it empties into the Atlantic Ocean, and it is distinguished by its large flat river delta of largely arable land (Figure II.1). There are 240,000 hectares of potentially irrigable land in the Senegal River Valley (SRV), and the land is suitable for rice, Senegal's dietary staple (Diouf et al. 2015). However, before the IWRM intervention, less than half of those 240,000 hectares were irrigated (Ndiaye 2007). Moreover, degraded irrigation systems, insufficient delivery of water, and a lack of appropriate drainage led to an increase in abandoned fields from 13,500 hectares in 1998 to 18,800 hectares in 2008 (URS Group 2009). Compounding the problem, insecure property rights, weak land registration and management tools, and recurring land conflicts have led to a poor investment climate in the SRV (MCC 2009a).

In line with Senegal's 1998 Master Plan for poverty reduction, MCC funded the IWRM Project to increase the volume of irrigation water available to farmers, reduce the risk of further abandonment of agricultural lands due to insufficient water supplies, and provide additional water for both human and animal consumption. The IWRM Project consisted of four activities (1) the Delta Activity, (2) the Podor Activity, (3) the Land Tenure Security Activity (LTSA), and (4) the Social Safeguard Activity (not implemented). This evaluation covers the Delta Activity, the Podor Activity, and the LTSA. In the 10 to 20 years after project completion, MCC expects 268,000 individuals to benefit from the project, to increase the area's average household income by 35 percent, and to improve food security (MCC 2015). Figure II.1 (below) shows the geographic locations of these project activities.

Figure II.1. IWRM Project areas



1. Activities

The **Delta Activity** took place in the western delta of the SRV, in the Departments of St. Louis and Dagana in the Region of St. Louis. By rehabilitating existing irrigation and drainage infrastructure, the activity aimed to increase available irrigable land and thereby increase the area of land cultivated in the Delta. It was also designed to increase crop intensity, which is the amount of cultivated crop area divided by the amount of crop area that could be cultivated, including through repeat cropping of the same area. Crop intensity is useful as a measure because it captures repeat cropping better than the total amount of cultivated land does—for instance, if farmers cultivate their entire field in one season, and on average cultivate half their land in a second season, their cropping intensity would be 1.5.

Specifically, the project's goal was to rehabilitate irrigation infrastructure for 19,490 hectares and extend the infrastructure to an additional 8,000 hectares, increasing the total hectares of land that used irrigation for agricultural production from 11,800 at baseline to 39,290 hectares at Year 5 (MCC 2009). In all, the Delta Activity's expected outputs were:

- 17 water control structures
- 36 kilometers of new canals
- 149 kilometers of rehabilitated canals
- 8 kilometers of protection dikes
- Temporary employment during construction
- An increase in water flow in the Lampsar Canal from 13 m^3 per second to 65 m^3 per second
- The establishment of an effective drainage system (MCC 2009b)

Three construction companies implemented the projects in lots: Condurail Engenharia, Consortium RAZEL BEC/SOGEA SATOM, and Consortium EIFFAGE/DLE, working from early 2013 to mid-2015. When the Compact closed in September 2015, it had built 17 water control structures and 37 kilometers of new canals; rehabilitated 181.3 kilometers of rehabilitated canals, 8 kilometers of protection dikes, 39.8 kilometers of drainage canals, and 39.8 km of drainage canals (as part of the effective drainage system); and created 1,519 temporary jobs (MCC 2015). The project also increased the total area with improved irrigation infrastructure to 38,391 hectares (MCC 2015a). MCA Senegal's final report stated that water flow in the Lampsar Canal did increase to 65m^3 per second, and that the project implemented a new and effective drainage system (USACS 2018a). Beneficiaries of the Delta Activity are defined in the Compact as including "households, owners or shareholders of farming enterprises, and households that have individuals employed in the operation of enterprise farms" within the area where the activity took place.

The Podor Activity was designed to install new irrigation and drainage infrastructure in Ngalenka, one of the sites listed in Senegal's 1998 Master Plan for development. Ngalenka is an area in the Podor Department, south of the departmental capital town of Podor, and was chosen for its large farming population and sufficient water resources, which suggested a high potential for rice production. The focus of the Podor activity was to construct a new 440 ha irrigated perimeter at Ngalenka, for which the following were to be built:

- 6 kilometers of protection dikes
- 23 kilometers of primary and secondary canals
- 14 kilometers of access paths
- 2 pumping stations

The Podor Activity was implemented by Joint Venture Construcoes/RC Senegal SA Company from November 2012 to March 2014, and considered final in April 2015 (USACS 2018a). At the end of the Compact, the Activity exceeded its goals by creating 450 hectares of irrigated land, constructing 7.7 kilometers of protection dikes, 24 kilometers of primary and secondary canals, 14 kilometers of access trails, and two pumping stations. Following the construction of the new irrigation infrastructure in Ngalenka, 53 farmers groups (GIEs), consisting of over 2,200 individuals and including 13 women's groups (commonly referred to as "*les groupements de promotion féminine*," or GPFs) cultivated rice in the first growing season in

July 2014 (MCC 2015a; MCC 2015b). Each GIE belongs to a water user association (WUA) to manage access to water and maintenance of irrigation infrastructure. Beneficiaries of the Podor Activity were defined as “households, owners or shareholders of farming enterprises, and households that have individuals employed in the operation of enterprise farms” within the area where the activity took place.

The LTSA was designed to support the creation and implementation of fair, efficient, and transparent processes for allocating land, as well as to offer equitable access to newly irrigated perimeters and strengthen local land governance. Its geographic scope encompassed and was larger than the Delta and Podor Activities, covering nine contiguous communes in departments of St. Louis, Dagana and Podor. The Delta Activity, Podor Activity and LTSA were carried out in coordination to ensure that LTSA work took place in all areas where irrigation infrastructure was improved or constructed. Because improved irrigation under the project was expected to lead to more land conflicts and potential abuses as the land became more productive, the LTSA was designed to reduce conflict, ensure protection of landholder rights, and improve the investment climate in the project area. The anticipated outputs of the LTSA included 10,003 plots mapped, corrected, or incorporated; 8,655 plots with formalized titles; 60,151 hectares mapped; formalized land rights for 3,440 hectares; 9 strengthened and functional technical support committees; 5,018 persons trained on a land tenure security tool; and 33 WUAs created. The LTSA was implemented by a consortium of firms known collectively as "Group FIT Council/SONED-Africa/CIRAD.”

The LTSA had two phases. During Phase I—the Research Phase, which extended from 2010 to 2012—there was an exhaustive inventory of existing occupation patterns, land use, and property rights claims in the area of IWRM irrigation investments, including both Delta and Podor activity areas. The land rights inventory methodology was designed to document both the formal (administrative) and informal (customary) land property rights of all landowners. In all, during the first phase the activity documented the land rights claims and mapped over 60,000 hectares of farmland in the following nine communes: Ross Bethio, Ronkh, and Diama in the Dagana Department; Gandon in the Saint-Louis Department; and Gamadji, Podor, Ndiayène Pendao, Guedé Village, and Dodel in the Podor Department. Phase I also included research to reveal, for public discussion, the land access challenges for all users of natural resources, including those of different ethnic groups, families, clans, landless farmers, herders, women, and youth.

For the Podor Activity in particular, the project developed and carried out (in Phase II) a participatory process involving local stakeholders which allocated the land within the Ngalenka perimeter: 60 percent of the planned Ngalenka irrigated perimeter was allocated to the three familial groups that exerted historical claims on the land, 20 percent of the land was allocated to local landless populations, and 10 percent was allocated to women’s cooperative groups. The remaining 10 percent of land was reserved for the farmers who had occupied and farmed about 79 ha of the 450 ha perimeter before its development.

Phase II of the LTSA, which began in 2012, included five key tasks: (1) the clarification and formalization of land rights in the nine communes in the LTSA intervention area, and the allocation of land and delivery of land use titles in Ngalenka following the allocation procedures and principles developed during Phase I; (2) completion and application of land management and planning tools (POAS) and the Charter for Irrigation Development for the Senegal River Valley, two tools meant to provide a more transparent land formalization mechanism; (3) training of local administrators to increase the capacity for local land governance, including land management, planning, and allocation; (4) establishment of geospatial databases for land rights and land use at the local government level; and (5) adoption of improved land registries, allocation procedures manuals, and conflict resolution processes at the local government level.

During the course of the project, 8,655 farmers, GIEs, or corporate entities in the intervention area received land use rights titles covering 15,246 hectares of land (MCC 2015c). This exceeded the project goal of 3,440 hectares by 443 percent. The 8,655 farmers and GIEs who received newly allocated land titles includes 53 GIEs who received land titles in the new Ngalenka perimeter, but is largely composed of individual applications from farmers and GIEs in project areas across Delta and Podor. (Elbow 2016). In addition, 5,018 stakeholders were trained in the use of land tenure security tools, including registries, procedures manuals, and databases. For the 53 GIEs[2] in Ngalenka, the LTSA also helped the groups obtain loans they needed to buy seeds, fertilizers, and pesticides. A timeline of the implementation of the activities is in Figure II.2.

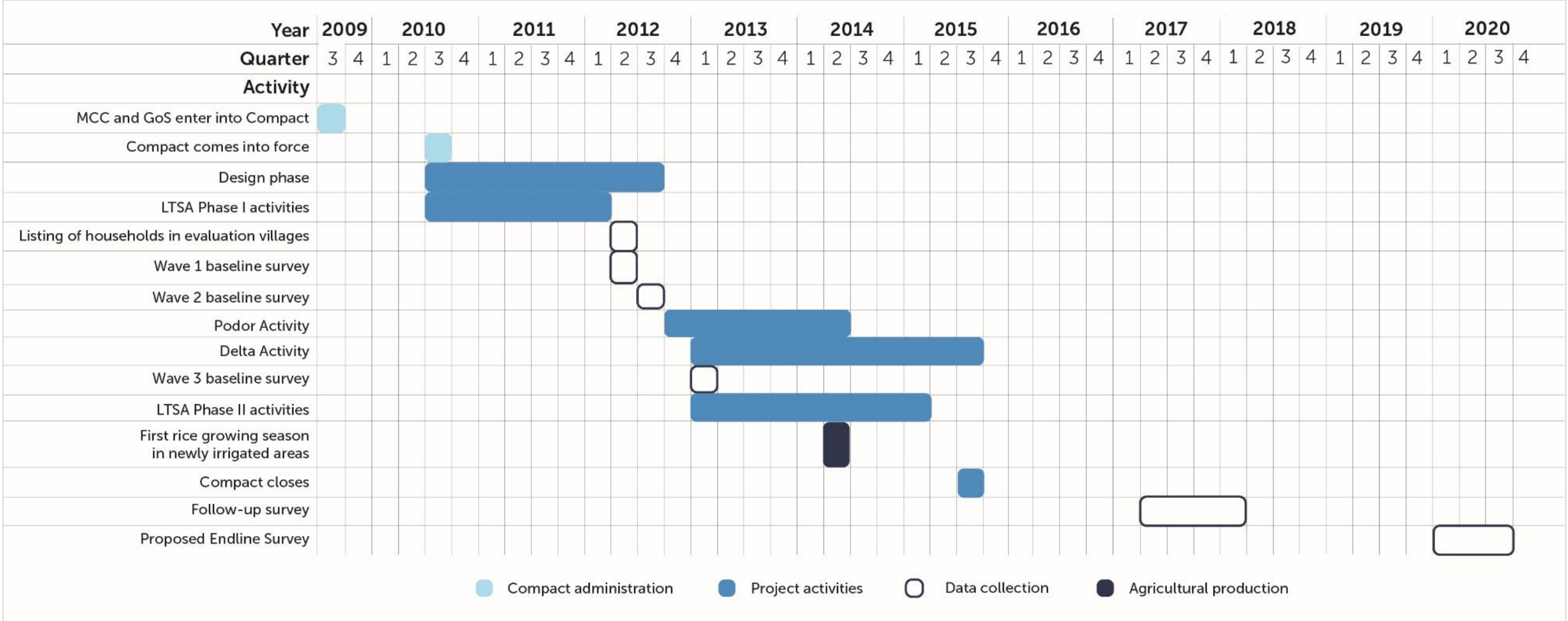
Project-affected people. MCC identified at least 1,200 people who were economically and/or physically displaced as a result of the project. Over the course of a dozen meetings with the project-affected people, MCC learned that in addition to being physically relocated as a consequence of the infrastructure work, people had also lost income because they weren’t properly trained and were not using appropriate farming techniques for irrigated rice cultivation in Ngalenka. They may have also been affected by infrastructure effects such as slow release of water from dispersion basins. Across both Delta and Podor, MCA-Senegal provided compensation worth roughly $10 million (5,788,273,057 CFA) to 1,092 individuals in the affected project areas; MCA-Senegal also provided supplies to schools, rehabilitated schools by constructing walls and latrines, supplied drugs and ambulances to health centers, replaced impacted homes, and constructed tanneries and ponds/drinking troughs for animals (MCA-Senegal 2015). The IWRM Project originally included a Social Safeguard Activity, but this was not implemented.

2. IWRM timeline and program logic

IWRM implementation activities were budgeted at roughly $170 million, and were completed when the Compact closed on September 23, 2015. The compact spent 100 percent of its funds (MCA-S 2015: 22). Figure II.2 shows the timeline of the IWRM Project activities, presented alongside the data collection timeline.

[2] As mentioned, thirteen of these GIEs were women’s groups, also known as GPFs.

Figure II. 2. Timeline of IWRM Project activities



The program logic, presented in Figure II.3, links the problems the IWRM Project was designed to address and its activities and sub-activities with the expected short and medium-to-long term outcomes and impacts. The program logic demonstrates linkages that can also be found in the Economic Rate of Return (ERR) calculation provided by MCC, in which both the area of agricultural land under cultivation and revenues per hectare would increase as a result of the IWRM Project. Figure II.3 shows the outputs of the project as reported by the compact completion report (MCC 2015), rather than the intended outcomes.

Figure II.3. IWRM program logic

Activity	Problem	Subactivity	Outputs (Years 1–5) 2010–2015	Short-term outcomes (Year 5) 2015	Medium/long-term outcomes (Years 6–10) 2016–2020	Impacts (Years 10–20) 2020–2030
Delta Activity ($159.4 m)	• Low agricultural yields have resulted in several thousand hectares of abandoned land • Low agriculture yields have been a persistent problem due to the poor quality of the existing irrigation and drainage infrastructure • There was insufficient delivery of available water to agricultural areas • The areas lacked an appropriate drainage system (leading to soil salinity)	• Construction in the Delta	• 1,159 temporary jobs • 17 water control structures created • 181.3 km of canals rehabilitated • 8 km of protective dikes constructed • 39.8 km of drains constructed	• Increase potentially irrigable land to 39,300 ha • Increase amount of land under production to 42,030 ha • Increase water flow (65m^3 per second) • Establish satisfactory drainage system	• Increased cropping intensity in the Delta (150%) & in the Ngalenka basin (80%) • Increased agricultural production - 277,000 tons of paddy rice - 115,000 tons of tomatoes - 130,000 tons of onions • Increased agricultural incomes • Strengthened job opportunities in farming sector • Improved land access Security for investments • Infrastructure servicing and maintenance • Contribution to increased investments in agricultural sector	• 268,000 beneficiaries of the project • 35 percent increase in household income • Improved food security
Podor Activity ($6.8m)		• Construction of a new irrigated perimeter with 450ha of cultivable land	• 7.7 km of protection dikes constructed • 24.4 km of primary and secondary canals constructed • 14 km of access paths constructed • 2 pumping stations created	• Construction of a new irrigated perimeter with 450ha of cultivable land		
Land Tenure Security Activity ($3.9m)	• Low investment climate due to (1) insecure property rights and (2) higher potential for land conflict due to higher demand for irrigated land as a result of IWRM Project • Recurring land conflicts • Limited formalization of rights of occupation • Lack of tools for land management • Land stakeholders' misunderstanding of tools and institutional framework for managing the land • Difficulty of access to the legal system	• Clarification of lands situation • Lands affectation & formalization of titles • Implementation & application of land-security tools • Capacity building • Implementation of land management committees	• 10,003 plots corrected or incorporated in the Land Information Service • 8,655 plots with formalized titles • Mapping of 60,151 ha • Land rights are formalized for 3,440 ha • Land rights of vulnerable groups are strengthened • Nine support technical committees are strengthened and functional • 7 land registers and 2 land books, update of land occupancy plans, land information system, and set-up of procedures manuals for lands distribution • 5,018 people are trained on land-tenure security tools • 33 water use organizations are created	• Improved local land governance • Continued use of improved land security tools • Fewer land conflicts • Remaining land conflicts are managed and resolved. • Land authorities have access to ongoing technical support and tools.		

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III. LITERATURE REVIEW

Existing literature reveals that agriculture is the sector with the greatest potential to reduce poverty among the poorest of the poor, who are disproportionately represented in that sector (Christiaensen et al. 2011; Ligon and Sadoulet 2018). This may be especially true of Senegal, where over half the country's population was directly employed in agriculture in 2017 (ILO 2018). However, agricultural yields in Africa have been low, and have had a slow growth rate over the past 40 years (Udry 2010). The main inhibitors of agricultural growth include a lack of irrigation on otherwise arable land (Hussain and Hanjra 2004) and an absence of formalized property rights (Lowry et al. 2017).

The evaluation of the IWRM Project will contribute to evidence on the effectiveness of two types of agricultural interventions: (1) irrigation infrastructure and (2) land tenure security and administration—both of which are part of IWRM. In the following sections, we give our evaluation context by reviewing the existing evidence on these types of interventions. We then describe how IWRM will contribute to this literature.

A. Irrigation infrastructure

Agriculture is an important driver of economic growth and alleviator of poverty in much of Sub-Saharan Africa (Dorosh and Thurlow 2018). However, much of the subcontinent lacks the necessary inputs to increase agricultural productivity. Hussain and Hanjra (2004) in particular found that irrigation significantly increases agricultural production and incomes. In Senegal specifically, sufficient irrigation from the Senegal River; better water delivery and drainage; and appropriate inputs, harvesting, and transportation have the potential to increase domestic rice production in the SRV and, in turn, broaden food security in Senegal (Matsumoto-Izadifar 2009). Moreover, areas with irrigation infrastructure are associated with higher cropping intensity (the number of times a crop is planted), land productivity, employment of farm labor, and agricultural wages, and households in irrigated areas also have higher incomes, experience less income inequality, and have lower levels of poverty than those in rain-fed settings (Hussain and Hanjra 2004).

Despite the substantial potential benefits of irrigation, most farmers in Senegal depend on rain-fed agriculture, even though a decline in overall rainfall and an increase in average national temperatures have made it less reliable to do so (USGS 2012). Across Sub-Saharan Africa, only 4 percent of arable land is equipped for irrigation, although 38 percent of all agricultural output comes from irrigated agriculture (You et al. 2010). Although the SRV has the potential for the development of 240,000 hectares, before the IWRM intervention, less than half that was irrigated (Ndiaye 2007).

A few studies have examined the impact of irrigation improvements on rice farming in the SRV. Connor et al. (2008) modeled increases in irrigable land within the valley, finding that new irrigation works have the potential to raise household incomes and spread economic benefits beyond farmers who have access to the newly irrigated fields. However, the authors also cautioned that these effects depend strongly on cropping intensity. Comas et al. (2012) found that irrigation works in the SRV increased food security, but that the cost of inputs to rice production exceeded returns, leading to farmers growing crops that do not require such expensive inputs.

Finally, Sakurai (2015) found that large-scale irrigation schemes had a greater effect on agricultural yields and profits than smaller-scale schemes. They attribute this effect to better management of irrigation facilities in large-scale schemes, but they also concede that there is great variation in management of small-scale schemes. However, Connor et al. (2008) and Comas et al. (2012) studied the SRV from the Mauritanian side of the river; only Sakurai's (2015) study uses data from the Senegalese side.

Outside of the SRV, multiple studies have revealed that irrigation interventions have increased agricultural production. Janaiah et al. (2004), for example, found that in Vietnam, three irrigation-related interventions (rehabilitated infrastructure, improved management, or both) reduced the input costs of agricultural production and increased agricultural yield 13 to 22 percent for rice. In Sub-Saharan Africa, Kuwornu and Owusu (2012) revealed 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 improved how much these crops yielded per harvest. Duflo and Pande (2007), however, found that the results of a similar intervention in India were mixed, depending on how close the farm plot was to the infrastructure. They reported that the construction of a large dam for irrigation increased production of water-intensive crops and increased total irrigated area downstream, albeit with only modest effects on crop yield. They did not find any significant effects on agricultural production in upstream districts. Similarly, a study on the distributional effects of large dams on upstream versus downstream communities in Nigeria and South Africa demonstrated that large-scale dam projects had a positive impact on the agricultural productivity of downstream regions, increasing total agricultural production by 1 percent, but had no significant impact in upstream regions (Strobl and Strobl 2011). That 1 percent increase in production was significant: it provided up to 12 percent of the study population's minimum per capita daily calorie needs (Strobl and Strobl 2011).

Improvements in irrigation infrastructure have also been found to have positive impacts on incomes and to reduce poverty. Janaiah et al. (2004) found that rehabilitated irrigation infrastructure and better management of irrigation decreased poverty rates by 12 percent in Vietnam. Similarly, Dillon (2011b) identified an increase of between 20 and 30 percent in consumption by agricultural households in Mali when they had access to irrigation as opposed to relying on rain-fed agriculture. Van Den Berg and Ruben (2006) evaluated the effect of Ethiopia's national irrigation improvements on income inequality by examining ex post outcomes, and found that households with irrigation spent more money and depended less on public programs than households without irrigation did, after accounting for pre-existing differences. Similarly, Tucker and Yirgu (2010), in an evaluation of irrigation in Ethiopia, found that households experienced a 20 percent increase in annual income when they adopted irrigation. The authors used quasi-experimental approaches to examine how the redistribution of water to canals (through motorized pumps) affects poverty, agricultural production, and nutrition; over the eight-year evaluation period, they found that households with this type of irrigation access had higher levels of consumption, agricultural production, and caloric and protein intake than households without access. Such households also tended to save more and share more of their resources with fellow village members.

There is also growing evidence on the difference between large- versus small-scale irrigation schemes in terms of their impacts on farmers' production and consumption, as determined by the area of land they cover. In Senegal, Sakurai (2015) compared the impacts of large-scale (which cover, on average, 761 hectares) versus small-scale (which cover, on average, 27 hectares) irrigation schemes in the SRV and found that farmers in large-scale irrigation schemes achieved significantly higher yields and profits than those in small-scale irrigation schemes.

Dillon (2011a) assessed the differences in household production and consumption among those with access to small-scale (covering 50 hectares or less) and large-scale (covering more than 300 hectares) irrigation infrastructure to examine whether the scale of an irrigation project affected how much it improved household welfare in Mali. Using propensity score matching, he found that small-scale irrigation has a bigger effect on agricultural production and agricultural income than large-scale irrigation does, but large-scale irrigation has a bigger effect on consumption per capita, suggesting that market integration and other externalities from large-scale irrigation projects may play an important role in realizing gains. Similarly, Lipton et al. (2003) argued that large-scale irrigation schemes can lead to greater improvements in farming outcomes by increasing market integration and by dispersing agricultural knowledge or technology as larger number of farmers are brought together. However, small farmers may be better placed to take advantage of smaller-scale irrigation works, as the barrier to entry can be lower. In short, irrigation projects may have heterogeneous effects, depending on the size of the intervention.

Finally, several studies have shown that the management of irrigation infrastructure impacts the effectiveness of the irrigation scheme. Bandyopadhyaya and Xie (2007) evaluated the impact of a program that transferred irrigation management from national government irrigation authorities to farmers in the Philippines. The authors found that the transfer was associated with an increase in maintenance activities undertaken by the irrigation associations, increased farm yields by between 2 and 6 percent, and was, at a minimum, poverty-neutral. They attributed these findings to an increase in local control over water delivery, faster water delivery, and better resolution of illegal water use conflicts. Sakurai (2015) largely attributed his finding in Senegal—that large-scale infrastructure led to significantly higher yields and profits than small-scale irrigation schemes—to the poor irrigation management found in smaller, village-level irrigation schemes.

B. Land tenure security and administration

As with irrigation, multiple studies show the influence of property rights on agricultural investment and productivity. Existing evidence suggests that there are three mechanisms through which a lack of land tenure can negatively affect investment and productivity and, in turn, influence economic outcomes. First, farmers may be less inclined to invest without a recognized title to their land, as the threat of losing land via intra-household disputes, land conflicts with neighbors, or uncertain inheritance may leave the farmer unsure whether he or she will receive a return on his/her investment (Sipangule 2017; Holden and Ghebru 2016). Importantly, the perception of land tenure security may play as significant a role in the farmer's decision to allocate resources as the actuality of land tenure security. Second, a farmer who does invest in his or her land may not be able to realize the full gains from the investment because he or she cannot sell or rent it out (Lawry et al. 2016). Third, a farmer may be unable to use his or her land as collateral to access credit without formal rights to it. However, other factors, such as a lack of lending institutions, or credit market failures also prevent households from obtaining credit, and the evidence associated with this mechanism is mixed (Udry 2011, Holden and Ghebru 2016).

Until recent decades, some land formalization efforts had little impact on economic growth due to their failure to recognize customary land rights, a lack of transparency in land allocation procedures, and insufficient participation from affected groups, as Deininger et al. (2011) revealed for Ethiopia. However, given the great potential of formal land rights to increase investment in the land, raise productivity, improve incomes, and reduce poverty, over the past two decades governments and donors have renewed efforts to formalize land rights (Diouf and Elbow 2016). For example, in addition to this Compact, MCC's five-year Compact in Burkina Faso, which ended in 2014, worked to apply the country's 2009 Rural Land Tenure Law (Diouf and Elbow 2016), decentralizing aspects of land management to local communities. Similarly, MCC's Compact in Benin reinforced the Benin Rural Landholding Law of 2007, which recognized customary rights in parallel with formalized property rights (MCC 2016). In Niger, a number of donor investments have helped to develop the institutional framework of the 1993 Orientation Framework for a new Rural Code, resulting in decentralized Land Commissions, which provide local and participatory mechanisms to improve management and resolution of land conflicts (Diouf and Elbow 2016).

Several studies reveal evidence of the positive impact of formalized land rights on investment in agricultural land, such as soil conservation programs. Chankrajang (2015) found that the provision of even partial land rights increased investments, land use intensity, and soil quality in Thailand. In Ghana, Goldstein and Udry (2008) found that secure land tenure has a significant effect on investment, particularly in land fertility. Deininger et al. (2008) found a similar relationship between land tenure and investment in Uganda, although the effect is dependent on whether landholders understand their rights. Similarly, Goldstein et al. (2015) found early evidence that an MCC-funded land demarcation initiative in Benin led to increased long-term investment in land parcels, although these investments had not yet led to greater agricultural productivity. In Rwanda, Ali et al. (2017) found that the nationwide land tenure regularization program had a substantial impact on investments and maintenance of soil conservation measures; these effects were especially pronounced for both married females and female-headed households. Deininger et al. (2011) found that land certification in intervention areas increased the propensity to invest in new or repaired land structures by 30 percentage points, and farmers spent twice as many hours working on those investments than farmers in control areas in Ethiopia did. A later evaluation of a land tenure formalization program in the same country found only limited impacts on investment and productivity, but did find impacts on access to credit (The Cloudburst Group 2016). In a systematic review of the literature, Higgins et al. (2018) found consistent support across multiple studies for a positive relationship between land tenure security and investment. Higgins et al. (2018) also suggest that increased perception of land tenure security among farmers is a more important causal mechanism than increased access to credit, because increased access to credit fails to account for differences among lending institutions or whether farmers face other barriers to credit.

The literature also points to positive impacts of property rights on agricultural productivity. Banerjee et al. (2002) found that a limited but large tenancy reform policy, which gave sharecroppers permanent and inheritable tenure on the land they sharecropped, had a positive effect on agricultural productivity in West Bengal, India, even though sharecroppers were required to pay 25 percent of their outputs to landlords. In Africa, Goldstein and Udry (2008) found that insecure land tenure in Ghana was associated with a lack of investment in land as well as poor fertility, leading to decreased agricultural productivity. They found that holding property rights had a major impact on productivity, but also found that women tended to be less confident of their land ownership, creating a gender imbalance in agricultural productivity. In Burkina Faso, Linkow (2016) found that merely the perception of land tenure insecurity was associated with a reduction in overall agricultural productivity of about 9 percent. In contrast, Bellemare (2013) found that formalization of land rights in Madagascar had no impact on productivity, but informal land rights had heterogeneous impacts. He attributes this to the way property rights were formalized during and after colonization. In a systematic review of the literature, Lawry et al. (2017) found evidence for an association between agricultural productivity and land tenure formalization, but noted that this association was stronger in Latin American and Asian cases than in African ones. They suggest stronger informal land tenure institutions in Africa or greater wealth in Latin America and Asia as possible explanations for this difference. Similar to Higgins et al. (2018), Lawry et al. (2017) provide evidence that increased perception of land tenure has a greater effect on agricultural productivity than increased access to credit.

C. Gaps in the literature, and the contribution of the IWRM Project evaluation

The evaluation of MCC's IWRM Project in Senegal will contribute to the evidence on the impact of irrigation schemes in developing countries because we plan to: (1) evaluate the impacts of both the rehabilitation of existing irrigation infrastructure and the construction of new irrigation infrastructure, which will add to the literature on both types of efforts; (2) use rigorous methods to isolate the impact of the irrigation schemes on productivity, income, and poverty; and (3) investigate the effect of irrigation on farming in West Africa, a region largely absent from the literature. In terms of irrigation, there is a notable lack of evidence on the impact of large irrigation schemes on agricultural production and incomes in West Africa, and on the SRV specifically. Much of the existing literature focuses on other parts of Sub-Saharan Africa or Asia, or on small irrigation schemes. The existing research on irrigation in the SRV uses models to predict the potential impact of irrigation, or methodologies that inhibit the ability to draw causal links between the irrigation scheme and impacts (Connor et al. 2008; Comas et al. 2012; Sakurai 2015).

Regarding land tenure security and administration, although many studies have assessed the impact of improved land tenure in developing countries, there is currently relatively little evaluation evidence on land tenure's impact on agricultural outcomes and poverty in West Africa. Similarly, few of the existing studies integrate qualitative and quantitative evidence. A number of evaluations are underway, including impact evaluations of MCC investments in Burkina Faso, Ghana, and Cabo Verde, although none have been completed to date. These evaluations, in addition to the evaluation of the LTSA, will provide robust evidence on the impacts of different land tenure security efforts in West Africa on agricultural investment, production, and incomes. The LTSA component of this evaluation will also contribute to the literature by strengthening the evidence on linkages between perceptions of tenure and agricultural investment though our qualitative interviews.

MCC's LTSA in Senegal provides a unique opportunity to understand the potential of comprehensive and inclusive land tenure efforts. The LTSA was designed to address many of the sustainability issues that have impeded the longevity of any impacts from earlier land tenure initiatives, including sufficient training, ongoing technical support, and local buy-in (Diouf et al. 2015). It is also designed to effectively formalize informal land rights through a transparent, participatory process that combines the land tenure and land allocation principles set out by the United Nations, Senegalese national policy, and customary land claims specific to the region. This evaluation of the LTSA also contributes to the literature by highlighting interviews with women and women's groups, a key gap identified in previous evaluations (Meinzen-Dick et al. 2019).

The IWRM Project simultaneously addresses two coinciding barriers to agricultural productivity: irrigation infrastructure and land tenure security. It is thus a rare opportunity to study the interaction between two interventions focused on those issues. The impact evaluation in this study addresses several questions around beneficiaries' formalization of their land, knowledge of formalization processes and perceptions of security, and the sections based on qualitative data examine outcomes for the LTSA as well as the Delta and Podor activities.

IV. EVALUATION DESIGN

We begin this chapter with an overview of our mixed-methods evaluation design for the Delta and Podor Activities and the LTSA, including listing each research question by topic area and describing the data collected for the evaluation. We then describe our quantitative and qualitative evaluation methodologies for each activity.

A. Design overview and research questions for the interim evaluation

To evaluate the IWRM Project, we are conducting a rigorous mixed methods evaluation. Because the program operated in two distinct areas of the Senegal River Valley, and each area received a separate package of interventions, we are implementing separate evaluation approaches for the Delta and Podor areas.

In Delta, we are conducting an impact analysis using a matched comparison group design to estimate the causal effects of the IWRM Project. Through this approach, we use survey data to compare the outcomes for households in areas that were exposed to the project's activities (the treatment group) to outcomes for similar households that were not exposed to these activities (the comparison group), controlling for the baseline values of these outcomes. We complemented the interim impact analysis with a qualitative outcomes analysis and an LTSA institutional outcomes study that used a combination of qualitative and quantitative methods. The qualitative outcomes analysis addressed research questions on what could be driving project impacts. It uses data from key informant interviews and focus groups with project stakeholders and beneficiary groups. The LTSA institutional outcomes study evaluated activities that took place at the commune level. These activities had commune-wide or institutional effects that are not captured in the impact evaluation, as the LTSA activities affected both the treatment and comparison groups. The institutional outcomes study used data from an in-depth case study, as well as administrative data provided by MCC and local government agencies.

In Podor, we use a quantitative pre-post evaluation design to estimate any effects of the project. We were unable to establish a credible comparison group for a matched comparison group design in Podor. The pre-post design does allow us to compare changes in outcomes for households that received newly irrigated land as part of the IWRM Project (the intervention group) before and after the intervention. We cannot attribute these changes solely to the IWRM Project, but our analysis of the data can yield suggestive evidence on whether the IWRM Project is contributing to any changes we found before and after the intervention. Our findings in Podor are buttressed by a qualitative outcomes analysis and LTSA institutional outcomes study similar to those carried out in the Delta activity area. We use a combination of qualitative and quantitative methods, and address research questions about the possible drivers of any changes in outcomes, and we also evaluate the land tenure security activities that took place at the commune level. This study used data from key informant interviews and focus groups with project stakeholders and beneficiary groups; an in-depth case study; and administrative data provided by MCC and local government agencies.

Our evaluation approaches for both Podor and Delta were designed to answer the main research questions of the IWRM Project on the use and availability of water, agriculture production, income, land security and conflicts, land administrative and governance, and sustainability. Table IV.1 lists each research question and the main evaluation method used to answer it.

Table IV.1. IWRM Project research questions and evaluation approach

Research question	Main analytical method	
	Impact/ pre-post	Performance evaluation*
Use and availability of water		
Have there been changes in the sources of water used for agricultural production?	X	
How has water availability changed, and have barriers or costs to accessing irrigation been reduced? Has the water supply become more reliable?		X
Has the amount of irrigated land increased?	X	
Has the role of WUAs changed, and how do they impact the use and availability of water?		X
Agriculture production		
Have there been changes in the amount of land used for agricultural production? Is land being used for production in different seasons than before?	X	
Has crop production improved? Have production methods, including the choice of inputs, changed? Have there been changes to the types of crops produced?	X	X
What factors are contributing to or constraining changes in agriculture inputs and production? Why are households changing or not changing agriculture production decisions, and how do those reasons vary depending on crop type, growing season, or income level?		X
How have changes differed by gender and among different income levels?	X	
Household income		
Have household income levels changed, including changes in components of household income, and has income shifted between agricultural and nonagricultural sources?	X	X
Do farmers perceive an improvement in their living standards?		X
Have agricultural profits changed?	X	
Land formalization and conflicts		
Have perceptions of land tenure security changed? Is there increased confidence in the land tenure system? If so, why?	X	X
Has the extent of land formalization changed? Is there greater awareness of the process for formalizing land?	X	X
Has demand changed for formalized land rights, and are the costs of formalizing land rights perceived as reasonable?		X
Has the number or severity of land conflicts reduced? Has the type or nature of land conflicts changed?	X	X
How has the IWRM Project affected women's access to land and irrigation? How has it affected the landless?		X
How have changes in land security perceptions, formalization, conflict, or conflict management affected investments on land?	X	X
What have been the constraints or barriers to land access? Do these differ depending on gender, income level, or age?		X

Research question	Main analytical method	
	Impact/ pre-post	Performance evaluation*
Land administration and governance		
Have local government agencies become more effective at land management, including land allocation, land formalization, and conflict resolution? Is there greater confidence in the efficacy of these institutions?		X
Do institutions receive adequate support to carry out their functions?		X
Sustainability		
What are the prospects for the sustainability of project activities post-Compact?		X
What impacts did the project have outside of project areas?		X
Who benefitted from each IWRM activity? Where and when did each activity occur?		X

*****Including individual interviews, group interviews, focus groups and an in-depth case study.

B. Interim evaluation timeline and data collection overview

Our interim evaluation focuses on measuring intermediate results of the IWRM Project. It relies on baseline data collected from 2012 to 2013, before compact implementation, as well as follow-up data collected from 2017 to 2018. The Compact ended in September 2015, and follow-up data collection started more than a year later to allow enough time for the project's impacts on agriculture production to materialize. At the time data were collected, land titles had been distributed for four years (beginning in 2013), new irrigation infrastructure in Delta had been operational for two years (beginning in 2015), and the new irrigated perimeter in Podor had been operational for three years (beginning in 2014). The interim evaluation report represents a starting point for answering research questions on project sustainability, changes in land formalization, and project impacts on agricultural profits and household earnings. A final evaluation report, with another round of data collection in 2020, will focus on longer-term outcomes. We also plan to examine whether positive impacts from the interim evaluation were sustained, and whether outcomes that had not yet been achieved during the interim evaluation had begun to emerge.

Primary quantitative data collection for the interim evaluation took place at baseline between May 2012 and March 2013, with follow-up between May 2017 and March 2018, to cover the full agriculture calendar.[3] 2,716 households were surveyed in all three waves of the baseline; of these households, 2,540 were surveyed again at follow-up. All three project activities—the Delta Activity, the Podor Activity, and the LTSA—had already begun when primary data collection occurred. Each round of quantitative data collection referred to the most recently completed agriculture season: the cold season (November to February), the hot season (March to June), and the rainy season (June to October). The hot season is the primary growing season in the area of the study, particularly for rice production. During the cold and rainy seasons, households focus more on cultivating vegetable crops and possibly on rain-fed crops.

[3] Baseline data were collected by the *Agence Nationale de la Statistique et de la Démographie* (ANSD), the national statistics agency in Senegal. Follow-up data were collected by the *Centre de Recherche pour le Developpment Economique et Social* (CRDES), a private firm based in Dakar, Senegal.

Data collection included household surveys of treatment and comparison group members in the Delta and of intervention group members in Podor. The follow-up data collection period began with the collection of recall data on the cold season (Wave 1), followed by collection of recall data on the hot season (Wave 2) and the rainy season (Wave 3). Table IV.2 summarizes the data collection periods for the follow-up survey round.

Table IV.2. Follow-up quantitative data collection schedule

Survey	Recall season
Household survey (Wave 1)	Cold season (November 2016–February 2017)
Household survey (Wave 2)	Hot season (March–June 2017)
Household survey (Wave 3)	Rainy season (June-October 2017)

The quantitative surveys assessed agricultural practices and the well-being of households, and included modules on household demographics and socioeconomics; household expenses and income activities; crop choices, irrigation schemes, production costs, harvest quantities, and agriculture revenue; and land security, formalization, and conflicts.

We collected qualitative data to support the quantitative data and to help answer certain research questions that quantitative data cannot fully address. The qualitative data were obtained through focus group discussions with members of GIEs and GPFs and key informant interviews with headquarters staff and field engineers from the *Société Nationale d'Aménagement et d'Exploitation des Terres du Delta* (SAED), leaders of WUAs[4], and individual community members in the areas affected by the IWRM interventions who did not belong to a GIE or a GPF. These interviews, which were carried out in early 2018, included women, landless residents, herders, and previously landless farmers. All qualitative interviews focused on some combination of the changes participants had experienced since the Compact ended in 2015, including changes in agriculture production, access to land and irrigation, income, and land conflicts. Case study data for the LTSA institutional outcomes study were collected in December 2017. Information was collected through individual and group key informant interviews, focus groups, observations, and reviews of reports from four communes. Data collection also included in-depth information from municipal officers and institutional representatives on the impacts and sustainability of the IWRM land tenure activities.

C. Quantitative evaluation methodology

For evaluating the IWRM Project quantitatively, we used a matched comparison group design for the Delta and a pre-post design for Podor. Our methods are described here in turn.

1. Matched comparison group design for the Delta

Our matched comparison group design for the Delta compares the outcomes for households in areas that were exposed to the project's activities in both irrigation and land tenure security (the treatment group) to outcomes for similar households that were not exposed to these activities

[4] By water user association, we include water unions, canal management committees, and water user committees, whose responsibilities may include organizing the schedule of irrigation, ensuring payment of water fees, and organizing maintenance such as removing weeds from canals.

(the comparison group), and controls for the baseline values of these outcomes. We use the outcomes for the comparison group to estimate the counterfactual (that is, what would have happened to the treatment group in the absence of the activities). Any difference in the outcomes of the two groups is attributed to the IWRM activities that took place in the treatment areas but not in the comparison areas.

a. Propensity score matching approach

The internal validity of a matched comparison group design depends on the similarity of the treatment and comparison groups before the intervention on any characteristics that could influence outcomes. To construct treatment and comparison groups, we used data from the baseline survey to conduct propensity score matching. Our objective was to identify a comparison group that was similar to the treatment group, on average, on observable characteristics, particularly those pertinent to agriculture production. Propensity score matching is a statistical analytical technique that allows us to take into account multiple variables to identify a comparison household that most closely resembles a treatment household (Rosenbaum and Rubin 1983; Imbens and Rubin 2015). For example, if a treatment household farms 0.5 hectares of rice and tomatoes during the hot season, does not farm in the other seasons, has five household members, and the household head is a 52-year old male, we would try to identify a comparison household that is as similar as possible on these observable characteristics.

To take into account multiple variables for matching, we calculate what is called a propensity score, which provides a numerical estimation for each household of how likely it is to be in the treatment group based on observational data. We considered baseline variables for inclusion in the propensity score model that predict treatment status and are correlated with outcomes of interest. We accounted for seasonal differences in agriculture production, as farmers' investment and crop decisions vary by season. For each agriculture variable, we often considered three separate variables for inclusion in the propensity score model to account for the rainy, cold, and hot seasons. To ensure the propensity score model could identify households that were a good match, we excluded variables that were highly correlated. For instance, we included variables on harvest yields, but excluded ones on crop revenue because high yields are correlated with high revenues. Table IV.3 lists the 36 variables available for inclusion in the model.

Table IV.3. Variables considered for the propensity score model

Variable name
Number of household members
Age of household head
Gender of household head
Likelihood that the household lives on less than $2.50 a day
Household head received some formal education
Amount of land used by the household for farming[ab]
Household has access to farm plots[b]
Household farmed land[b]
Household harvested from its land[b]
Household used a sophisticated irrigation system (annual measure)

Variable name
Household cultivated rice[b]
Household harvested rice[b]
Household knows the deliberation process to receive a land title
Household is concerned about losing land
Percentage of farm plots with any type of land title[b]
At least one plot has access to a river or lake water source[b]
Household received revenue from farming
Household is satisfied with its irrigation system for farming
Total agriculture investment costs per hectare (primary growing season only)
Indicator for high levels of imputed baseline data

[a] Required for inclusion in the propensity score model.

[b] Variable included separately for each of the three agriculture seasons.

To calculate the propensity score for each household, we built a propensity score model using the stepwise function in Stata. Stepwise builds a logit function from the pool of available variables that yields the best prediction of treatment status. That model is then used to predict each household's likelihood of being in the treatment group (its propensity score). Each household receives a propensity score between 0 and 1. We matched each treatment household to a comparison household using what is called "nearest neighbor matching" by finding the comparison household with the closest propensity score to the treatment household. To ensure the matched households would be as similar as possible at baseline, we required the difference between each match's propensity scores to be no greater than 0.1.

We found significant differences, on average, between the full sample of treatment households and the potential comparison households. This led us to expect that many comparison households would be too different from treatment households to be included in a matched sample that achieves baseline equivalence. To address this issue, we allowed each comparison household to be matched with up to five different treatment households (known as matching with replacement), thus making maximum use of comparison households that *were* similar to treatment households. Even with this approach, a small percentage of treatment households could not be matched successfully to a comparison household and had to be omitted from our analytic sample. (See below for further details on the matched sample size).

b. Study sample and data collection

Before the IWRM Project started in 2012, MCA-Senegal contracted with *Agence Nationale de la Statistique et de la Démographie* (ANSD), the national statistics agency in Senegal, to conduct baseline data collection. ANSD first conducted a census of all households in the treatment and comparison areas. The questionnaire used in the census included questions on household characteristics and an inventory of household members, including their age, gender, ethnicity, literacy levels, and employment status. The baseline evaluator, IMPAQ International, used the census data to create treatment and comparison samples by matching households in the treatment area to households in the comparison area. IMPAQ selected a sample of 1,637 households for the treatment group and 1,637 households for the comparison group to ensure the sample would be large enough for us to be able to detect meaningful impacts of the intervention on key outcome measures. ANSD attempted to survey each household in the sample frame three times at baseline, once for each of the three agricultural seasons (cold season, hot season, and rainy season) from May 2012 through March 2013 (see Table IV.4 for more details on the changes in sample size). We refer to each seasonal survey as a wave.

The baseline household survey contained modules on household assets, expenses, education levels, and income; agriculture production, including crops, irrigation access, production costs, harvest quantities, and revenue; and land security and conflicts. In addition to the household survey, ANSD also conducted a community survey of village leaders. The survey collected data on village-level characteristics, such as public services, community organizations, land conflicts, and agriculture practices.

After the survey was completed, IMPAQ conducted a baseline equivalence analysis. The results showed statistically significant differences between the treatment and comparison groups on key outcomes of interest that were not part of the matching model, including farming practices. Because IMPAQ did not have data from the census before matching on, for example, the area of land under production, irrigation methods, and crops cultivated, the matching model was not able to take into account those important variables to ensure that the two groups were equivalent at baseline. Differences between the treatment and comparison households at baseline could introduce bias into estimates of the project's impact, so we re-did propensity score matching using the pool of comparison households identified by IMPAQ, but conducted matching with replacement and we used additional baseline variables, as described in the previous section. All households that were surveyed during all three seasons at baseline and that were also found during the follow-up survey round were eligible to be selected for the matched comparison group. Table IV.4 tracks how the sample size evolved over time with survey attrition and through different design scenarios.

Table IV.4. Sample sizes over time (Delta)

Sample frame	Treatment	Comparison
Census sample frame	8,688	2,984
IMPAQ matched sample	1,637	1,637
Surveyed in at least one wave at baseline	1,518	1,393
Surveyed in all three waves at baseline	1,422	1,294
Surveyed in all three waves at baseline and at follow-up	1,361	1,179
Re-matched analytic sample	1,136	470[a]

[a] Each comparison household could be matched to up to five treatment households. When weighting the sample to the number of times that a household is matched, our comparison group contains 1,136 households.

Our final matched sample for the Delta contains 1,136 treatment households and 470 comparison households, retaining 83 percent of the treatment households eligible for matching. As noted, we expected many comparison households to be too different from treatment households to be included in a matched sample. Therefore, we allowed each comparison household to be matched to up to 5 treatment households. So, although only 470 unique comparison households are included in our analytic sample, once we weight the sample for the number of times that a comparison household is matched to a treatment household, we have a comparison sample size of 1,136 households, equal to the size of the treatment group.[5] The match rate is in-line with our anticipated sample size described in our evaluation design report and for which we calculated minimum detectable impacts for key outcome measures (Moorthy et al. 2017).[6]

For three waves of follow-up data collection conducted between May 2017 and March 2018, we contracted with a private research firm based in Dakar, Senegal. The Senegalese agricultural seasons include the cold season, (*contre-saison froide*) which takes place from about December to February, the hot season (*contre-saison chaude*) which is from about March through June, and the rainy season (*hivernage*), which generally runs from about July to November. Conducting the survey for each of these three agricultural seasons allows us to capture and compare to the baseline changes in agriculture production and farming behavior for each season while limiting recall bias (which happens when the respondent has to answer questions from memory).

Our household questionnaire assessed the well-being of households and agricultural practices. Table IV.5 lists the modules and key topics that were covered in the follow-up surveys.

Table IV.5. Overview of household survey modules

Module	Key topics covered
Household roster	Demographic information on all household members, such as age, gender, and education
Land roster	List of and information on all parcels owned or worked by the household. Plot-level details on property rights, locations, and uses, including identifying the owner and main decision maker for each parcel
Household expenses	Consumption costs for goods and services, including food and social activities
Non-agricultural household income	Non-agriculture income, such as labor activities, rent, pensions, and social programs
Land security and conflicts	Perceptions about and experiences with land disputes and resolutions; land formalization
Agriculture production	Crop choice, irrigation schemes, production costs, harvest quantities, and agriculture revenue

[5] 230 of the comparison households were matched once to one treatment household; 120 comparison households were matched to between 2 and 4 treatment households; and 120 comparison households were matched the maximum five times to 5 different treatment households.

[6] Different matching approaches provide a trade-off between power and bias. For matching with replacement, we were able to retain a large number of treatment households while ensuring the treatment and control groups were balanced on key baseline measures. To do this though, we had to rely on a small pool of similar comparison households that were matched multiple times.

We programmed the questionnaire using Survey Solutions, an electronic data collection platform developed by the World Bank. We programmed the survey in French as well as Wolof and Pulaar, the primary languages spoken in the surveyed regions. Interviewers were able to toggle back and forth between languages at any point in the survey. The majority of the surveys were conducted in either Wolof or Pulaar, depending on the respondents' primary language. Data collection was carried out primarily in face-to-face interviews using computer assisted personal interviewing (CAPI) with some surveys using computer assisted telephone interviewing (CATI) from a call center in Dakar. Wave 1 of the follow-up survey was completed using solely CAPI. Wave 2 was completed using CATI with CAPI for households which could not be contacted via the telephone, as well as for a number of households which were reserved for quality assurance purposes. Wave 3 was completed using CAPI with some CATI for data retrieval and backchecking.

c. Outcomes and domains

We calculate and report outcomes that directly correspond to the evaluation's research questions. Table IV.6 shows each key outcome and its associated domain. We report outcomes separately for each farming season and also provide an annual measure for relevant outcomes such as agriculture revenue, investment, and profit. When interpreting project impacts, we look at patterns within each domain.

Table IV.6. List of outcomes by domain (Delta)

Outcome	Domain
Satisfaction with the availability of irrigated water	Use and availability of water
Total amount of land irrigated (ha)	Use and availability of water
Percentage of farm plots that were irrigated	Use and availability of water
Used a simple gravity irrigation system	Use and availability of water
Used a sophisticated irrigation system	Use and availability of water
Household has farm plots	Agricultural production
Household farmed land	Agricultural production
Land under production (ha)	Agricultural production
Total agriculture investment costs (CFA)[a]	Agricultural production
Agriculture investment costs per hectare (CFA)	Agricultural production
Household cultivated rice	Agricultural production
Area of rice cultivated (ha)	Agricultural production
Rice investment costs (ha)	Agricultural production
Rice yield (kg/ha)	Agricultural production
Agricultural profit [a]	Agricultural profits and household income
Household harvested crops	Agricultural profits and household income
Total revenue all crops (CFA)[a]	Agricultural profits and household income
Revenue per hectare for all crops (CFA)	Agricultural profits and household income
Total rice revenue (CFA)	Agricultural profits and household income
Revenue from rice yield (CFA/ha)	Agricultural profits and household income
Household earnings (off-farm)[a]	Agricultural profits and household income
Annual household consumption[b]	Agricultural profits and household income
Household is concerned about losing land	Land formalization and conflict

Outcome	Domain
Household reported any land conflicts	Land formalization and conflict
Ratio of plots with any land title	Land formalization and conflict
Household knows deliberation process to receive land title	Land formalization and conflict

Note: All outcomes except the ones under the domain land formalization and conflicts are reported separately for each agricultural season. We do not report rice production outcomes for the cold season, as farmers typically do not plant rice in the cold season in the SRV. FCFA = African Financial Community Franc or West African Franc, the currency of Senegal; ha = hectares.

[a]Measure is also reported as an annual outcome that combines all three agricultural seasons.

[b]Measure is calculated for the full sample and for the sample that reports agriculture profits.

In the cold season ("contre-saison froide"), farmers generally do not cultivate rice as the most commonly-available variety is unsuitable at that time of year. Our survey results found that some farmers reported cultivating rice in the cold season; however, during call-back interviews, farmers revealed that they sometimes reported cultivating rice in the cold season that was actually late-harvested rice that had been planted during the rainy season. As in any season-specific agricultural survey, the start and end dates of the growing and harvesting periods we identify as hot, rainy and cold are somewhat fluid rather than firmly fixed to particular dates. The baseline data collection also revealed rice production in the cold season that can reasonably be assumed to be late-harvest rainy season rice. Our follow up data collection schedule purposely followed the same order and timing of baseline data collection with the first wave of data collected on the cold season, the second wave on the hot season and the third wave on the rainy season. Therefore, our cold season findings refer to the 2016-2017 cold season. Our hot season and rainy season findings refer to the 2017 agricultural seasons and our data collection for the rainy season was carried out well after the end of the rainy season in order to capture as much of the late-harvest data as possible.

d. Baseline equivalence

For our matched comparison group to yield unbiased impact estimates, it must be similar to the treatment group before the intervention starts. In other words, the comparison group in the Delta needs to provide a good approximation of the counterfactual. To test this, we can estimate if the two groups are statistically equivalent on observable characteristics that are related to the outcomes we are measuring. We examined equivalence on all variables listed for inclusion in the matching algorithm in Table IV.3 as well as all three waves of variables for measures on irrigation, agriculture investment, crop revenue, and land tenure security, and an annual measure of household consumption. We examined absolute effect size differences between group means at baseline whereby an effect size difference of greater than 0.25 standard deviations does not satisfy baseline equivalence (Ho et al. 2007). See Appendix Table A.2 for complete results of the baseline equivalence tests. Differences are bolded when the effect size difference is greater than 0.25 standard deviations.[7]

[7] In the Appendix, we also provide baseline equivalence results for the full sample of households that were surveyed in all three waves at baseline and were surveyed at follow-up, showing that there were large and significant differences between the treatment and comparison groups before re-matching.

With the matched sample, we find only one baseline difference greater than a quarter standard deviation out of 53 baseline measures, which we would expect to find based on chance alone. That difference is on a measure of land tenure security during the final wave of baseline data collection where treatment households report knowing the deliberation process to receive a land title at higher rates than comparison households. This could also be because some of the land security activities had begun implementation prior to wave 3 of baseline data collection. The intervention could have possibly affected responses among the treatment group for this measure. We find no differences on any baseline measure that are between 0.20 and 0.25 standard deviations. Based on our analysis, we achieved baseline equivalence on the matched sample. Using a propensity score matching approach greatly improved baseline equivalence.[8]

For some outcomes, we estimate impacts only among households that farmed for that season as the measure is not relevant for households that did not farm. For example, the type of irrigation system that a household uses or the household’s satisfaction with the availability of water to farm is not relevant to households that did not farm. However, it is possible that the project induced more farmers in the treatment group to farm, which could introduce bias into our matched sample if we only examined farming households. To check this, we assessed baseline equivalence by season among households in the matched sample that farmed. We analyzed baseline equivalence on the same set of 53 variables we used for the overall sample. We found only one measure that had a difference greater than 0.25 standard deviation units, and one other measure for which the difference was between 0.20 and 0.25 standard deviation units. We are therefore confident we have baseline equivalence among the matched sample that farms.

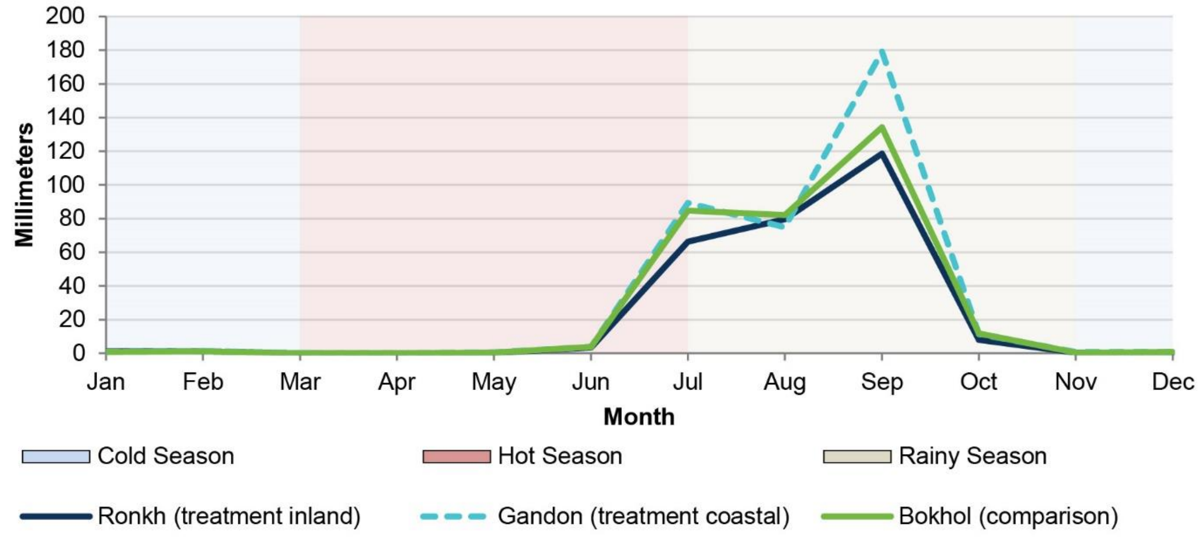
The key assumption for unbiased impact estimates in a matched comparison group design is that any changes in outcomes due to external factors unrelated to the IWRM Project, such as precipitation patterns, market conditions, and other interventions, are not systematically different between the two groups. Through our qualitative research, we found no evidence of systematic differences between the treatment and comparison areas in additional agriculture interventions that existed during the IWRM Project. We also did not uncover differences in market conditions between the two areas, although our research was limited and there could be differences due to easier access to the main port city of St. Louis for the treatment group.

To test differences in precipitation patterns, we examined rainfall data at treatment and comparison sites during the baseline and follow-up years of the study. We picked centroid coordinates in two treatment *Communauté Rurales* (CRs)—Gandon on the coast and Ronkh farther inland—because the treatment area was more geographically diffuse, and the coastal climate can be different than the inland climate. We compared those findings to the Bokhol comparison CR, because all comparison CRs were inland. We used data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) (Funk et al. 2015) to calculate monthly rainfall totals for each area. We focus on rainfall as a proxy for broader climate factors

[8] Due to item nonresponse at baseline, we imputed a small amount of missing baseline data to maximize our sample size for the matched comparison group design. Appendix B shows baseline equivalence results on the matched sample without imputing any baseline characteristics. Our baseline equivalence results are similar to the matched sample with imputed data, evidence that our imputation strategy is not driving our results. Technical details on our imputation strategy are in Appendix A.

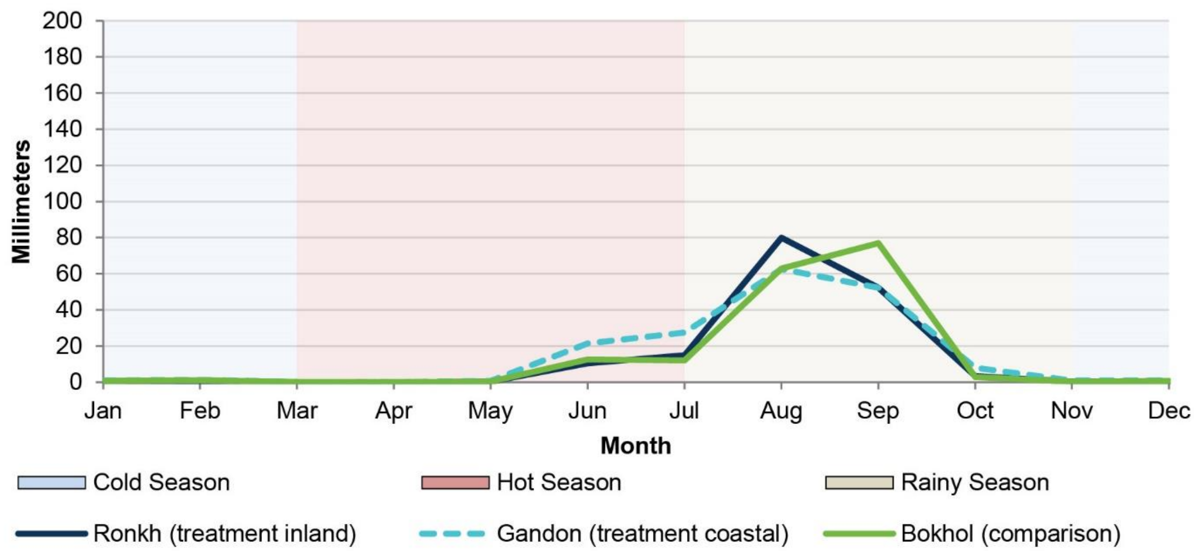
because detailed rainfall data are available in both treatment and comparison areas.[9] Figure IV.1 shows monthly rainfall data in 2012, the baseline year of the study, and Figure IV.2 shows the precipitation results for 2017, the follow-up year of the study.

Figure IV.1. Monthly precipitation for study areas in 2012 (the Delta)



Source: Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS).

Figure IV.2. Monthly precipitation for study areas in 2017 (the Delta)



Source: Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)

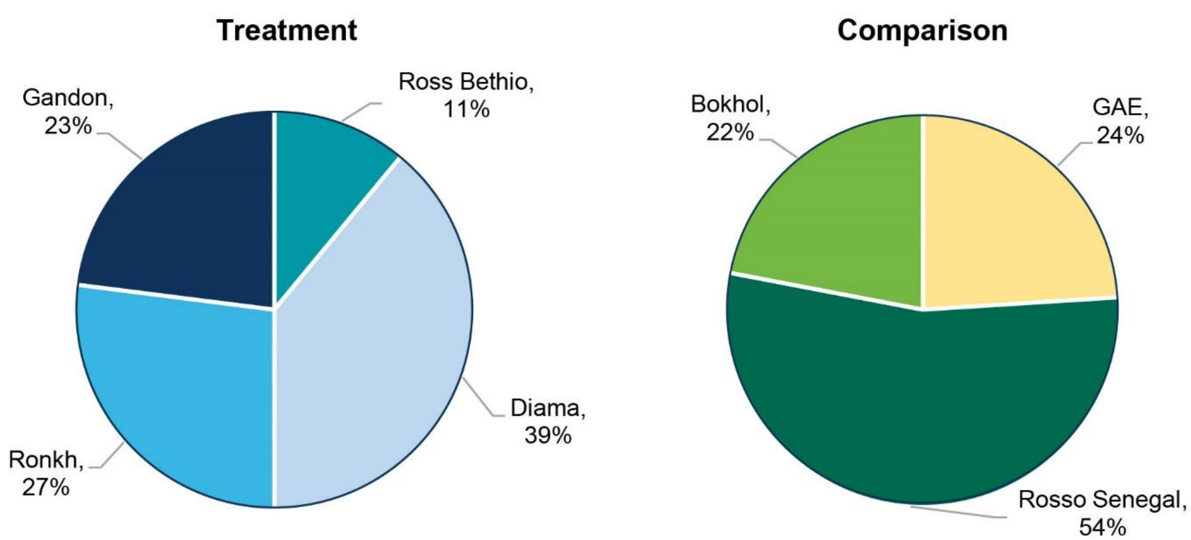
[9] Temperature and humidity data are only available in the Delta from the weather station in St. Louis. This is a coastal treatment area, so we could not contrast those results with those for inland treatment and comparison areas.

In 2012, the baseline year, the inland treatment area and the comparison area had similar precipitation patterns, with the latter having slightly more rainfall. Rainfall in the coastal treatment area was similar to rainfall in the comparison area, except that the coastal treatment area received more rainfall in September. At follow-up, in 2017, the study areas received appreciably less rainfall than in 2012, and the rainfall patterns of the three types of areas were even more similar. The comparison area of Bokhol received a larger amount of rain slightly later in the season compared to the treatment areas. Still, we find that rainfall patterns in the comparison and treatment areas were similar enough that weather patterns are unlikely to be biasing our impact estimates.

e. Sample characteristics

The sample for the matched comparison group was drawn from surveyed households in four CRs for the treatment group and three CRs for the comparison group (Figure IV.3.). The largest percentage of treatment households came from Diama, and a slight majority of comparison households were in Rosso Senegal (weighted for matches).

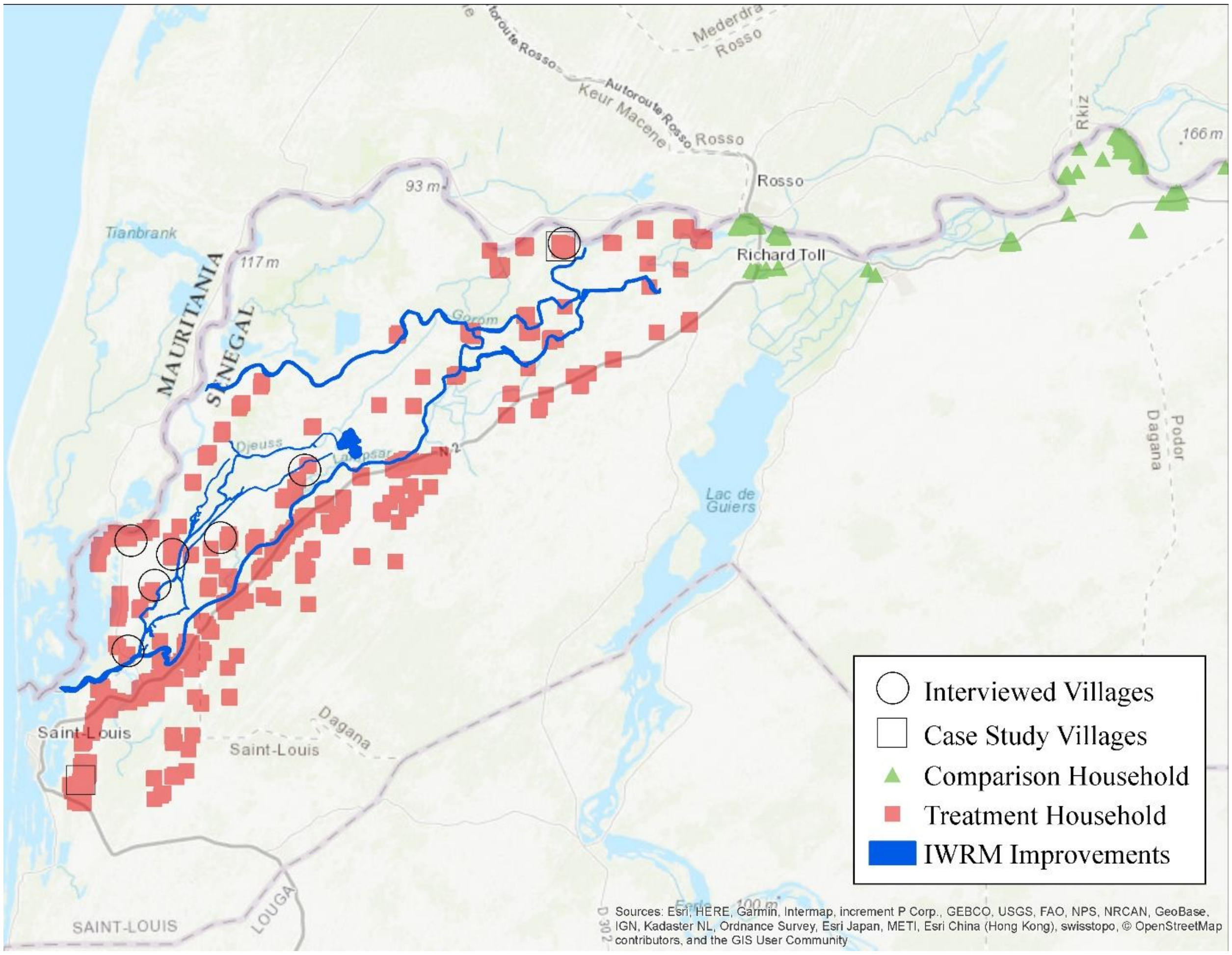
Figure IV.3. Matched sample location by commune



Notes: The matched comparison group contains 1,136 treatment households and 1,136 comparison households, weighted for the number of times each comparison household is matched to a treatment household.

Although the comparison area is relatively compact to the west of the Delta region, the treatment area ranges from the coastal CR of Gandon to other more inland CRs of Ronkh and Ross Bethio. Figure IV.4 shows the treatment and comparison households in the Delta region as well as their location in relation to prominent water sources and IWRM Project irrigation improvements.

Figure IV.4. Map of treatment and comparison households (the Delta)



Note: Household markers are much larger than the actual area of the house to preserve the anonymity of survey respondents, so many household markers overlap with one another. This is particularly true for comparison households, which are clustered in a smaller geographic area. In other words, not every comparison household marker is visible due to the close proximity of the households.

Our matched comparison group sample exhibits similar demographic and socioeconomic characteristics between the treatment and comparison groups at baseline (Table IV.7). The average household size is 10, more than three-quarters of household heads are male, around one-third received some formal education, and household heads are typically around 50 years old. Around two-thirds of the households live on less than $2.50 a day. The average number of plots farmed among all households varies between 0.74 and 1.74 depending on the season. Among households that farm, the majority report farming only one plot, and over 90 percent report farming on three plots or fewer for all seasons, in both the treatment and comparison groups (not shown in table). Effect size differences between the treatment and comparison groups were small and not significant.

Table IV.7. Socio-demographic characteristics of the Delta study sample

Variable	Mean (treatment)	Mean (comparison)	Sample (treatment)	Sample (comparison)
Household size	10	10	1,136	1,136
Age of household head	49	50	1,136	1,136
Household head is male	81%	80%	1,136	1,136
Household head received some formal education	32%	38%	1,136	1,136
Poverty likelihood (living on <$2.50/day)	69%	67%	1,136	1,136
Number of plots used for farming				
Cold season	1.60	1.74	1,136	1,136
Hot season	1.21	1.06	1,136	1,136
Rainy season	0.74	0.73	1,128	1,133

Source: IWRM Project baseline household survey data.

Note: Comparison group sample size is weighted to account for multiple matches to a treatment household.

f. *Impact analysis*

Our primary estimation equation measures the causal impacts of the IWRM Project on our analytic sample at the household level. To estimate impacts, we regress each outcome variable on the treatment indicator (whether the households received interventions as part of the IWRM Project), controlling for the baseline measure of the outcome and relevant demographic and socioeconomic variables, including age and gender of household head, likelihood household lives on less than $2.50 a day (see below), and whether the household head knows how to read and write. We use robust standard errors and include sample weights to adjust for comparison households being matched to multiple treatment households (also known as frequency weights). The general estimation equation follows as:

$$(1) \qquad Y_{i,post} = \beta_0 + \beta_1 IWRM + Y_{i,pre} + \beta_i X_{it} + \varepsilon_{it}$$

where $Y_{i,post}$ is the outcome of interest; *IWRM* represents whether the household received the intervention (and β_1 capturing the treatment effect); $Y_{i,pre}$ is the baseline measure of the outcome variable; X_{it} symbolizes a vector of demographic and socio-economic control variables, and ε_{it} is a random error term. We report results as significant at the 5 percent level (*p-value*s below 0.05).

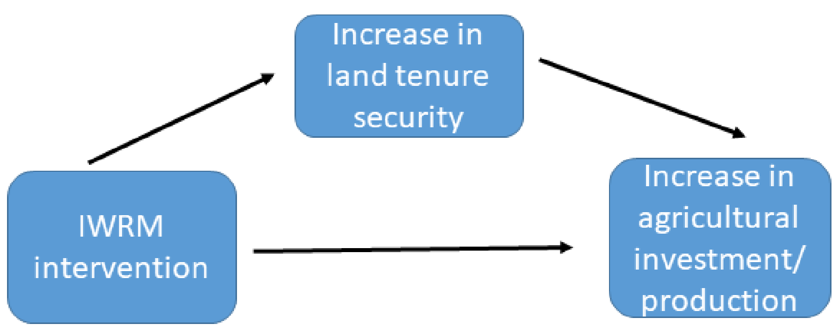
We also conducted subgroup analyses for agriculture production outcomes with the subgroups determined by the gender of the household head and the poverty level of the household. To divide our sample into poverty subgroups, we used the Poverty Probability Index to estimate the likelihood that a household is living on less than $2.50 a day (Schreiner 2016). This index provides an easy way to quickly capture poverty likelihood and includes conversions to compare results across countries. Combining several closely related indicators of poverty into one measure also reduces measurement error, captures the breadth of poverty, and maximizes reliability. We divided our sample into three groups: households scoring between zero and

25 percent on the index (the best-off households, or the least likely to be living on less than $2.50 a day), households scoring between 25 and 75 percent, and households that scored above 75 percent (the poorest households). The subgroup analyses are exploratory to identify if patterns of impacts vary by these characteristics. This analysis is limited in that it is conducted at the household level but there could be variation in economic status within the household and the plot manager and the plot farmer could differ by gender.

To investigate changes in crop cultivating decisions, we conducted group tests for measures where we want to test the changes in a group of variables as opposed to estimate an impact for one variable. This is because a household's decision to cultivate one type of crop affects their decision to cultivate another crop a plot. Because crop cultivation decisions are not independent, we ran a **seemingly unrelated regressions model** with all of the crop variables of interest as dependent variables to test differences over time between the change scores for the treatment group and for the comparison group. We use the same covariates as in our primary impact estimate model (equation 1). We then test whether the treatment coefficients for various crop cultivating decisions are jointly distinguishable from each other.

Our main impact analysis estimates the total effect that the IWRM Project has on each outcome. Yet, there are two pathways that make up the total effect: the indirect effect and the direct effect. One way the IWRM Project can affect agricultural production is through its effect on land tenure security (as a result of the LTSA). With more tenure security, households may then invest more in their land and farm more on their land, increasing agricultural production. This is the *indirect effect* of the IWRM Project on agricultural production. The IWRM can also operate through irrigation improvements and other unspecified paths, all of which we classify as the *direct effect*. Figure IV.5 illustrates the projected pathways for how the intervention affects agricultural outcomes. We decompose the total effect into the direct and indirect effects of the IWRM intervention by using **mediation analysis**. The sum of the direct and indirect effects equals the total effect of the IWRM Project on each outcome.

Figure IV.5. IWRM Project mediation analysis model



To conduct this analysis, we use the Ratio-of-mediator-probability weighting (RMPW) method following Hong, Deutsch, and Hill (2015). Logically, in order for the effect of the IWRM Project on agriculture production to operate through land tenure security, there must first be an effect of IWRM on land tenure security. The RMPW method requires a binary mediatior, so we use an indicator for whether the household has at least one titled plot. We present the results of the mediation analysis in Chapter V.[10]

2. Pre-post analysis for Podor

In Podor, we compare changes in outcomes for households who received newly irrigated land as part of the IWRM Project (the treatment group) before and after the intervention. Due to a smaller treatment sample and larger differences between treatment and the initially identified comparison areas, we are unable to conduct a credible matched comparison group analysis for households in this region. In contrast with the Delta, our analysis framework in Podor does not result in causal impacts of the IWRM Project but does yield suggestive evidence as to whether the IWRM Project is contributing to the changes we are finding before and after the intervention.

a. Study sample and data collection

Whereas in the Delta the treatment group is defined as households in villages with access to the irrigation works that would be rehabilitated as part of the IWRM Project, in Podor, the treatment group is defined as households that were allocated land in the new irrigated perimeter as part of the project. At baseline, when the previous evaluator sampled households from the treatment area, it did not know which households would ultimately be allocated land within the Ngalenka perimeter. The survey firm therefore attempted to survey all households in the treatment area, believing that a substantial portion of the surveyed households would be allocated land in the perimeter.

We determined assignment to the treatment group based on results of our follow-up survey in 2017 to 2018 where respondents reported whether they had access to newly irrigated land within the Ngalenka perimeter within the past year. We conducted back-checks with a subsample of households to confirm the accuracy of the data from this survey question. In total, we found 249 households in the Podor treatment area that identified having land within the Ngalenka perimeter. Table IV.8 summarizes the evolution of the sample in Podor throughout each identification process.

[10] Additional technical specifications for our matched-comparison group design, including baseline data imputation and results using non-imputed data, are available in Appendix A.

Table IV.8. Sample sizes over time (Podor)

Sample	Treatment area
Census sample frame	1,617
Surveyed in at least one wave at baseline	1,467
Surveyed in all three waves at baseline	1,224
Surveyed in all three waves at baseline and at follow-up	1,143
Identified as having land within the Ngalenka perimeter (treatment group)	249

Sources: IMPAQ baseline report; baseline data set; follow-up data set.

Our follow-up data collection in Podor mirrored our approach in the Delta (described in section IV.B.1.b). We surveyed households three times over the course of 12 months to collect recall data on each of the three agriculture seasons.

b. Outcomes and domains

We measured the same kinds of quantitative outcomes for the Podor sample as we did for the Delta (IV.C.1.c). One key difference is that we lack a comparison group in Podor, and we have to ensure each outcome is measured the same way at both baseline and follow-up, otherwise any differences we find could be due to questions that capture different information. We based the follow-up survey on the survey developed by IMPAQ and conducted at baseline. We revised the survey to improve how we measured key outcomes. At the time, we planned to use a matched comparison group design in Podor, so improving the way we measured a result at follow-up would yield a more precise measure of the impact relative to the comparison group. However, because we ultimately used a pre-post design in Podor, we had to remove outcomes that were not measured the same way they were at baseline. For example, we do not measure household consumption in Podor because the follow-up questionnaire used a different recall period and different list of consumption items than the baseline questionnaire.

For Podor, we focus on results from the hot season, that is, the main growing season, and the cold season. No one farmed within the Ngalenka perimeter during the cold season because of an unintended consequence of the intervention: land designated for vegetable farming was too limited and diffuse to justify the costs of running the irrigation pumps. We present results for the rainy season at follow-up in Appendix C because those findings are driven by factors outside of the project. Although no farming took place during the rainy season within the Ngalenka perimeter because of the same issues that were there in the cold season, factors external to the intervention reduced the amount of farming done overall. They included: (1) a delay in bank credit to purchase seeds, with some households not receiving credit due to arrears; and (2) a public notice that the Senegal River level would be lower than usual, reducing the amount of water available for irrigation. Table IV.9 lists our key outcomes and their associated domain.

Table IV.9. List of outcomes by domain (Podor)

Outcome	Domain
Satisfaction with the availability of irrigated water	Use and availability of water
Total amount of land irrigated (ha)	Use and availability of water
Percentage of farm plots that were irrigated	Use and availability of water
Used a simple gravity irrigation system	Use and availability of water
Used a sophisticated irrigation system	Use and availability of water
Household has farm plots	Agricultural production
Household farmed land	Agricultural production
Land under production (ha)	Agricultural production
Total agriculture investment costs (FCFA)[a]	Agricultural production
Agriculture investment costs per hectare (FCFA)	Agricultural production
Household cultivated rice	Agricultural production
Area of rice cultivated (ha)	Agricultural production
Rice investment costs (ha)	Agricultural production
Rice yield (kg/ha)	Agricultural production
Agricultural profit	Agricultural profits and household income
Household harvested crops	Agricultural profits and household income
Total revenue all crops (FCFA)[a]	Agricultural profits and household income
Revenue all crops per hectare (FCFA)	Agricultural profits and household income
Total rice revenue (FCFA)	Agricultural profits and household income
Revenue from rice yield (FCFA/ha)	Agricultural profits and household income
Household earnings (off-farm)	Agricultural profits and household income
Household is concerned about losing land	Land formalization and conflict
Household reported any land conflicts	Land formalization and conflict
Ratio of plots with any land title	Land formalization and conflict
Household knows deliberation process to receive land title	Land formalization and conflict

Note: All outcomes except the ones under the domain land formalization and conflicts are reported separately for the cold and hot seasons. We do not report rice production outcomes for the cold season, as farmers typically do not plant rice in the cold season in the SRV...FCFA = Franc CFA, the currency of Senegal; ha = hectares

[a] Measure is also reported as an annual outcome that combines all three agricultural seasons

c. Sample statistics

In our analytic sample for Podor at baseline, the average household size was nine. The average age of the household head was about 48; 89 percent of household heads were male, and just 8 percent reported having received some formal education. Just over three-quarters (77 percent) of households lived on less than $2.50 a day. Households reported farming on an average of between 0.81 and 1.23 plots depending on the season at baseline. Socio-demographic characteristics of our study sample in Podor are summarized in Table IV.10 using baseline data.

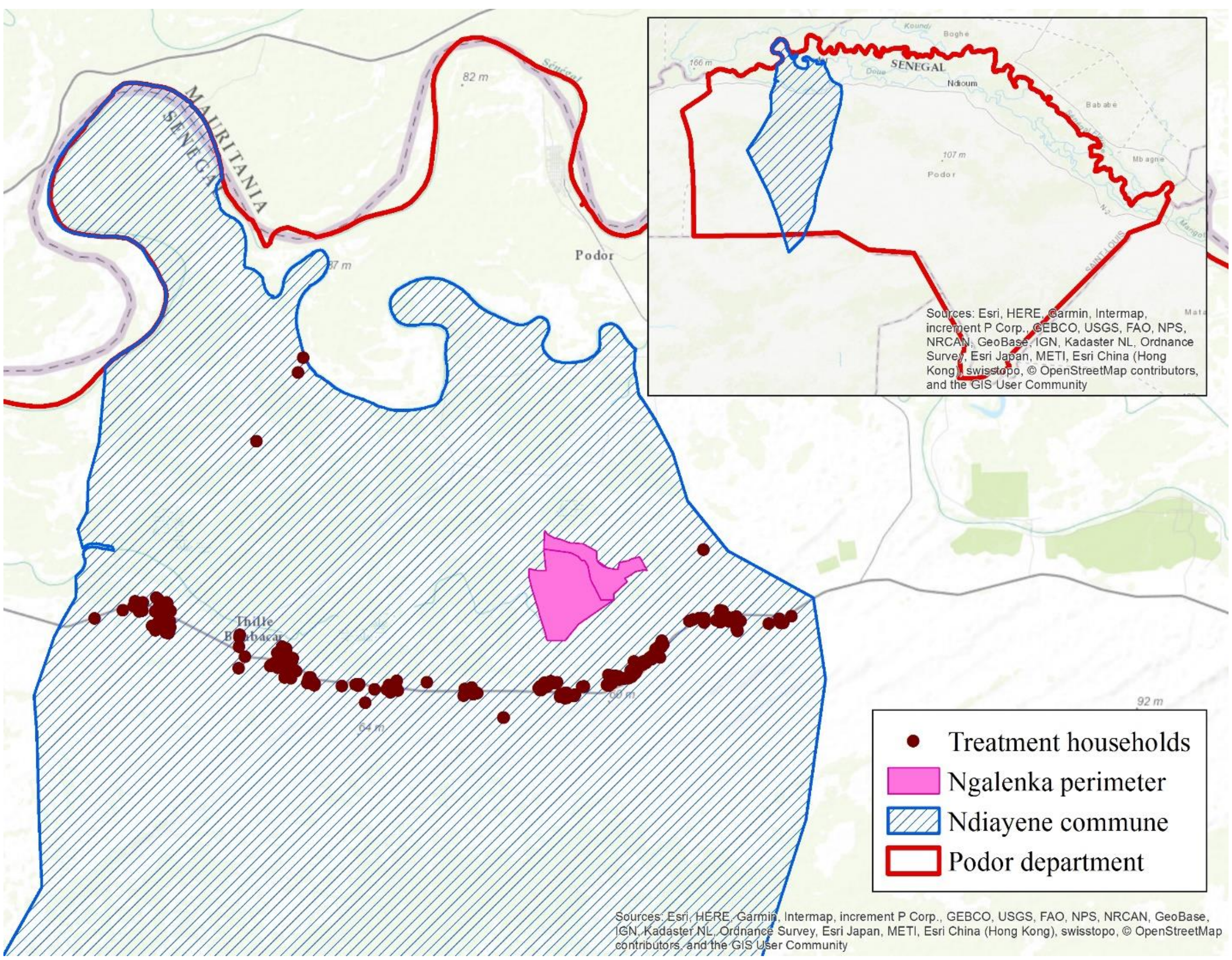
Table IV.10. Socio-demographic characteristics of the study sample (Podor)

Variable	Mean (treatment)	Sample size (treatment)
Household size	9	249
Age of household head	48	249
Household head is male	89%	249
Household head received some formal education	8%	248
Poverty likelihood (living on <$2.50/day)	77%	249
Number of plots used for farming		
Cold season	1.23	249
Hot season	0.81	249
Rainy season	0.96	249

Source: IWRM Project baseline household survey data.

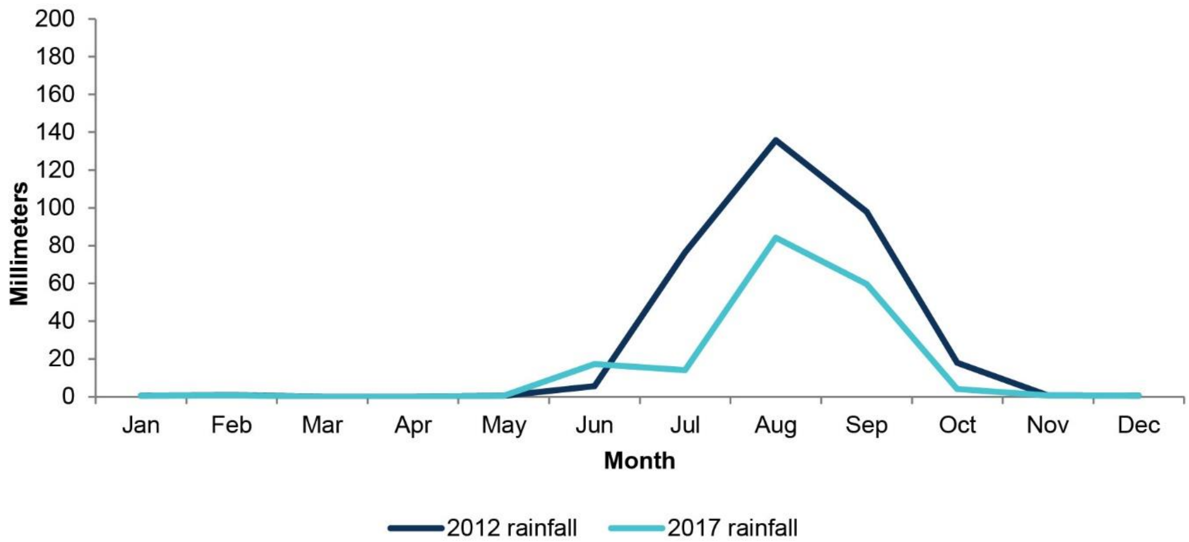
Our analytic sample in Podor is drawn from the CR Ndiayène Pendao and is concentrated among households near the new Ngalenka irrigated perimeter. Figure IV.6 shows a map of the Podor region with the location of our treatment households and the Ngalenka perimeter.

Figure IV.6. Location of households in analytic sample (Podor)



As with the Delta sample, we wanted to test whether changes in weather patterns could bias our outcome estimates. Because we don't have a comparison group in Podor, we were particularly concerned about any major differences in weather patterns between the baseline and follow-up years. Using the same CHIRPS data set in the same way described in IV.C.1.d, we calculated total monthly rainfall in the Ngalenka perimeter during the baseline and follow-up years of the study (Figure IV.7).

Figure IV.7. Monthly precipitation at baseline and follow-up (Ngalenka perimeter)

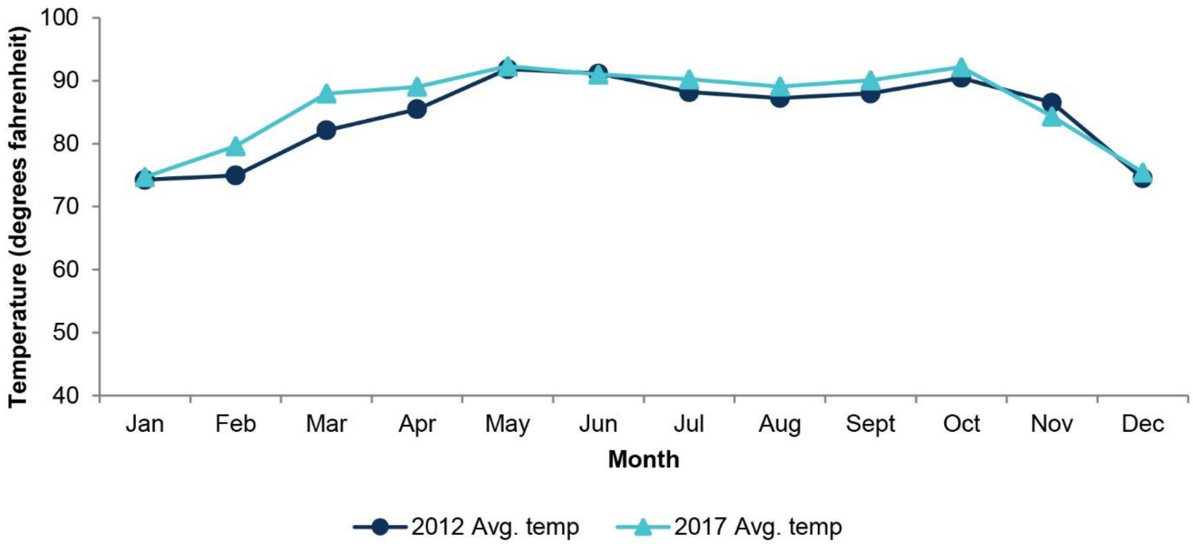


Source: Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)

Monthly precipitation totals during the rainy season in 2017 were substantially lower than rainfall around the Ngalenka perimeter in 2012. If lower rainfall totals resulted in less agriculture production, it would raise a concern that our pre-post estimates for Podor would be biased downward. If rainfall levels were similar at baseline and endline, then we would expect our pre-post estimates to be larger. Further, lower than average rainfall might lead to farmers using the irrigation pumps more often in the rainy season, resulting in higher annual irrigation costs and potentially lower agriculture profits, biasing our results downward.

We also checked average monthly temperatures for Podor at baseline and follow-up (Figure IV.8) and found them to be fairly similar. Temperatures were slightly higher in Podor in 2017 during the early months of the year. We do not think our pre-post results will be significantly affected by these small temperature differences. Overall though, there are many factors that could bias our pre-post results in both directions. We do not know the overall direction of the bias given the limited rigor of this analysis so provide these pre-post estimates as suggestive evidence as to the effectiveness of the IWRM Project. The results should be interpreted with caution.

Figure IV.8. Average monthly temperature at baseline and follow-up (Podor)



Source: Weather Underground.

d. Analysis approach

To analyze the Podor sample, we conducted a pre-post analysis to estimate changes in outcomes over time for the same sample of households who reported receiving land within the Ngalenka perimeter (treatment group).

To estimate changes over time, we ran a binary regression with the form:

$$(2) \qquad Y_{it} = \beta_0 + \beta_1 POST +_{it}$$

where Y_{it} is the outcome of interest *i* in year *t* (baseline or follow-up); *POST* is a binary variable that is equal to one in the follow-up year and zero in the baseline year; and ε_i is a random error term. The coefficient of interest is β_1, which gives the average pre-post change in the outcome. β_0, the intercept, is the mean at baseline. We use robust standard errors and estimated this equation separately for each outcome measure.

Because we are examining changes before and after the intervention, it is important to estimate changes among all households in the sample, including for measures that are only answered by farming households. A household that farms at baseline in a certain season may choose not to farm at follow-up in the same season, and vice versa. If we only examine outcomes among farming households in each season, our results could be biased, because the decision on whether to farm or not could be affected by the intervention. Therefore, we examine changes over time among all households in our sample, including for agricultural measures like the amount of land irrigated. A household that farmed at baseline would have survey data with a value for the amount of land irrigated. If the same household did not farm at follow-up in the same season, it normally would not have a value for the amount of land irrigated. In this analysis, we use a value of zero for that household at follow-up so the household will be in the analytic sample for both time periods for that measure. We trim outliers at baseline and follow-up at plus and minus three standard deviations from the median. For per hectare measures (including investment, revenue, profit, and rice harvest), we trim outliers at baseline and follow-up at plus and minus two standard deviations from the median to account for the inflated top-end of the distribution caused by small plot sizes. Small differences in sample sizes between baseline and follow-up are due to outlier trimming, survey nonresponse, and item nonresponse.

We conducted a subgroup analysis like the one we used with the Delta sample to estimate agriculture production outcomes separately by household poverty and education levels. Our conclusions from this analysis are more limited than the ones for the Delta sample because this analysis is based on a smaller sample size and a less rigorous evaluation design. We also conducted group tests to measure changes in crop production between baseline and follow-up among the treatment group in Podor.

To explore how changes in land tenure security affect changes in agricultural investment and production for farmers involved in the Podor Activity, we conducted a correlational analysis. We examined how the changes between baseline and follow-up in land tenure security are related to the change between baseline and follow-up for agricultural investment and production outcomes.

D. Qualitative Methodology for the Delta and Podor

We used qualitative methods, complemented by quantitative methods, to conduct a descriptive outcomes analysis to address research questions for which we did not have a counterfactual. We also used qualitative methods to examine the mechanisms that brought about project impacts and to better interpret the estimates produced through the pre-post analysis and land tenure institutional study. Our qualitative analysis draws on an array of data sources, including key informant interviews and focus groups with project stakeholders and beneficiary groups, and hydro-engineering observations of irrigation infrastructure.

Mathematica carried out focus group discussions, key informant interviews, and infrastructure observations in February and March 2018 among beneficiaries and stakeholders in the IWRM Project to strengthen the validity and reliability of our quantitative findings and to give individuals and groups affected by the project beyond those who were included in the survey sample an opportunity to describe their experiences with the project. These data collection activities were conducted by experienced staff from Centre de Recherche pour le Developpement Economique et Social (COGEMAP), a research and data collection organization based in Dakar.

1. Study sample

To understand the context of our impact analysis and to answer questions for our performance evaluation, we drew on information collected through focus groups with GIE and GPF members, and individual interviews with key stakeholders including SAED headquarters and extension staff, WUA leaders, and community members who do not belong to a GPF or GIE. We purposively selected for data collection three of the four communes where both LTSA and irrigation activities took place—two in the Delta Activity area, with large surface areas near the

IWRM irrigation infrastructure (Diama and Ronkh), and one in the Podor region that included the only IWRM infrastructure built in the region (Ndiayène Pendao). We looked for communes where the full suite of interventions were implemented in order to get the clearest possible picture of the implementation process and the combined effects of the interventions and to ensure that key features and populations were included in the analysis. Getting a variety of perspectives in the same communes allows us to triangulate different sources of information and understand the reasons and mechanisms for the outcomes we found. Table IV.11 shows our data collection sources, collection methods, the number of people we interviewed or focus groups we conducted, and the sample definition. Following the table, we describe the focus of each type of interview, the sampling method, and the selection criteria we used.

Table IV.11. Qualitative data collection specifications

Data source	Data collection method	Number	Sample
Members of GIEs in areas that benefited from the interventions	Focus group discussions	Delta: 5 Podor: 4	Members with knowledge of the interventions and their effects
Members of GPFs in areas that benefited from the interventions	Focus group discussions	Delta: 4 Podor: 3	Members with knowledge of the interventions and their effects
Community members in areas that benefited from the interventions who do not belong to GIEs or GPFs	Interviews	Delta: 6 Podor: 5	Community members who are eligible for membership but are not members
WUA leaders	Interviews	Delta: 4 Podor: 1	Leaders of WUAs in target communes
SAED engineers and extension staff	Interviews	Delta: 2 Podor: 1	SAED engineers responsible for irrigation works maintenance, and extension staff responsible for conducting WUA training and providing technical assistance to farmers
SAED headquarters staff	Interviews	1	SAED staff whose experience implementing the IWRM activities included thorough knowledge of changes. These staff were in St. Louis, not in the target communes.
Irrigation works and rice perimeter sites	Observation	Delta: 3 days Podor: 3 days	Entire Ngalenka perimeter in Ndiayène Pendao; most of the infrastructure in the Delta project areas (communes of Ross-Bethio, Diama, Gandon, and Ronkh)

GIE = farmer groups; GPF = les groupements de promotion féminine; SAED = Société Nationale d'Aménagement et d'Exploitation des Terres du Delta du fleuve Sénégal et des vallées du fleuve Sénégal et de la Falémé; WUA = water user association.

- **Members of GIEs and GPFs.** We carried out 16 focus groups (each with 6 to 12 participants) with members of GIEs and GPFs in the three selected treatment areas of the Delta and Podor to investigate which project-related factors caused changes in agriculture production, what the perceptions of water reliability and land tenure security were, whether there were barriers to accessing irrigation for crops, what the composition of household income was, level and type of land conflict, and perceptions of land institutions and the land formalization process. We investigated levels of interest in investing in the newly irrigated land, any obstacles people faced in obtaining access, and their perceptions about the costs and benefits related to access. We conducted focus groups separately in the Delta and in Podor, and separately for GIEs (mainly male members) and GPFs (all female members). In the GPF focus groups, we included women from both female-headed households and male-headed households, and examined women's particular points of view and the differential effects the interventions may potentially have had on them. Across all 16 focus groups, we attempted to ensure representation across regions, demographic and socioeconomic strata (including sex, ethnicity, age, and income levels), farming experience, and differential access to water sources.

- **Community members who do not belong to GIEs or GPFs.** We conducted interviews with 11 community members who were eligible but did not belong to a GIE or GPF to compare their experiences and perceptions of the project to those of GIE or GPF members. Although these respondents are not direct beneficiaries of the project, as members of the community, they are stakeholders.

- **WUA leaders.** We interviewed four leaders of WUAs in the Delta and one in Podor to learn more about whether and how water use has changed, how the roles of WUAs have changed, and whether water availability, access, and supply have changed. We also asked about changes in the amount of irrigated land. (We asked GIE leaders in Podor for the same kinds of information in focus groups).

- **Interviews with SAED engineers and extension teams.** We conducted three interviews with staff at SAED, including engineers responsible for irrigation works maintenance and extension staff responsible for conducting WUA training and giving technical assistance to farmers in the Delta and Podor regions. We sought to refine our understanding of where and when the implementation of irrigation activities took place and who benefited from these activities in order to identify the project activities that our impact estimates in the Delta can be attributed to.

- **SAED headquarters staff.** We interviewed SAED headquarters staff whose experience implementing the IWRM activities includes thorough knowledge of changes at all administrative levels and across activities. This interview was held at SAED headquarters in St. Louis.

- **Observations of infrastructure.** Working with the project's irrigation engineer, our hydrological engineer observed key features of the irrigation implementation, including whether pumps are functional, canals are maintained, the perimeters are properly connected to the drainage system, and perimeters are under production during the growing seasons.

In addition to the qualitative methods and sources listed above, we also gathered administrative data, such as maintenance plans.

2. Qualitative data collection process

Before training the data collection team, Mathematica developed semi-structured protocols and focus group discussion guides mapped to the evaluation's research questions. These were designed to elicit participants' perceptions of the IWRM Project's implementation activities and promote open discussion of both the benefits and drawbacks of the changes in their communities. After review and approval by MCC, COGEMAP translated the protocols into Wolof and Pulaar and pre-tested the instruments in communities near and similar to the project areas. Qualitative data were collected from January to March of 2018. After transcribing all interviews from local languages to French, the data collection team and evaluation team carried out coding in NVivo. The codeframe used for the qualitative analysis is contained in Appendix D.

3. Qualitative analysis

We analyzed qualitative data to identify patterns of consensus, instances of divergent or contradictory views, and variation across local areas and different samples. We used two primary analysis methods to address our research questions: (1) thematic framing, and (2) data triangulation.

Thematic framing. To uncover patterns, themes, and issues in the data, we developed a coding scheme with a hierarchy of conceptual categories and classifications linked to the research questions and the logic model. We updated this coding framework as we systematically reviewed and assessed our data according to the project's theory of change and program logic. Using NVivo software to assign codes to the qualitative data enabled us to access data on a specific topic quickly and organize information in different ways to identify themes and compile evidence supporting them. For instance, farmers described their appreciation of the new irrigation infrastructure in language that had similar underlying themes. Our coding structure captured those similarities. Conversely, men and women viewed access to newly irrigated land differently; our coding structure classified those different perspectives in a concrete manner. Those divergent perspectives also illustrated challenges in project implementation. Further, the software allowed us to group respondents by gender, age, geographic location, and other salient characteristics to permit analysis by group.

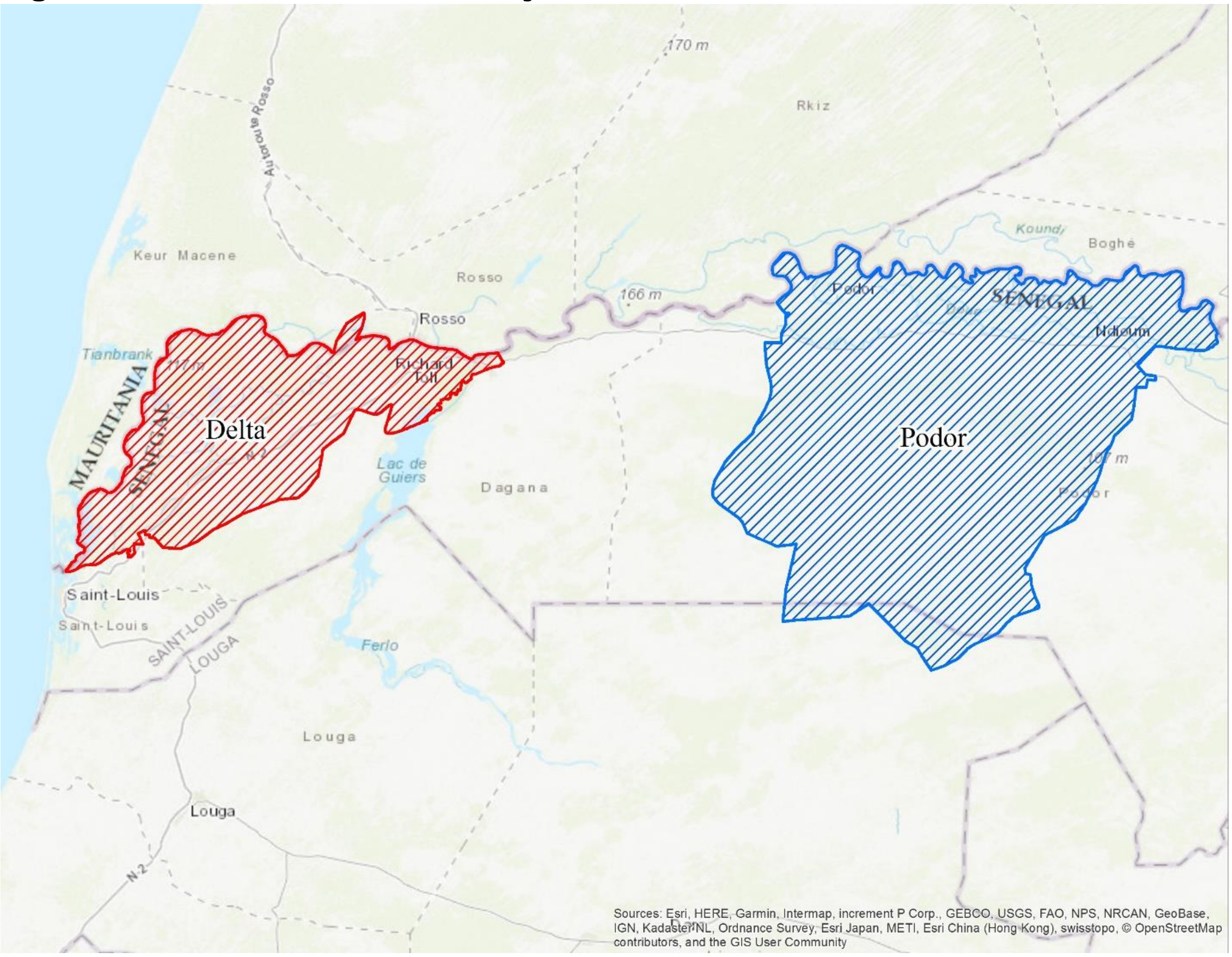
Triangulating data. Because our analysis incorporated data from several different sources, including household survey data, focus groups, key informant interviews, infrastructure observation, administrative data, and project documentation, we tested for consistency and discrepancies in findings across these data sources by triangulation. This process facilitates confirmation of patterns or findings and the identification of important discrepancies. Our coding hierarchy also enabled us to integrate quantitative results and apply quantitative attributes to qualitative data and support triangulation across data sources and types. For example, when investigating the project's impact on women's access to land, we triangulated among survey data on land use, results from focus groups on perceptions of access to newly irrigated land, and data from the project and land registry information on the number of women assigned land.

E. Case study analysis for the LTSA institutional outcomes study

We used a case study methodology to study the implementation and outcomes of the land tenure interventions at the commune level, and beneficiary perspectives of land institution effectiveness. Case study methodology for evaluation uses a variety of data sources and data collection techniques to examine a complex and specific element of a project in order to attain the richest possible understanding of the project element in its context. The research questions we addressed using these methods were about activities that occurred before the baseline survey and activities that occurred at the commune level and may have had commune-wide or institutional effects.

Figure IV.9 shows the areas in which the LTSA took place.

Figure IV.9. Location of LTSA Project Areas



1. Study sample

The LTSA institutional outcomes study draws on information collected through individual and group key informant interviews, focus groups, observations, and reviews of reports from four communes: Gandon, Ronkh, Ndiayène Pendao, and Guedé Village. In each commune, our data collection team visited the communal headquarters building and met with officers involved in land tenure management, including the following:

- The person(s) responsible for land management and registration, which could be the first deputy mayor, municipal secretary, or Domain Commission president
- Other members of the Rural Council and its Domain Commission (the land tenure committee)
- Staff in the domain management office—the land agent or information technician

- Members of cooperatives (GIEs*)* and women's cooperatives (GPFs*)* (in all communes except Guedé Village)

The team also conducted observations in the registry offices in each commune, observing how the books and files were kept, stored, and used; whether citizens were coming to the office to conduct business; and how the public officers interacted with them. The team examined the types and content of the forms and documents of land tenure and observed how the computerized land information system was being used. In communes where the computer equipment was in operation, the team tested its functionality by asking the land agent to retrieve files of specific landholders who had been interviewed as part of the survey.

The team also visited the offices of national and international programs that are now providing support and technical assistance to the communes for land management, including:

- SAED headquarters in St. Louis
- SAED Podor regional headquarters in Ndiayène Pendao
- PDIDAS—a World Bank funded initiative to develop agriculture and agribusiness in Delta
- AIDEP—an initiative funded by *Agence Francais de Developpement* to improve food security in Podor, which includes land tenure security components

Table IV.12 lists the meetings, visits, interviews, and other activities conducted during the December 2017 data collection. Following the table, we detail the focus of each type of interview, the sampling method, and the selection criteria we used.

Table IV.12. Case study data collection

Data source	Data Collection Method	Location / Commune	Sample
SAED Staff	Interview	• St. Louis, headquarters • Ndiayène Pendao, Podor regional headquarters	SAED staff providing support and technical assistance to the communes for land management
AIDEP	Interview	• St. Louis • Ndiayène Pendao	Staff providing assistance in Podor for food and land tenure security
PDIDAS	Meeting	• St. Louis	Staff working to develop agriculture and agribusiness in Delta
Commission Domaniale (CD)	Interview	• Gandon (2 members) • Ronkh • Ndiayène Pendao (6 members, including the vice president and the municipal secretary) • Guedé	The president of the CD is sometimes responsible for land management and registration, whereas members of the CD are members of the land tenure committee
Municipal secretary and SIF manager	Working session	• Gandon • Ronkh • Ndiayène Pendao • Guedé	The municipal secretary is sometimes responsible for land management and registration, whereas the SIF manager is most knowledgeable about the computerized land information system

Data source	Data Collection Method	Location / Commune	Sample
Deputy mayor	Interview	• Gandon (2, one of whom is the president of the management of the POAS)	The person responsible for land management and registration
Mayor	Visit	• Ronkh	n.a.
Administrative data	Review	• Gandon • Ronkh • Ndiayène Pendao • Guedé	Conflict and land transaction volume data
Commune-level land tenure documents	Dossier review	• Gandon • Ronkh • Ndiayène Pendao • Guedé	A random selection of land tenure files
Members of farmer GIEs and GPFs	Interviews / focus groups	• Gandon (2 GIE members and 3 GPF members) • Ronkh (2 GIE groups and 3 GPF presidents) • Ndiayène Pendao (14 presidents of GIEs and GPFs)	Farmers within the communes where land interventions were conducted
Clients	Observation	• Ronkh	Citizens coming to registry offices to conduct business and interact with public officers
Perimeter	Observation	• Ngalenka	Newly irrigated land

n.a. = not applicable.

- **Interviews with SAED, PDIDAS, and AIDEP staff.** We conducted five interviews with staff of SAED, PDIDAS, and AIDEP who are responsible for working with farmers in the communes where the interventions were implemented. We sought to refine our understanding of where and when the implementation of LTSA and irrigation activities took place and who was affected by these activities. We focused on the changes that have occurred and their implications for security of and investment in land.

- **Interviews with commune-level land managers and land committees, including members of the Commissions Domaniale, municipal secretaries, SIF managers, and mayors and deputy mayors.** We interviewed more than 20 commune-level land managers and land committee members in the four communes we focused on to learn how the land formalization process has changed, how governing institutions have altered their approach to land management, and what constraints and barriers hindered land access. We also collected administrative data from the land managers on land conflicts and land transaction volume.

- **Land tenure documents.** We carried out a deep-dive review of a selection of land tenure files in the selected communes to understand how land managers grant to individuals, households, and producer enterprises or associations the rights of occupancy and use of land in the form of *titres d'affectation*, how they survey and record land rights, and how they accommodate transfer of land rights. The condition of these data did not permit us to verify the land tenure status of respondents to the household survey.

- **Members of GIEs and GPFs and clients.** We carried out seven focus groups with members of GIEs and GPFs in three of the four selected communes (we were not able to meet with any cooperative members in Guedé) to assess differing perceptions of the process of gaining the rights of occupancy and use of land in the form of *titres d'affectation*, as expressed by those seeking formalization of their land use. We also observed clients in Ronkh as they visited registry offices to understand in more depth the experience of seeking land rights, conducting business with land officials, and interacting with public officers.

- **New irrigated land.** We visited the Ngalenka perimeter to observe the newly irrigated land and how it was being used by farmers. We looked at the amount of land that was under cultivation, the types of crops, the access to water, and the number of people working.

In addition to the sources listed above, we also gathered administrative data from the communes and project reports on land registration rates, land transfers, land disputes and dispute resolution, where available. We also drew on data collected as part of the household survey to provide additional information on land access and conflicts.

2. Case study data collection

During an exploratory data collection mission in the fall of 2016, members of the core Mathematica team conducted meetings and interviews with local stakeholders to (1) investigate whether other activities took place in the treatment areas during the period of our study that could affect the outcomes related to land tenure; (2) determine more precisely the location and timing of project activities; and (3) identify the key subgroups of beneficiaries for the land tenure activity. The team carried out interviews with GIE and GPF members, WUAs, land officials, and the Domain Commission in Gandon, Diama, and Ronkh, which aided in the design of the land institutions case study.

In December 2018 Mathematica's evaluation economist and land tenure expert with support from our local research team carried out a deep-dive examination of land tenure institutions involved in the LTSA. The goal of this case study was to gather in-depth information from municipal officers and institutional representatives on the impacts and sustainability of the IWRM land tenure activities by observing the functioning of land tenure administration and the use of tools and procedures that the project implemented. The team also conducted archival review, reading through the project reports and in-person reviews of the land registries in the four communes. The Mathematica team identified specific questions to be answered and developed semi-structured discussion guides that were mapped to the evaluation's research questions and refined based on exploratory research. Questions were designed to elicit participants' perceptions and experiences with the IWRM Project and promote open discussion of the benefits, drawbacks, and operation of the land tenure system that the project operated in. Interviews were conducted in French whenever possible, and in local languages when necessary or more helpful. Data were collected in the form of notes during and after each meeting, interview, and observation.

3. Case study analysis

Preliminary analysis for the case study was conducted each evening by the team in the field. This process allowed team members to confirm answers to research questions and identify new questions for follow-up, clarification, and further exploration. After finishing the field research and reviewing the collected documents, we continued to analyze the collected documents and other case study data to identify whether and how well implementation was conducted, whether and how systems were working, and what factors helped and hindered the accomplishment of outcomes. Variations across data sources and communes confirmed or highlighted aspects of implementation and operation that otherwise might have been be overlooked. We used data triangulation as the prime analysis method to address our research questions. This was done within each commune using data from a variety of perspectives. The team's findings were complemented by findings from our analysis of survey data and of qualitative interviews and focus groups with other project beneficiaries and stakeholders from the same communes. This allowed us to triangulate information and understand the reasons and mechanisms for the outcomes we found.

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V. EVALUATION FINDINGS: DELTA

In this chapter, we present our evaluation findings of the IWRM Project in the Delta area. We begin with a summary of our key evaluation findings. We then present results by the following topic areas: water use and availability, agricultural production, agricultural profits and household income, land administration and governance, land formalization and conflicts, and project sustainability. Under each topic area, we blend findings from our quantitative and qualitative analyses to fully answer each of the project's research questions.

A. Summary of key findings

- Our quantitative data show that the IWRM Project increased farmers' satisfaction with the availability of water in the intervention areas of the Delta. This is supported by qualitative findings revealing that almost all the beneficiaries we interviewed appreciated the increased availability of water from the project as a major driver of agriculture improvement in the Delta, including their ability to cultivate year-round. However, farmers farther from the water sources and canals reported less satisfaction than those closer, who have easier access.

- In the primary agriculture season, the hot season, the IWRM Project led to a statistically significant increase in land under production of 0.56 hectares on average for the treatment group, an increase of 80 percent over the comparison group mean. Almost all of this land was irrigated and used to cultivate rice. We found that the increase in area of land used for production was significant regardless of the household's economic status or whether the household was headed by a male or female.

- Overall, farmers are spending more money on agriculture inputs for their larger tracts of land and receiving more revenue, but maintaining a similar level of productivity, meaning we find no changes in *per-hectare* agriculture investment or revenue during the main growing season. Most of the changes in total agriculture production investment and revenue are driven by rice farming, a main focus of the IWRM Project. During the main farming season, the project led to an 11 percent increase in the number of households that cultivated rice, the average area of land dedicated to rice production increased by 91 percent from 0.64 to 1.22 hectares, and yields increased by 940 kg/ha on average. The IWRM Project also affected the mix of crops that households cultivated as they focused more on rice production at the expense of cultivating other crops. The project intended households to also expand vegetable farming during the secondary farming seasons (cold and rainy seasons), but we did not find evidence that this took place.

- Our qualitative findings confirm that farmers' choice of crops is largely guided by the availability of water and agricultural inputs. Farmers also reported that aside from inputs provided by the project, private structures such as banks provided credit for seed and fertilizer inputs. Farmers also said, however, that these inputs were expensive given the increased land under production and that they had other expenses for the mechanized irrigation needed to access water for land located in some areas fed by the new irrigation infrastructure.

- As a result of the IWRM Project, households have shifted the placement of their resources to focus more on farming in the main growing season, resulting in higher agriculture profits and less revenue from off-farm income sources. The increase in agriculture profit appears mainly driven by an increase in land under production. There was also a reduction in annual off-farm revenue because shifts in economic resources have yet to lead to large economic gains. We find no aggregate change in household consumption, and households were still able to meet their basic needs.

- MCA helped WUAs to formalize through restructuring, obtaining permits of association and establishing offices, and through interventions to strengthen the WUAs' technical capacities. The function of the WUAs is to help communities to sustain the irrigation infrastructure in concert with SAED. WUAs might not be operating as well as they need to, and WUA leaders were almost unanimous in stating they lack material means (for maintenance) and financial resources to ensure the operation of the infrastructure and a good supply of water.

- The Land Tenure Security Activity aided local land institutions to develop principles and policies for land use and land allocation. Commune land officials implemented the policies during the compact but state that they have not had enough funds to fully implement land formalization activities since the compact ended. Land management practices differed considerably by commune.

- The IWRM Project led to positive impacts in land formalization. More households know the process they have to follow to receive a land title, and more households applied for and received land use titles at the commune level. We do not find any project impacts on reducing land conflicts but we see no increase in land conflict despite the likely improvements to land value due to the improved irrigation system. We note there were few conflicts reported at baseline.

B. Use and availability of water

To provide easier access to and a higher volume of water from the Senegal River, the project built new irrigation canals and rehabilitated those that already existed. The evaluation was designed to determine if, as a result, water is more available to households and whether more land is irrigated. We focus on answering four research questions:

1. Have there been changes in the sources of water used for agricultural production?
2. How has water availability[11] changed, and have barriers or costs to accessing[12] irrigation been reduced? Has the water supply become more reliable?
3. Has the amount of irrigated land increased?
4. Has the role of WUAs changed, and how do they impact the use and availability of water?

[11] By availability, we mean the volume of water

[12] By access, we mean the delivery of water

Main findings

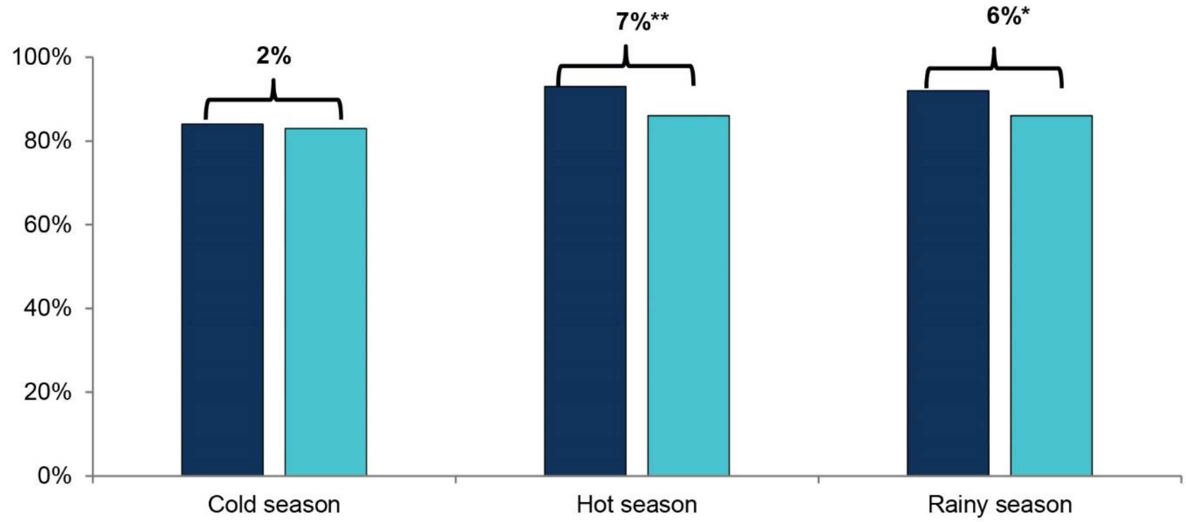
- The IWRM Project increased farmers' satisfaction with the availability of water in the Delta. Almost all the beneficiaries we interviewed appreciate the increased availability of water as a driver of agriculture improvement. However, farmers farther from the water sources and canals reported less satisfaction than those closer to them.
- Farmers found the additional costs of increased mechanized irrigation high. The higher cost of irrigated water affects access to water or the amount of water that can be used by some farmers.
- MCA helped WUAs to formalize and strengthened their technical capacities. The function of the WUAs is to help communities sustain the irrigation infrastructure in concert with SAED. However, WUAs might not be operating as well as they need to; WUA leaders almost unanimously stated they lack the means for maintenance and to ensure the operation of the sections of irrigation infrastructure for which they are responsible.

1. Source, availability, and access to water for agriculture production

Before the IWRM, several canals and waterways branching from the Senegal River brought fresh water to the Delta. As described in Chapter II, many of the waterways were degraded, and water flow was inadequate, so large tracts of arable land in the area had been abandoned. The project rehabilitated several primary canals and built new irrigation canals, water control structures, and a main drainage canal.

In our quantitative impact analysis, we do not find that farmers changed the **source** of water for agricultural production (research question 1). The main source of water remains the Senegal River through irrigation canals or other waterways in the Delta. However, our quantitative analysis does show that the IWRM Project increased the **availability** of water in the treatment areas of the Delta, as measured by farmers' satisfaction with water availability. Our impact findings reveal that significantly more households in the treatment group reported satisfaction with the availability of water for irrigation, exceeding satisfaction levels in the comparison group by 7 percentage points in the hot season and 6 percentage points in the rainy season. Satisfaction levels did not differ between the two groups in the cold season, which is not a main growing season (Figure V.1). However, even without the IWRM intervention, there was a high degree of satisfaction with the availability of water for irrigation, as evidenced by the high mean values (over 80 percent) for the comparison group. High levels of satisfaction with water availability could reflect that farmers in the comparison group have had the same infrastructure for a long time, adapting to it for their agricultural needs and accepting it as status quo. Although the IWRM Project led to farming households in the treatment area being more satisfied with the availability of water for irrigation, there was not that much room for improvement on this measure.

Figure V.1. Satisfaction with the availability of irrigation water, among households that farmed (Delta)



Source: IWRM Project baseline and follow-up household surveys

Note: Result are among households that report farming in each wave. We present the comparison group mean and the adjusted treatment mean, which equals the comparison mean plus the impact estimate. Impact estimates are shown as the difference between the two means and are given in percentage points. Households are marked as satisfied with the availability of irrigation water if they reported they were either satisfied or very satisfied. They are marked as unsatisfied if they reported they were neutral, unsatisfied, or very unsatisfied with the availability of irrigation water.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Qualitative interviews and focus groups with farmers, community members, leaders of WUAs, and engineers from SAED support these findings. Stakeholders described how the IWRM Project allowed many farmers in the treatment area to switch from obtaining water through degraded and hand-dug canals to obtaining water from the project's new and rehabilitated irrigation infrastructure. Again, however, they noted that the source of the water remained the same. Farmers and SAED engineers also confirmed that the infrastructure has led to more water being available to farmers for irrigation, and that the project provides easier access to fresh water for animal husbandry and other household needs. Nonetheless, some farmers described challenges in relation to access to water for certain fields, reliability of water, the costs of irrigation, and management of water.

Regarding the availability of water, our qualitative data from farmers and SAED engineers indeed show that the amount of water for irrigation has improved; households in the treatment areas have more water since the IWRM Project was completed. According to the stakeholders we interviewed, the MCA project infrastructure, including the irrigation canals, has allowed them to access water almost year-round in the agricultural fields, which is a substantial improvement over the pre-project period. This WUA president from Diama expressed a common sentiment: "Since the completion of the MCA project, water is available in quantity and at any time, during the dry [hot] season and during the rainy season. That's a major change."—W1[13]

Our qualitative research confirms that to increase the supply of water available, the project built, enlarged, and straightened canals, and cleaned them to remove *typha*, a fast-growing weed that clogs the canals. Many of the farmers interviewed individually or in focus groups in Ronkh, Gandon and Diama, including men and women, expressed appreciation for the arrival of the project in their community because it made more water available. Many qualitative respondents, particularly small producers and women, stated that before the project, they were faced with many technical and financial challenges with irrigation infrastructure that impacted their agricultural productivity. With the increased availability of water from the irrigation canals, farmers in our focus groups and group interviews reported that water had become more reliable and easily accessible through the gravity-fed system. Several farmers reported that all they had to do was open a sluice gate, and water would flow directly to their fields at the correct level. The SAED agents we interviewed agreed. One agent in the area described the change: "For example, before, to irrigate a surface of 15 hectares he [a farmer] needed linked pipes, which went 500 meters [from the canal]. Now the pipes are located close to the farms." —S1

The increased availability and reliability of water has benefited many farmers in the area. This GIE member and rice farmer in Ronkh summed up the feelings of many farmers:

> The arrival of MCA has been very beneficial for us because they have developed infrastructure for the water in the valley. They have created quality waterways, paths, and basins for us. Frankly, there are no more problems with regards to water. Perhaps what remains to be done is the irrigation infrastructure for those who have not benefited, but there has been progress, because it is well done if compared to the past years; the infrastructure and the basins are perfect. —E1

However, some farmers we interviewed, especially those with fields farther away from the fresh water sources, reported a variety of barriers to accessing water. One such barrier was the distance between a farmer's plot and the nearest irrigation canal: farmers whose plots are farther from the irrigation canal have trouble accessing it because either the gravity system is not able to bring water to their plots, or there are physical obstacles, such as dikes, between the fresh water source and their field. In addition, many farmers we interviewed complained of the high cost of diesel, which supplies power to the pumps needed to bring water to some fields. The president of a village GIE in Diama described some of the challenges farmers face when their plots are far from a canal:

> We use a motopump and an 800 meter pipe to irrigate [our market gardens]… it's more expensive now. If the branch of the river was close to our fields, pumping would not be expensive for us; the water would go directly in the canals to the

[13] Attributions of qualitative quotations are coded based on type of interview, numbered for each individual quoted. The six types of interviews are W=WUA leader, S=engineer or agriculture agent, E=GIE member, F=GPF member, C=community member, and L=land agent, dominal commission or other land authority

> fields. In the [fields with Dior-type soil[14]] where we are, we use connections of pipes where the water passes a long distance, therefore the pump burns huge amounts of diesel. That is why it is … expensive for us to access the water. —E2

In some cases, even the motopumps cannot bring enough water to irrigate crops. In another village in Diama, a member of the Mboubène Maure GPF described another, less common scenario:

> You know the canal does not reach our fields. The canal is far from our fields. That is why we have taps, and the water bills are expensive. That is why we restrict our irrigated plots to be able to get by at harvest time, because if we use too much water, and the harvest is not good, we will not be able to sell the harvest and pay our water bills … The water bills are expensive. —F1

In short, fields that are far from the water source, and fields that are blocked from canals by obstacles such as dikes, require farmers to spend money on fuel to operate motopumps or to use expensive tap water for agricultural production.

Using quantitative survey data, we examined whether the IWRM Project changed farmers' methods of irrigation due to the rehabilitation and construction of canals. We classify an irrigation system as simple gravity irrigation if no pump is used and as sophisticated irrigation if a household reported using a diesel or electric pump, a sprinkler system, central pivot irrigation, or drip irrigation. Because 90 percent of farming households reported farming on one to three plots in any agricultural season, we report whether a household uses an irrigation system on any of its plots.

Unexpectedly, we find that the project led to a large decline in simple gravity irrigation among farming households in the cold season (22 percentage points) and a smaller but still statistically significant decline of 6 percentage points during the hot season (Table V.1). Farming households appear to be shifting toward more sophisticated irrigation systems, particularly in the cold season, a finding emphasized in our qualitative results as well. As far as the types of sophisticated irrigation systems that are being used, farmers reported overwhelmingly that they were using diesel or electric pumps, and many farmers noted that costs of irrigation were higher due to increased mechanization.

[14] The Delta Activity area is characterized by several soil types. Clay soil is appropriate to rice farming, whereas a sandier soil, known locally as Dior, is appropriate to market garden crops.

Table V.1. Impact estimates for water and irrigation, among households that farmed (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimates	*p*-value	Sample (T)	Sample (C)
Cold season						
Used a simple gravity irrigation system	6%	28%	-22%**	0.00	443	620
Used a sophisticated irrigation system	89%	67%	22%**	0.00	443	620
Farm plots that were irrigated	98%	91%	6%**	0.00	448	627
Total area of land irrigated (ha)	2.39	1.49	0.91**	0.00	431	596
Hot season						
Used a simple gravity irrigation system	8%	15%	-6%**	0.00	605	579
Used a sophisticated irrigation system	90%	87%	3%	0.11	605	579
Farm plots that were irrigated	96%	99%	-3%**	0.00	607	579
Total area of land irrigated (ha)	2.39	1.39	1.00**	0.00	587	559
Rainy season						
Used a simple gravity irrigation system	12%	8%	5%	0.12	235	272
Used a sophisticated irrigation system	85%	90%	-5%	0.08	235	272
Farm plots that were irrigated	85%	99%	-14%**	0.00	274	273
Total area of land irrigated (ha)	1.73	0.86	0.86**	0.00	225	259

Source: IWRM Project baseline and follow-up household surveys

Note: Result are among households that report farming in each wave. We present the adjusted treatment mean, which equals the comparison mean plus the impact estimate. Sample sizes vary based on survey response and farming rates. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median. A household used a type of irrigation system if it reported its use on at least one of its farm plots. We classify an irrigation system as simple gravity irrigation if no pump is used and as sophisticated irrigation if a household reported using a diesel or electric pump, a sprinkler system, central pivot irrigation, or drip irrigation. Beyond these two types of irrigation, farmers could report using a watering can for irrigation, no irrigation, or some other form of irrigation identified by the respondent.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

2. Area of irrigated land

Given the shift from simple gravity irrigation to more sophisticated irrigation, we want to understand if there was a change in the percentage of plots that farming households irrigated. We find mixed results, with a significant increase in the percentage of farm plots irrigated in the cold season, a small but significant decrease during the hot season, and a larger significant decrease during the rainy season. In all three seasons, the mean level of plots irrigated was very high, particularly in the cold and hot season, when almost all plots received some form of irrigation. As expected, the mean was lower in the rainy season, when more farming households rely on rainwater for their crops. The project appears to have caused a shift in irrigating from the rainy season to the cold season, with little change in the hot season.

To better understand these mixed findings for the percentage of plots that are irrigated, we estimated the impact of the IWRM Project on the total area of land irrigated. We find that, after the project, farming households in the treatment group irrigated significantly more land, on average, in all three seasons—by 0.91 hectares in the cold season, 1.00 hectares in the hot season, and 0.86 hectares in the rainy season—compared to the comparison group. Because the average amount of irrigated land increased for the treatment households, the lower ratio of plots they irrigated in the hot and rainy seasons means that farming households are focusing their efforts on irrigating larger plots at the expense of smaller ones. This could be due to households concentrating their production on plots that are connected to the improved irrigation.

The qualitative data also support that the amount of irrigated land available to farmers increased as a result of the IWRM Project. For example, there was a substantial increase in irrigated land in the commune of Diama, near the southwestern end of the IWRM Project area. Previously, there was a great deal of land in that area that had no reliable source of water; with the creation of the compensatory canals built by the project to replace the irrigation water formerly drawn from the Djeuss[15] (which now forms part of the drainage system), the land can now be used. A SAED engineer described the change since the project interventions:

> We have seen, these last two years, that there have been a lot of market gardeners who have come to settle there … it is the compensatory canal that allows the farmers to settle down and have fresh water … and develop some land there to allow market garden[ing]… They do not have plots yet [for rice]. They grow onions, potatoes, tomatoes, eggplant. They grow anything. —S1

> The new irrigated land affected women as well as men. One member of a GPF in Diama summed up the experiences of the women in her group as well as others: “Before, we did not even have fields. It is with the [IWRM] Project that we started to practice agriculture. There was just the land, but no water to make agricultural fields. Now with the help of the canal, we have fields since we have enough water.”—F2

Although the impact analysis shows an average increase in irrigated land, and stakeholders reported a net gain in irrigated land due to the project, some fields that were previously used for agriculture became more difficult to irrigate after the intervention. Farmers we interviewed reported that some farmers who had previously had access to water from the main canal or river are prevented from accessing water as easily as before by the newly constructed irrigation infrastructure. In particular, some of the dikes built by the IWRM Project create a barrier between the canals and the fields. One example of this occurred in Ronkh. A WUA leader there explained how some farmers benefited from the irrigation infrastructure, but others now have difficulties because of it:

[15] Compensatory canal refers to one of two canals built to the north (*canal compensateur droit*) and south (*canal compensateur gauche*) of the newly built drainage canal known as the *emissaire*, or by its original name, the Djeuss.

> After the [MCA project], there was a dike erected from Ronkh to Ross Béthio. With this dike, the water does not go back to the inland areas. These areas that are beyond the canal have no water. … It is the dike that prevents water from accessing these areas that it watered before. … The fields of our ancestors, those which our grandfathers left us … and which allowed us to have considerable incomes, it is now difficult to get water for these fields. —W2

Moreover, although women also had access to the newly irrigated land, they did not always receive equal access. Many women said they received smaller plots or were not being given access to rice plots at all. In one case, women in Ronkh noted that some land that was set aside for women was later claimed by the men of the village.

3. Role of WUAs

WUAs have existed informally in the Delta since at least 2002. Starting in 2011, MCA helped WUAs to formalize through restructuring, obtaining a permit of association, and establishing an office in Dagana. MCA's interventions also worked to strengthen the WUAs' technical capacities for maintenance of the irrigation infrastructure, billing, collection, logistics, mapping, the use of GPS, and securing land tenure.

SAED is responsible for maintenance of the primary canals and the hydraulic system overall, including pumping and drainage stations. WUAs may assist in the maintenance of secondary canals and facilities, depending on location and needs, organize teams for weeding, and carry out other tasks to assist with the provision of irrigation. Individual farmers and GIEs are responsible for tertiary canals. In addition, WUAs have an overall role in alerting SAED of maintenance needs by closely monitoring the infrastructure, overseeing the annual maintenance work on tertiary and sometimes secondary canals, and ensuring the integrity of the irrigation infrastructure, including identifying the locations of unauthorized canal connections. At the level of the pump units supplying the plots, the WUAs work in synergy with the GIEs to ensure that users of the infrastructure have good water availability. They plan and manage the schedule for providing water to different fields.

The managers appointed by the members of the WUA[16] oversee the maintenance of irrigation infrastructure (including sluice gates, animal watering stations, irrigation canals, and so on), control the availability of water for the farmers, and collect water user fees. According to the stakeholders we interviewed, to safeguard the availability of water in all seasons, it is necessary to ensure the proper functioning of the canals—for example, ensuring that cattails (*typha*) do not prevent the flow of water to the fields. It was not clear in our interviews with farmers and GIE members whether the project training had improved the functioning of the WUAs in the period since the infrastructure was completed. Respondents noted that some of the maintenance for which the WUAs are responsible is either subcontracted out or performed by volunteers.

Despite these new responsibilities, the WUA leaders interviewed specifically mentioned that they did not have the resources to adequately maintain the infrastructure for which they are responsible. In fact, the WUA leaders we interviewed were almost unanimous in stating that they

[16] Each water user is a member of or represented by a WUA.

lack material means (for maintenance) and financial resources to ensure the operation of the infrastructure and a good supply of water to the agricultural fields. In this regard, a WUA leader in the Delta, who noted the benefits of the MCA project, also outlined these challenges:

> I am [name] the vice-president of a Union of Cooperatives... The Union covers five villages. …
>
> With the MCA project, frankly, we were happy upon its arrival and everything that was expected of them, they have done their best. But at present, we see that there are deficiencies, and there are things that are lacking. After their departure, we found that follow-up remained. We have difficulties that we cannot control. The water flows everywhere (overflows the canals), and the sluice gates are not well installed, and there are some animal watering stations that were made at specific locations, but we cannot habituate the animals to go there. … there are places where, in two years, the canals will no longer function and [we face] other difficulties. —W3

In addition, although focus group participants were able to describe some of the roles of WUAs, not all the WUA participants we interviewed were certain of their functions and responsibilities, nor motivated only by the common good that WUAs are designed to maintain. There were reports of members using the organizations for purposes other than the roles described above. For example, one WUA member reported that some WUA members were not focused solely on the needs of the maintenance of the water sources; there may have been ulterior motives for people joining, including the possibility of personal gain. He noted the following change over time:

> For me, the ambitions that we had at the start when volunteering were better, … because since they [the population] have seen that the WUA has begun to have importance, there has been a lot of talk [as opposed to action]. … It worked better previously, because at the beginning it was only volunteers, each could give their ideas, we even had project proposals, and everyone moved forward quickly. —W2

Two farmers remarked that some WUA members use the organizations as GIEs; thus, their goals again deviate from the roles originally envisioned for the WUAs, with activities mainly oriented toward the search for revenue. They see these takeovers of the WUAs as representing a cost to the associations, because members may be involved for personal benefits, not in order to ensure the availably of irrigation water for all.

C. Agricultural production

The primary aim of the IWRM Project in the Delta region was to increase rice production and the amount of land cultivated for agriculture. We focus on answering four research questions:

1. Have there been changes in the area of land used for agricultural production? Is land being used for production in different seasons than before?
2. Has crop production improved? Have production methods, including the choice of inputs, changed? Have there been changes to the types of crops produced?
3. What factors are contributing to or constraining changes in agriculture inputs and production? Why are households changing or not changing agriculture production decisions, and how do those reasons vary depending on crop type, growing season, or income level?
4. How have changes differed by gender and among different income levels?

Main findings

- In the hot season, the IWRM Project led to an increase in land under production of 0.56 hectares, on average, for the treatment group: an increase of 80 percent over the mean for the comparison group. Almost all of this land was irrigated and used to cultivate rice.
- Throughout the entire sample, we find that the area of land used for production increased, and these increases were significant for people of varying economic status and for both male-headed and female-headed households.
- Overall, farmers are spending more money on agriculture inputs for their larger tracts of land and receiving more revenue, but are maintaining a similar level of productivity.
- Most of the changes in agriculture production investment and revenue were driven by rice farming. During the main farming season, the project led to an 11 percent increase in the number of households that cultivated rice, the average area of land dedicated to rice production increased by 91 percent, from 0.64 to 1.22 hectares, and rice yields increased by 940 kg/ha.
- The project also affected the mix of crops that households cultivate, as they focused more on rice production at the expense of cultivating other crops. We do not find evidence of households expanding vegetable farming during the secondary farming seasons (cold and rainy seasons).
- Farmers' choice of crops is largely guided by the availability of water and agricultural inputs. Farmers reported that after the project private structures such as banks facilitated an increased availability of seed and fertilizer inputs. However, farmers also found inputs cost more given the increased land under production and because of the additional expenses for mechanized irrigation needed to move water in parts of the new infrastructure.

1. Impacts on agricultural land use

We begin by examining whether the increased availability of water for irrigation from the canals that led to a larger area of irrigated land (discussed above in Section VI.B) also resulted in increased area of land under production for the treatment group. Indeed, using quantitative survey data, we find that the IWRM Project led to an average per-household increase in area under production of 0.56 hectares (80 percent of the comparison mean) across the entire sample during the hot season, which is the main growing season (Table V.2).

In the rainy season, we also observed a significant increase in the average area of land under production—by 0.20 hectares—for households in the treatment sample (an increase of 95 percent of the comparison mean). There was no difference in the area of land under production between the treatment and comparison groups in the cold season.

Table V.2. Impact estimates for land under production, among all households (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimate	*p-value*	Sample (T)	Sample (C)
Cold season						
Land under production (ha)	0.97	0.82	0.16	0.06	1,129	1,128
Hot season						
Land under production (ha)	1.27	0.70	0.56**	0.00	1,109	1,105
Rainy season						
Land under production (ha)	0.41	0.21	0.20**	0.00	1,088	1,061

Source: IWRM Project baseline and follow-up household surveys

Note: Sample includes all households with non-missing data. We present the adjusted treatment mean, which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median.

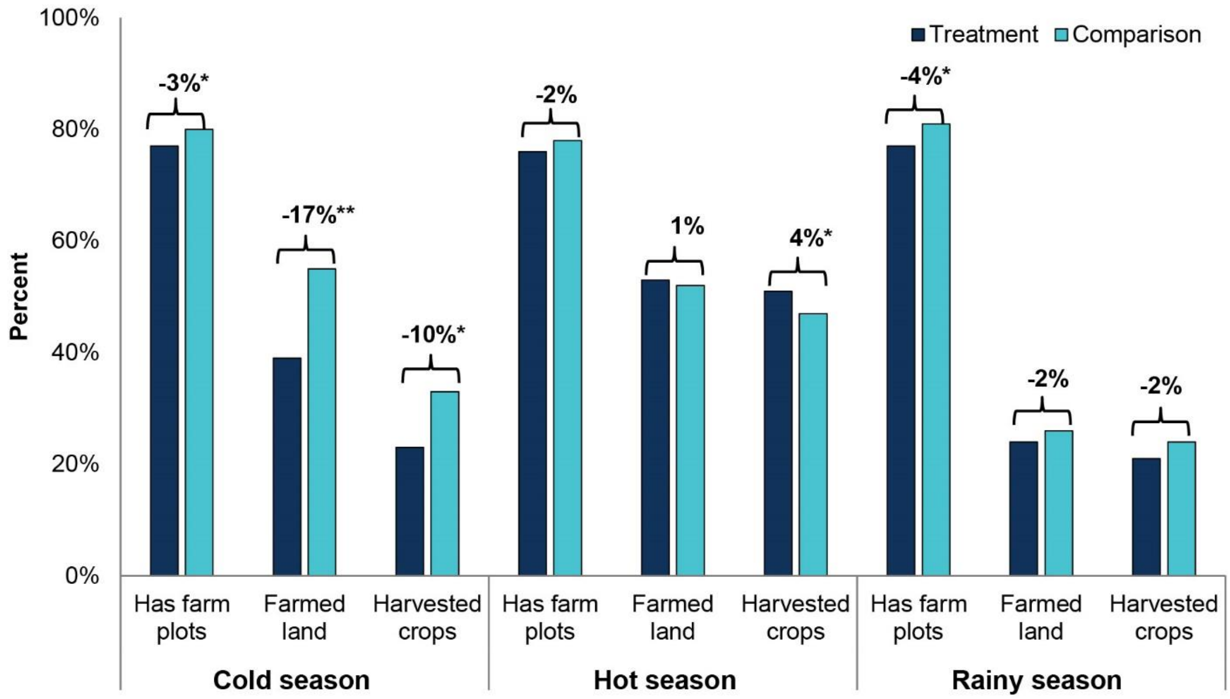
*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

To better understand the impacts we are finding for land under production, we examine changes in the share of households that have farm plots, farmed land, and harvested crops in each season. These are all binary measures. A household has farm plots if it reported that it possessed, borrowed, used, rented, or managed any farm land. This measure might be fairly stable over time for owning land, but renting and borrowing land can be fluid from season to season and year to year, as households decide whether it makes economic sense to farm a particular plot.

We find that in the hot season, when we saw a statistically significant increase in the area of land under production, there was no change in the share of households who farmed (Figure V.2). In other words, the increase in land under production was due to established farming households cultivating more surface area (either larger plots of land or more plots), as opposed to more households engaging in farming activities. We also find that the project led to an increase in the share of households that harvested crops. With the same share of households farming, this means that, as a result of the IWRM Project, fewer households had a failed harvest, perhaps due to better access to irrigation water.

Figure V.2. Share of households that reported land use, among all households (Delta)



Source: IWRM Project baseline and follow-up household surveys

Note: We present the comparison group mean and the adjusted treatment mean, which equals the comparison mean plus the impact estimate. Impact estimates are shown as the difference between the two means and are in percentage points. All measures are estimated on the full matched-comparison group sample. A household has farm plots if it reported that it possessed, borrowed, used, rented, or managed any farm land. A household farmed land if it reported that it cultivated any crops on farm land. Sample sizes are 1,136 for both the treatment and comparison groups in the cold season, 1,122 for the treatment group and 1,108 for the comparison group in the hot season, and 1,097 for the treatment group and 1,067 for the comparison group in the rainy season.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

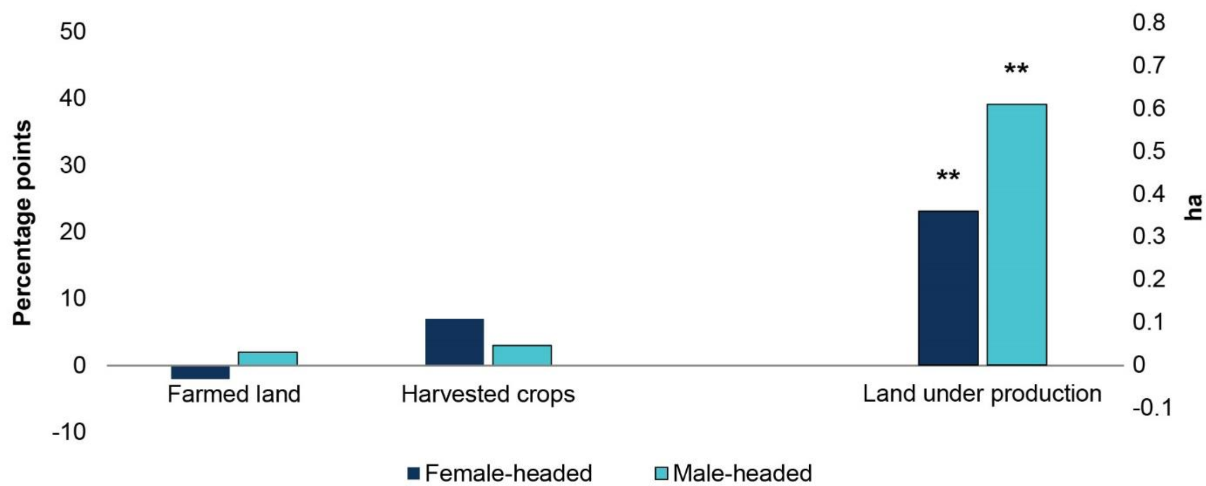
For the cold and rainy seasons, one aim of the IWRM Project was to create favorable farming conditions for households, when many households grow smaller plots of vegetable crops or additional crops of rice. One way to incentivize farmers to intensify farming is through the irrigation cost structure. The payment structure for access to irrigation has variations based on type of service and discounts to encourage farming in more than one season. A SAED representative described the scheme this way.

> For each type of user, there are conditions that are put in place. So, if you are a water user, you can use irrigation services or you can use drainage services. The amounts that you pay are not the same as for someone who uses only irrigation or the one who uses only drainage. But also there is… a policy of intensification of farming, so there are benefits for those who do dual cropping, that is to say, someone who plants two seasons in the year pays less than the person who plants one season.—S2

However, in the survey data, we find that the IWRM Project seemed to result in households maintaining the focus of their agricultural efforts on the main growing season. In the cold season, we find a decrease in the share of treatment households that farmed land (a decrease of 17 percentage points, or 31 percent, Figure V.2). Because there was no net change in the area of land under production, this suggests that treatment households that did farm in this season increased the area under production (an average increase of 0.93 hectares, not shown). In the rainy season, there is little change in the share of households farming, so again the increase in the area of land cultivated is driven by existing farmers cultivating a larger area of land. The project did not draw more households into farming in this season, either. Therefore, the project did not increase cropping intensity. This finding is backed up by evidence from SAED, which reported that in the Delta, cropping intensity was only 49 percent in 2016 and 75 percent in 2017, far below the project's 150 percent target (USAC 2018a).

We also examine agriculture production impacts by the gender of the household head and the poverty level of the household, focusing on the main growing season (hot season), where we find the largest overall impacts of the IWRM Project. In general, both male- and female-headed households benefited from the IWRM Project (only about one-fifth of households were female-headed). We find no differences in the impacts on rates of farming or harvesting crops for male-headed or female-headed households (Figure V.3); both were small and not statistically significant. Both types of households benefited from more land under production, though the average increase in land for male-headed households—0.61 hectares—was almost double the average increase for female-headed households. (The difference between those impact estimates is not statistically significant, likely due to the small sample of female-headed households).

Figure V.3. Agriculture production impacts by gender of household head, among all households (hot season, Delta)



Source: IWRM Project baseline and follow-up household surveys

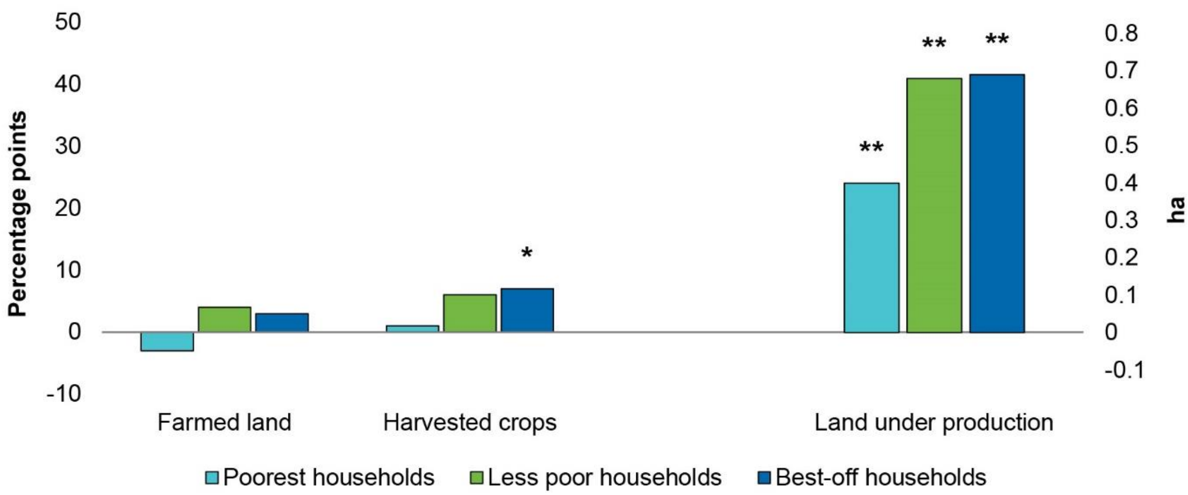
Note: Agriculture production impact estimates are presented by subgroup for the gender of the household head for the main growing season (hot season). Impact estimate units are in percentage points unless otherwise noted. A household farmed land if it reported that it cultivated any crops. Sample sizes for female-headed households vary between 209 and 216; sample sizes for male-headed households vary between 889 and 911.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

To divide our sample into poverty subgroups, as described in Section IV.C, we used the Poverty Probability Index to estimate the likelihood that a household is living on less than $2.50 a day (Schreiner 2016). It is important to note that even the best-off households in our sample are still relatively poor and disadvantaged.[17] We find some evidence that benefits of the IWRM Project accrued more often to the better-off households. All three groups of households benefited from increased land under production as a result of the IWRM Project, though the magnitude of the impact estimate is largest for the best-off households and less-poor households and smallest for the poorest households (Figure V.4).[18] Better-off households may be seeing larger impacts because they have more resources to take advantage of the new irrigation infrastructure, including the ability to buy or rent more or larger plots or to have previously owned land that is newly productive. The best-off households were alone in experiencing significant impacts in harvesting any crops. These households might have more money to invest in agriculture production, reducing risks to crop failure. We find no differences among all three poverty groups in the share of households that farmed land. Complete subgroup results by gender of household head and poverty group are included in Appendix B.

Figure V.4. Agriculture production impacts by poverty level (hot season, Delta)



Source: IWRM Project baseline and follow-up household surveys

Note: Agriculture production impact estimates are presented by subgroup for the poverty status of the household using the Poverty Probability Index for Senegal (Schreiner 2016). Impact estimates are presented for the hot season. Impact estimate units are in percentage points unless otherwise noted. A household farmed land if it reported that it cultivated any crops. The sample size for the poorest households varies from 434 to 438 for the treatment group and is 310 for the comparison group. For the less poor households the sample size is from 404 to 406 for the treatment group and 477 to 478 for the comparison group. For the best-off households the sample size is from 271 to 278 for the treatment group and 318 to 320 for the comparison group.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

[17] We also find that the share of female-headed households does not show a statistically significant difference between the three poverty groups among all households in our sample (chi-squared *p-value* < 0.01). In other words, female-headed households are not concentrated within any particular poverty group.

[18] The differences between impact estimates for the best-off and poorest household for land under production is not statistically significant.

2. Crop choices and production methods

We now turn to examining changes in crop production methods among farming households. Qualitative interviews highlighted a number of factors that led to improvements in agricultural production since the project started. The two main factors are (1) increased access to water due to irrigation infrastructure and (2) the availability of agricultural inputs facilitated by the project in partnership with private organizations, such as banks. We start with a closer look at the increased access to water through the use of irrigation.

In our qualitative research, we find that almost all of the community members we interviewed consider increased availability of water through the rehabilitation of the canals by MCA to be one of the main drivers of change in agriculture production in the Delta. Farmers noted that they have benefited from irrigation infrastructure, technical training, and increase in irrigated land, resulting in an improvement in agriculture. Appreciation was expressed by many. A female farmer in Diama summed up the common sentiment:

> [MCA] allowed the access to water on all fields through the canals. As a result, agriculture was accessible to everyone. It's thanks to MCA. The project was beneficial for all of us. …Today, we have a foreign investor (a white) for the cultivation of melon. … It is with the help of MCA that investors dare to come. All this is possible with access to water.—F3.

The increased availability of water due to the project has also allowed agricultural production to occur in new places in the treatment area. Interviews indicated efforts to farm have begun in some locations in the Delta where livestock, trade, and leather tanning (among women) were the main activities before the project.

Qualitative interview respondents from GIEs and GPFs, as well as other members of the communities affected by the MCA project, stressed that the availability of agricultural inputs such as seeds and fertilizers also played a role in the improvement in agricultural production. Access to inputs has been facilitated after the IWRM Project by private structures such as the *Caisse Nationale de Crédit Agricole du Sénégal* (CNCAS). CNCAS offers producers seeds and fertilizer in requested quantities on credit. The use of agricultural inputs is widespread among the farmers in the areas of the MCA interventions and used systematically and in large quantities by the GIEs and GPFs who cultivate large irrigated areas. According to the majority of participants interviewed in the Delta, however, use varies based on financial capacity. The Delta farmers interviewed who have used the inputs supplied through these sources reported that the quality of the inputs was good.

The project supplied some farmers directly with fertilizer, especially women's groups. The amounts supplied, however, were inconsistent. For example, a women's group in Diama that grows vegetable crops reported receiving enough fertilizer to use (sparingly) for more than a year, whereas another women's group in Ronkh reported not receiving enough, which negatively affected yields. However, all respondents agreed on the importance of this key input. The president of a Ronkh GIE emphasized the almost universal refrain:

> "Without fertilizer it is impossible or very difficult to have a good harvest because the lands are degraded and some lands are salinized and abandoned."—E3

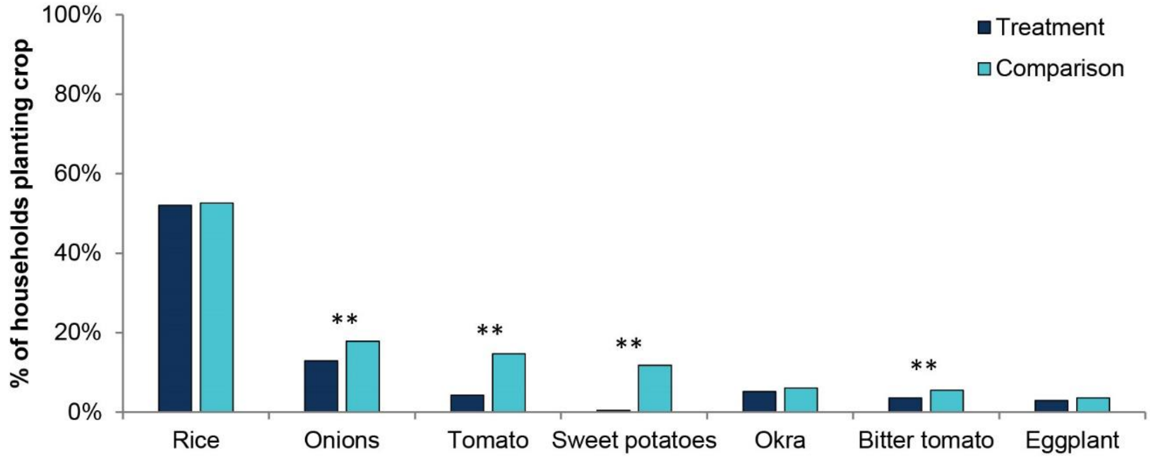
> Some of the farmers interviewed in the Delta who used the seed and fertilizer inputs supplied have seen increased yields. In one of many examples, a farmer and herder in Bissette 1 in Diama reported that due to the inputs, "There have been changes; because if you currently get 100 bags of rice in each field, you previously had 50; or 70 bags currently, when before you harvested 50 or 40 bags. There you see that there have been changes."—C1

The IWRM Project also anticipated it would change farmers' crop cultivation decisions by encouraging rice production, particularly during the hot season, and vegetable production, particularly during the cold and rainy seasons. The IWRM Project was not alone in focusing on increasing rice production; the GoS has also independently been pushing for an expansion of rice production as laid out in government policy documents (GoS 2014).

Using quantitative survey data, we examined crops that were cultivated by at least 5 percent of the sample during any of the three agriculture seasons at baseline.[19] Seven crops fit that criterion: Rice, onions, tomato, sweet potato, okra, bitter tomato (*jaxatu* or solanum aethiopicum*)*, and eggplant. Because the decision to cultivate one crop is related to the decision to cultivate another crop, we tested for changes between treatment and comparison groups over time by using a seemingly unrelated regression framework, as described in Section IV.C.1. We find that the crop mix changed significantly (joint test *p-value* < 0.01). Although the proportions of households cultivating rice were similar in the treatment and control groups, treatment households became less likely to cultivate other crops, particularly onions, tomatoes, sweet potatoes, and bitter tomatoes (Figure V.5). Although the IWRM Project succeeded with focusing households on cultivating rice, it was not successful with encouraging agricultural production of other key crops during the rainy and cold seasons. In fact, it had the opposite result, with treatment households focusing more on cultivating rice at the expense of other crops. Post compact monitoring reports confirm that tomato and onion production are below expectations in the Delta Activity area, with 5,641 tons of tomatoes produced and 17,372 kilograms of onions produced in 2017 (USAC 2018a). This stands in contrast to project assumptions. The project's logic model and ERR analysis assumed large increases in tomatoes and onion production in the rainy and cold seasons. Without this change, the project's actual economic rate of return will likely be lower than predicted.

[19] We also checked the sample at follow-up to ensure we were not missing any crops that at least 5 percent of the sample decided to cultivate at follow-up that were cultivated by less than 5 percent at baseline. No additional crops met this threshold.

Figure V.5. Proportion of households that cultivated each crop during the year



Note: Figure displays the percentage of households in the matched-comparison group sample that reported cultivating each crop during any season for the follow-up year of data collection. Comparison households are weighted according to the number of times they are matched to a treatment household. Crops listed are the seven most popular crops cultivated among the entire survey sample at baseline. Sample sizes are 1,136 for both the treatment group and the comparison group.

* Difference of means is significantly different from zero at the .05 level, two-tailed test.

** Difference of means is significantly different from zero at the .01 level, two-tailed test.

However, there are a number of factors that influence crop choice according to the farmers interviewed, including soil type, the availability of water, and the availability of agricultural inputs. In some communities, rice has become more predominant because of the availability of water, as the quantitative data showed. There is also an express effort to farm rice in more than one season to take advantage of the now-abundant water. A member of a water users' association in Amoura in Diama described the successful efforts to get farmers to grow rice in an area of the perimeter that will be irrigated in a particular season. He sums up the efforts:

> "Before they [MCA] came, we had a single [rice] season. But since the arrival of MCA, we are managing to do two seasons."—W3

In TabaTreich, a member of a GIE also noted the increased focus on rice production:

> "Now, we only grow rice."—E5

3. Rice production, revenue, and investment

Because one of the main aims of the Delta Activity was improving the production of rice, as suggested by the results presented above, we examined impacts on rice production specifically. In the **hot season**, the main growing season for rice, our survey data show that a larger proportion of households in the intervention area cultivated rice compared to households in the comparison area. During the hot season, 41 percent of households in the intervention area cultivated rice, compared to 37 percent in the comparison area (Table V.3). Correspondingly, households in the intervention area also used a significantly larger amount of land for cultivating rice (an average of 1.22 hectares versus 0.64 hectares in the comparison area). The difference of 0.58 hectare in land under rice production was about the same amount as the increase in overall land under production, as shown above (Table V.2). In other words, the increase in farm land under production observed in Table V.2 was used almost exclusively for rice production.

Table V.3. Impact estimates for rice production (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimates	*p-value*	Sample (T)	Sample (C)
Hot season						
Among all households						
Household cultivated rice	41%	37%	4%*	0.01	1136	1136
Area of rice cultivated (ha)	1.22	0.64	0.58**	0.00	1112	1105
Among farming households						
Rice investment costs per hectare (‘000 FCFA)	377	306	71**	0.01	603	579
Rice yield (kg/ha)	5,379	4,439	940**	0.00	604	579
Rice revenue (‘000 FCFA)	405	225	180**	0.01	607	577
Rice revenue per hectare (‘000 FCFA)	227	210	17	0.47	605	579
Rainy season						
Among all households						
Household cultivated rice	14%	18%	-4%**	0.00	1128	1133
Area of rice cultivated (ha)	0.38	0.18	0.20**	0.00	1090	1061
Among farming households						
Rice investment costs per hectare (‘000 FCFA)	181	219	-38*	0.02	281	273
Rice yield (kg/ha)	3,626	4,676	-1,050**	0.00	281	273
Rice revenue (‘000 FCFA)	496	344	152*	0.01	281	273
Rice revenue per hectare (‘000 FCFA)	255	518	-263**	0.00	281	273

Source: IWRM Project baseline and follow-up household surveys

Note: We present the adjusted treatment mean, which equals the comparison mean plus the impact estimate. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Sample sizes vary based on survey response and whether the measure contains all households or just farming households. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables. We do not report rice production outcomes for the cold season, as farmers typically do not plant rice in the cold season in the SRV. Our survey results found that some farmers reported cultivating rice in the cold season but call-back interviews revealed that this was mainly harvesting late rice that was planted during the rainy season, as detailed in section IV.C.1.c.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Although the hot season is the main rice growing season, farmers could also expand rice production during the **rainy season**, using different rice varieties and cultivation practices. Farmers interviewed in the qualitative research noted that some farmers cultivate rice once and others more than once per year using different varieties. However, in our quantitative data, we do not find evidence of an increased proportion of households farming rice during the rainy season.

A lower fraction of households in the intervention area (14 percent) cultivated rice compared to the fraction of households in the comparison area (18 percent). However, the amount of land devoted to cultivating rice increased by an average of 0.20 hectares. This increase is the same as the increase in the amount of land under production (0.20 hectares per treatment household) observed for the rainy season (Table V.3). This suggests that among households that chose to farm in the rainy season, the project resulted in households expanding land under production to farm rice, as opposed to farming vegetable crops. As described in section IV.C.1.c, we do not report on cold season rice production as the variety available is not suitable for cultivation at that time of year.

The IWRM Project was designed to improve land productivity through improvements in irrigation and, due to land tenure security, lead to increases in land investments. Rice production costs can include water fees, inputs (seeds, fertilizer, phytosanitary products), payments to agricultural workers, and/or payments for the equipment, diesel, and/or electricity for those who use pumps. The size of the investments made by farmers depends on several factors, including access to credit, the size of the area sown (for rice), and the quantity of inputs used. In the Delta, the costs of investments are high due to both the extent of the areas developed and the use of mechanization. Farmers we interviewed noted in particular the high cost of electricity for pumps and fertilizer.

We find that the IWRM Project resulted in farming households investing more in rice production per hectare during the hot season. We find a negative impact on rice investment per hectare among farming households in the rainy season (Table V.3). Farming households appear to be concentrating their resources during the main rice-growing season.

Given that treatment households increased the area of rice cultivated and their per-hectare rice investment costs (depending on the season), we would expect to find changes in the amount of rice harvested per hectare. In fact, in the hot season where we find strong evidence that area of rice under production and rice investment costs per hectare increased, we find that the project led to an increase in rice yield of 940 kg/ha on average (Table V.3). Nonetheless, the average rice yield in the treatment group, 5,379, was below the assumed average rice yield in the project's ERR of 6,800 kg/ha. It is unclear what assumptions went into the predicted rice yield. During the rainy season, where we saw a significant decline in rice investment costs per hectare, we find a significant decrease in rice yield. The average treatment yield is again below the predicted yield from the ERR.

As stated in the description of water usage, our qualitative data show that in the Delta, the location of a farmer's field relative to the river and the network of irrigation infrastructure and extension canals can impact cost to access water and availability of water, both of which can affect yield. Nonetheless, most farmers interviewed reported that, since the MCA project, rice yields have been satisfactory to good. For example, this farmer and herder from the community of Bissette 1 said: "After the harvest, you will have something to store … in order to meet the needs of your family; whereas before, you could sell everything and have nothing to keep for your own needs."—C1

Elsewhere, yields were better. The president of a water union in Polo 3 noted how much better the rice harvests have been there, saying: "Over the past three years, harvests have increased, and farmers will go up to harvesting 9 tons, 10 tons, because the water is sufficiently available. Our only success, it is to have good harvests."—W1

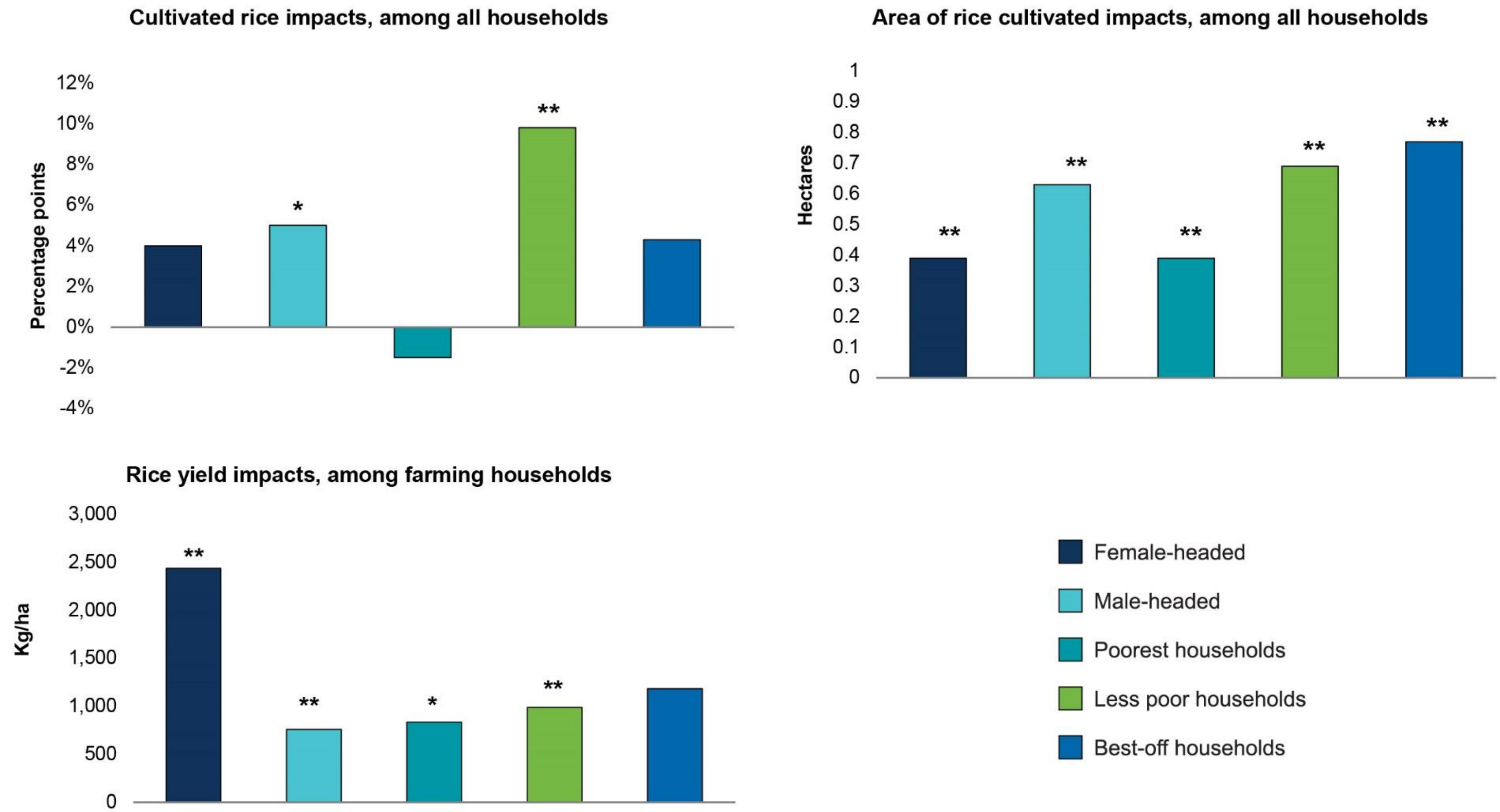
As treatment farming households cultivated more rice in the hot and rainy seasons, we find, as expected, that the IWRM Project led to a significant increase in total rice revenue in each season among farming households. For instance, in the hot season, we find that the IWRM Project led to an average increase in revenue per farming household of 180,000 FCFA, or $321[20] (Table V.3). Farmers are selling and trading similar proportions of their rice harvest. In the treatment group, hot season farmers sold 27 percent of their rice harvest and traded 27 percent of their rice harvest. In the rainy season, where we find lower rice yields, farming households in the treatment group decreased their rice revenue per hectare. Market prices also affect the amount of rice revenue a household receives from its harvest. In Senegal, a commission composed of representatives from producers, distributors, farmers' bank, SAED, and other stakeholders sets a target wholesale price for rice. That price varies in practice based on local market conditions, rice quality, quantity being bought/sold, and other factors. Given this, we do not have evidence that the increase in rice production in the hot season as a result of the IWRM Project significantly affected wholesale rice prices, which aligns with the ERR that assumed a constant price for rice during and after the project period. Beyond selling rice, households also consume the rice they cultivate. In the hot season, treatment farmers reported consuming 22 percent of their rice harvest, while control farmers reported consuming 25 percent of their rice harvest.

As we did with our analysis of general agriculture production, we conducted subgroup analyses on rice production by gender of household head and poverty level. We focus on rice production during the hot season, the main growing season (Figure V.6). We find that across all subgroups, the area of rice production increased, though the magnitude of change for male-headed households and better-off households was larger relative to female-headed households and the poorest households (the differences in impact estimates between the groups is not statistically significant). Among poverty groups, the middle poverty group (less poor) saw the greatest increase in the share of households that cultivated rice. Finally, we look at rice yield per hectare, where we find that yield gains benefited all groups. The small number of female-headed households in our sample appeared to benefit the most, increasing their rice yield by a statistically significant 2,436 kg/ha on average.[21] The large impacts for women could reflect that female-headed households tended to harvest vegetable crops before the intervention, and while they may have cultivated rice, they had little success in harvesting rice due to lack of water access on their plots. The IWRM Project allowed them to successfully harvest rice for the first time, whereas male-headed households had been successfully harvesting rice before so saw more limited (but still significant) yield gains. Impact estimates by poverty group were similar in magnitude, demonstrating broad-based increases in rice yield across the treatment group. Complete subgroup results by gender of household head and poverty group are included as Appendix B.

[20] Impact estimates on revenue and costs are calculated using West African francs (FCFA), the currency of Senegal. For ease of interpretation, we provide a converted value to U.S. dollars using the current exchange rate of around 560 FCFA to 1 USD (source: https://www.oanda.com/currency/converter/, July 22, 2018).

[21] There were 59 female-headed households in the treatment group that cultivated rice. There were 542 male-headed households that cultivated rice in the treatment group.

Figure V.6. Rice production impacts by subgroup (hot season, Delta)



Source: IWRM Project baseline and follow-up household surveys

Note: Rice production impact estimates are presented by subgroup for the gender of the household head and for the poverty level of the household for the main growing season (hot season). Poverty status of the household is calculated using the Poverty Probability Index for Senegal (Schreiner 2016). Impact estimates include all households in the sample except for rice yield, which contains only farming households. Sample sizes vary by treatment and comparison group for each subgroup. Sample sizes for rice yield are smaller since the measure is calculated among farming households only. Appendix B provides complete results with sample sizes.

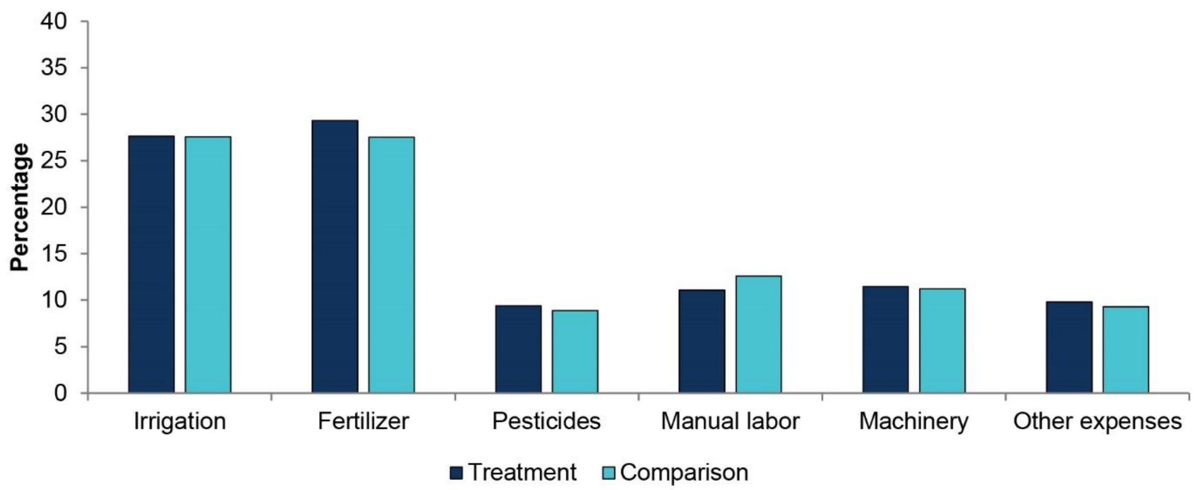
*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

4. Total agricultural production, including other crops

Beyond rice production, farming households are making decisions about how to use economic resources to farm all of their crops in each agricultural season. To evaluate this, we examine how the project affected agriculture costs among farming households. We define agriculture costs as the total amount of reported expenditures on fertilizer, pesticides, machinery, labor, and other farming expenses, such as transportation, management fees, storage and warehouses, and financial fees. Figure V.7 shows the average share of agriculture costs that a farming household is spending on each component cost for the treatment and comparison group at follow-up. Fertilizer and irrigation take up by far the largest share of investment costs for both the treatment and comparison group, nearing 57 percent of overall investment costs for the treatment group. Since the decision to allocate a larger share of resources to one input affects resources provided to other inputs, we estimate whether there are significant differences in resource allocation across all inputs using a seemingly unrelated regressions framework. We find no significant difference between the treatment and comparison groups during the hot season.[22]

Figure V.7. Composition of agriculture investment costs, among farming households (hot season, Delta)



Source: IWRM Project follow-up household survey

Note: Figure displays the share of total agriculture investment costs that farming households spent on each cost component among the matched-comparison group sample during the hot season for the follow-up year of data collection. Comparison households are weighted according to the number of times they are matched to a treatment household. The sample contains 607 treatment households and 577 comparison households. A comparison to baseline values is not possible due to differences in survey questions. Using a seemingly unrelated regressions framework, there is no significant difference in resource allocation across all inputs between the treatment and comparison groups.

[22] We examined results for the cold and rainy seasons as well. In general, the findings are similar with fertilizer and irrigation continuing to take up the largest share of investment costs on average. Small differences in resource allocation between the treatment and comparison groups did result in significant differences overall for those seasons (*p-value*<0.01).

When examining overall agriculture costs, we find that as a result of the IWRM Project, costs increased in all three growing seasons, by a total of 262,000 FCFA for the year as a whole (or $468, Table V.4).[23] As the project led to an increase of land under production, we would expect—and do find—that households are spending more to farm a larger amount of land. However, when looking at agriculture expenditures on a per-hectare basis, we find more expenses per hectare during the cold season, no change in the hot season, and fewer expenditures per hectare in the rainy season. Given the more intense focus on rice production, this could reflect an increased emphasis on preparing for production in the main hot season and less emphasis on rainy and cold season production.

We next look at changes in total farm revenues for all crops sold and traded, and find farm revenues have increased in general for treatment households who farmed. Overall, we find that total farm revenue increased on average by 558,000 FCFA (or $996) per year due to the project. Total revenue increases were significant during the hot season and the main growing season, as well as during the rainy season, among the smaller number of households that farmed then. However, when examining revenue changes on a per-hectare basis, results show no change in revenue per hectare for any season. (We calculate and discuss agriculture profit—the difference between total agriculture revenue and investment costs—in the next section).

Table V.4. Impact estimates for agriculture investment and revenue, among farming households (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimate	*p-value*	Sample (T)	Sample (C)
Cold season						
Agriculture investment costs (‘000 FCFA)	552	409	143**	0.00	426	616
Agriculture investment costs per hectare (‘000 FCFA)	1,091	408	683*	0.03	435	600
Revenue all crops (‘000 FCFA)	775	559	216*	0.02	231	344
Revenue per hectare all crops (‘000 FCFA)	625	722	-98	0.18	230	324
Hot season						
Agriculture investment costs (‘000 FCFA)	552	384	168**	0.00	589	574
Agriculture investment costs per hectare (‘000 FCFA)	335	383	-48	0.10	597	562
Revenue all crops (‘000 FCFA)	952	551	401**	0.00	515	485
Revenue per hectare all crops (‘000 FCFA)	654	725	-71	0.54	524	477
Rainy season						
Agriculture investment costs (‘000 FCFA)	388	217	171**	0.00	279	273
Agriculture investment costs per hectare (‘000 FCFA)	211	249	-38*	0.03	276	261

[23] Impact estimates on revenue and costs are calculated using West African francs (FCFA), the currency of Senegal. For ease of interpretation, we provide a converted value to U.S. dollars using the current exchange rate of around 560 FCFA to 1 USD (source: https://www.oanda.com/currency/converter/, July 22, 2018).

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimate	*p-value*	Sample (T)	Sample (C)
Revenue all crops (‘000 FCFA)	964	468	496**	0.00	215	235
Revenue per hectare all crops (‘000 FCFA)	572	457	115	0.20	214	224
Seasons combined						
Agriculture investment costs (‘000 FCFA)	923	661	262**	0.00	741	804
Revenue all crops (‘000 FCFA)	1,390	833	558**	0.00	623	684

Source: IWRM Project baseline and follow-up household surveys

Note: We present the adjusted treatment mean, which equals the comparison mean plus the impact estimate. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. The sample contains all households who farmed in each season. For measures with the seasons combined, households are included if they farmed in any season. Sample sizes vary based on survey response. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Overall, our findings suggest that the IWRM Project led to an increase in land under production, which was mostly used to farm rice in the hot season. Farmers are spending more money on agriculture inputs for their larger tracts of land and receiving more revenue, but are maintaining a similar level of per-hectare agriculture investment and revenue during the main growing season.

D. Agricultural profits and household income

In this section, we look at whether and how the impacts on annual farm revenue and investment costs described above were reflected in changes in agricultural profits and household income. We examine the following research questions:

1. Have agricultural profits changed?
2. Have household income levels changed, including changes in components of household income, and has income shifted between agricultural and nonagricultural sources?
3. Do farmers perceive an improvement in their living standards?

Main findings

- Agriculture profit increased for all three farming seasons combined, with the largest increase during the main growing season. The increase in agriculture profit appears mainly driven by an increase in land under production. We find mixed results by season for changes in agriculture profit per hectare.
- Among farming households, we find a trade-off between off-farm earnings and agricultural profit. The IWRM Project resulted in a shift in labor allocation with more farming in the hot season and more off-farm revenue activities in the cold season. For all three farming seasons combined, we find a reduction in off-farm household earnings.
- We find no aggregate change in household consumption among all households in our sample and among farming households only as an increase in agricultural profits and a commensurate decrease in off-farm household earnings led to no net change in household welfare.

1. Changes in agricultural profits

We begin our analysis by examining changes in agriculture profit.[24] Using survey data, we find that overall among farming households, the IWRM Project led to an annual increase in agricultural profit with an average increase of 193,000 FCFA (about $344) across all three farming seasons combined (Table V.5). While we find no significant change in agricultural profit in the cold season, we find a significant increase in agricultural profit in the hot season, the time when most households decided to farm. In that season, profit increased by an average of 200,000 FCFA (roughly $357) per household.

Table V.5. Impact estimates for income and agricultural profits (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimates	*p-value*	Sample (T)	Sample (C)
Cold season						
Among all households						
Off-farm household earnings ('000 FCFA)	249	353	-103**	0.00	1128	1124
Among farming households						
Agricultural profit ('000 FCFA)	73	112	-39	0.36	443	626
Agricultural profit per hectare ('000 FCFA)	135	400	-265*	0.02	386	486
Off-farm household earnings ('000 FCFA)	261	153	108**	0.00	207	324
Hot season						
Among all households						
Off-farm household earnings ('000 FCFA)	215	414	-199**	0.00	1118	1093
Among farming households						
Agricultural profit ('000 FCFA)	313	113	200**	0.00	593	577
Agricultural profit per hectare ('000 FCFA)	252	354	-102	0.25	500	473
Off-farm household earnings ('000 FCFA)	235	374	-139**	0.00	452	432
Rainy season						
Among all households						
Off-farm household earnings ('000 FCFA)	218	299	-81**	0.00	1092	1048
Among farming households						
Agricultural profit ('000 FCFA)	314	202	113*	0.03	278	273
Agricultural profit per hectare ('000 FCFA)	156	52	104**	0.00	186	174
Off-farm household earnings ('000 FCFA)	348	466	-118	0.13	176	164

[24] We calculate agriculture profit for each household in our sample as the difference between total household agriculture revenue and total household agriculture investment costs. Revenue includes reported sales from harvesting crops (including trading crops). Investment includes reported costs for fertilizer, pesticides, machinery, labor, and other farming expenses, such as transportation, management fees, storage and warehouses, and financial fees.

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimates	*p-value*	Sample (T)	Sample (C)
Seasons combined						
Among all households						
Off-farm household earnings (‘000 FCFA)	680	1,023	-344**	0.00	1136	1136
Household consumption (‘000 FCFA)	2,975	2,984	-9	0.84	1056	1004
Among farming households						
Agricultural profit (‘000 FCFA)	430	237	193**	0.00	754	805
Off-farm household earnings (‘000 FCFA)	729	945	-216**	0.00	754	805
Household consumption (‘000 FCFA)	3,168	3,143	25	0.44	709	733

Source: IWRM Project baseline and follow-up household surveys

Note: We present the adjusted treatment mean, which equals the comparison mean plus the impact estimate. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The exchange rate at the time this report is being written is around 560 FCFA to 1 USD. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Sample sizes vary based on survey response. Agricultural profit measures include farming households that reported both revenue and investment data. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

To better understand the changes in seasonal agriculture profits, we examined total agriculture revenue from harvests and total agriculture investment for each season among households that farmed (Table V.5). As described earlier, we find significant increases in agriculture investment costs and agriculture revenue for each season Farming households, on average, are both investing more and receiving more revenue from selling and trading their crops relative to the comparison group. This seems to be largely driven by the increase in land under production for the treatment group. Profit results are more mixed when examining on a per hectare basis. We find that the project led to a decline in agriculture profit per hectare in the cold season, no change in the hot season, and an increase in profit per hectare in the rainy season when a smaller share of households farmed.

While most farmers we interviewed qualitatively in the Delta Activity area reported a relative improvement in income from agriculture, some farmers reported that their revenues had decreased. Farmers who noted an improvement in their economic situation identified an increase in their harvests due to increased water availability and an increase in or new uptake of market gardening along with their rice production. Other farmers—both men and women—who have not experienced improvements in their income believe that the difficulties lie mainly in the small size of their parcels (or of the plantable parts of their parcels), which, according to the farmers, is due to unequal distribution of land, problems accessing irrigation, and problems with the soil, such as erosion, salinity, and unsuitability for rice. Several farmers reported being cautious about expanding the number of seasons in which they cultivate or increasing the size of their agricultural loans (for inputs) in order to reduce risk.

2. Changes in household income

Farming is just one component of a household's income. We also estimated how the IWRM Project affected off-farm household earnings, because households can reallocate labor toward agricultural production or off-farm labor, depending on opportunities and risks presented by the irrigation and land tenure security interventions of the IWRM Project. We calculate household off-farm earnings based on reported labor income; that is, household members who reported being paid for work outside of farming their own land. This includes salaried positions, non-agriculture labor (like tailoring or catering), and agriculture labor on a farm outside of the household (like a day-laborer), as well as revenue from a business such as a small grocery or print shop.[25] We focus our analysis on the components of household income – namely agricultural profit and off-farm earnings to understand how the project affected income across all three seasons. To examine overall well-being, we measure how the IWRM Project affected household consumption.

In all three seasons, we find that household earnings decreased for the treatment group as a result of the IWRM Project (Table V.5). Across all three seasons among all households in our sample, we find that off-farm household earnings decreased by 344,000 FCFA per household on average (about $613). When examining this measure among the households that report agricultural profits, we still find a significant negative impact, but the magnitude is almost three times smaller. To understand how households are making trade-offs between on-farm and off-farm income opportunities, we examined how off-farm income changed in each season among households that reported agricultural profits. In the cold season, we find that off-farm revenue increased significantly at the same time that there was no change agricultural profits. In the hot season, we find that off-farm revenue decreased significantly as agricultural profits rose. Although our rainy season results for off-farm earnings among farming households are not significant, the magnitude of the impact also suggests a trade-off between working on the farm and working off the farm. The IWRM Project seems to have caused a shift in labor allocation to focus more on farming household plots in the main growing season, resulting in higher agriculture profits and less revenue from off-farm income sources, while shifting away from farming in the cold season and toward more off-farm revenue sources.

To examine if the project had an overall welfare effect, we estimate impacts on household consumption. We find no change in household consumption looking at both our overall sample and only among the households that reported agricultural profits. This aligns with our findings that there was an increase in agricultural profits along with a commensurate decrease in off-farm household earnings, leading to no net change in household welfare.

Our qualitative research also explores diversification in sources of income and improvements in quality of life. In the Delta project area, women reported gaining new access to land through GPFs created through the project (see Section V.F). Although their land parcels were small, often 0.50 hectares or less, women we interviewed argued that this is a positive change, as it has enabled some to have income-generating activities. Before the project, they had virtually no access to agriculture. But due to the project, respondents noted an improvement in

[25] We do not include reported costs from operating a business in our measure of household earnings.

their quality of life, as more are now able to cultivate, harvest, commodify, and even sell products in the market and meet the needs of their families.

E. Land administration and governance

In this section, we describe institution-level outcomes of the LTSA for the Delta region. We address the following research questions:

1. Have local government agencies become more effective at land management, including land allocation, land formalization, and conflict resolution?
2. Do institutions receive adequate support to carry out their functions?
3. Is there greater confidence in the efficacy of these institutions?
4. What impacts did the project have outside of project areas?

To answer these questions, we conducted an in-depth case study in Gandon and Ronkh, two of the four Delta communes that received the LTSA. We spoke with officials involved in land administration, land tenure committee members, and land management technicians, as well as members of GIE and GPF in these two communes and managers of other land-related projects in the area. To broaden the analysis and learn more about the beneficiary perspective on the effectiveness of local institutions in land management, we later interviewed farmers in the treatment areas of the Delta Activity.

Summary of findings

- Policies for land use and the principles for land allocation are understood by officials in the communes we examined, and they were implemented during the LTSA project with the result of a large increase in land formalization during the project.
- Since the end of the compact these improved land allocation practices have not been used as they were expected to be.
- Land management practices differed considerably by commune.

1. Effectiveness of local government land management and conflict resolution

The LTSA was designed to help solve the problem of unrealized land productivity in Senegal. The problem existed in part because of insecure land tenure and the minimal capacity of communal agencies to manage and regulate landholding. As described in Chapter II, in the Delta area, the LTSA offered to the selected communes a package of interventions that would allow the pertinent agencies and officers to effectively carry out the landholding management and land allocation responsibilities assigned to them. Based on Senegal's laws and decrees, the Rural Councils, Domain Commissions (DCs), and their technical staff had the authority and legal instruments to perform the following tasks:

- Plan and arrange rural land territories, survey and record landholdings, and create irrigated subdivisions (*perimétres)*
- Grant to individuals, households, and producer enterprises or associations the rights of occupancy and use of the subdivided, irrigated parcels in the perimeters, in the form of

*certificats d'affectation (*or *titres d'affectation),* subject to terms and conditions that insure proper management and sustained use of the land

- Survey and record, give grants of rights in other lands located outside of the perimeters, and issue documents of verification to the landholders
- Record and keep copies of the records (inventory lists, *certificats,* and other documents of proof and verification) so that accurate proof of each landholder's rights can be produced for future transactions and dispute resolution
- Enforce the conditions of good management and sustained use, withdraw the rights of use and occupancy for mismanagement or abandonment of the land, and withdraw and reallocate land to accomplish the transfer of a parcel or a general rearrangement of the subdivision

The LTSA was expected to help the communes improve their performance of these tasks by providing them with five improved tools of land policy, management, and procedures, which are listed here and described in more detail below:

1. Spatial and land use regulatory plan (POAS)
2. Procedures for the allocation of land rights and principles of landholder priority
3. Review and approval of citizen applications for land titles
4. Landholding data management—the SIF and registry office operations
5. Technical training and public outreach methods

For each activity, the project would provide technical assistance in defining and developing materials, provide experts as consultants and trainers, and cover costs for needed equipment, field operations, and testing of systems. It would then help to demonstrate the effectiveness of the new processes by using the new tools to receive, review, and approve numerous citizen applications for land titles.

In order to determine whether the tools introduced by the project have proven effective and been sustained, we selected for follow-up visits in December 2017 two communes in the Delta: Gandon and Ronkh.

a. Spatial planning and land use regulation–POAS

Principles for land use are widely understood by commune officials in the Delta zone: SAED and other projects dating from the mid-2000s had introduced a method of spatial arrangement regulatory land use planning, called the *Plan d'Occupation et d'Affectation des Sols* (POAS), to the communes we visited. Each plan contains maps of the whole commune and its division into zones best suited for different uses—such as rice and grain production, horticulture, herding, and village housing. The maps also show the roads and trails for movement of livestock and the water sources for human and livestock use. The text of the plans contains rules for seasonal grazing and movement of herds through cultivated areas. To improve POAS implementation, LTSA provided additional accurate zone maps and placed billboard signs, hedges, and fencing to mark livestock corridors and water points. LTSA trained each communal

Gandon, located in the southern part of the Delta Activity zone, covers 42,000 ha of land and has a population of approximately 38,600. Approximately 39,000 of Gandon's 42,000 ha are cultivable, but at the start of the IWRM Project, large tracts of land were dedicated to herding and less than 1,400 ha were under irrigated cultivation (CIRAD/FIT/SONED 2012). Ronkh, located in the northern part of the Delta Activity zone, covers 58,740 ha and has a population of approximately 30,000. About 43,200 ha of its area is cultivable, of which 31,680 ha were under cultivation (including but not limited to irrigated areas) (CIRAD/FIT/SONED 2014). The communes both received the full set of LTSA interventions, as described in Section II. Below, we report outcomes for each of the communes and describe commonalities and differences in intervention outcomes.

DC in the procedures for the allocation of land rights and the principles of landholder priority. LTSA also trained and covered the costs for the zone commissions (ZC), which are subordinate to the DCs, to regularly monitor land use and conflicts. In addition, the project supported a schedule of monthly field visits to villages within the zones, at which the ZC and DC members conducted public education, monitored local conditions of land use, and mediated disputes.

In December 2017, we found that the mayors, deputy mayors, and DC members still valued the tools, procedures, and training provided by the IWRM Project; they spoke highly of the quality of the POAS and the other materials furnished by the project. They have continued to use and refer to the plans, maps, and rules in the actions they are able to take when land management issues arise. However, because of severe limitations of finance and budgets, technical capacity, and mobility, they indicate that they have been unable to maintain the plans and their enforcement and mediation tasks as routine operations.

Regular meetings of the ZCs have not been taking place. Instead, in both communes, the DC and land registry officers receive information about land questions and problems sporadically, from resident complaints and when they have the opportunity to go out to the field on other municipal business. If a particular dispute or problem is disruptive or appears to be of harm to citizens then an ad hoc mission of mediation or other intervention is organized.

b. Principles and procedures for the allocation of land rights

In each of the participating communes, the LTSA worked with the Rural Council and undertook public education to adopt a statement of principles and procedures that would guide future allocations of land in response to citizen requests. In the past, citizens were not encouraged to assert their right to request land; generally, the small number of applications that the Rural Councils received were from established landholding families and farm operations. Most existing landholders relied on their customary rights without asking for formalization, and people who lacked land rights—women, descendants of herders, and other landless farmers—lacked understanding about their rights and encouragement to formalize them. The principles and procedures were intended to remedy these inequities by clarifying the groups of people in the local communities, evaluating their needs for land and existing landholdings, and reaching a consensus on statements of priorities or quotas in the land titling and land management processes.

In this activity, the Gandon Rural Council set a list of priorities for claimants to land rights, with first preference offered to local residents who had received grants of land rights in the past but were never installed on land, then to applicants seeking formalization of existing customary rights, then to landless persons. Small farm operators were to receive the lowest preference and a 10 percent quota of available lands was to be offered to women.

The preferences and female quota were similar in Ronkh, which also set a limit of 100 hectares as the largest grant to any large-scale farm operation and a 50-hectare limit for a regular local farm operation.

The processes of formalization followed by the LTSA in 2015, as included in LTSA reports, appear to be consistent with the principles for allocating land described above. In particular, an accounting of the percentage of applications received from women by the project field teams and SIF in May 2015 shows that in Gandon, 345 of 1,706 applicants then pending were from women (16.7 percent). In Ronkh, the figures were 47 applications from women out of 468 total (10 percent) (CIRAD/FIT/SONED 2015a).

Since the end of the compact in 2015, however, the communes have not continued to calculate and report on the categorical breakdown of the applications or the land grants approved; thus, there is no efficient way to determine whether the priorities are being honored. In Ronkh, in January 2014, the Rural Council signed a protocol with the national agencies and the bio-fuel company Senhuile allocating 20,000 hectares to the company. This was inconsistent with the 100-hectare limitation set in the principles policy. However, members of the Rural Council told the press at the time that they did not believe they had the power to act contrary to the national agencies and could not vote to reject the land grant (ActionAid 2014).

c. Changes in number of applications for land titles and land allocation

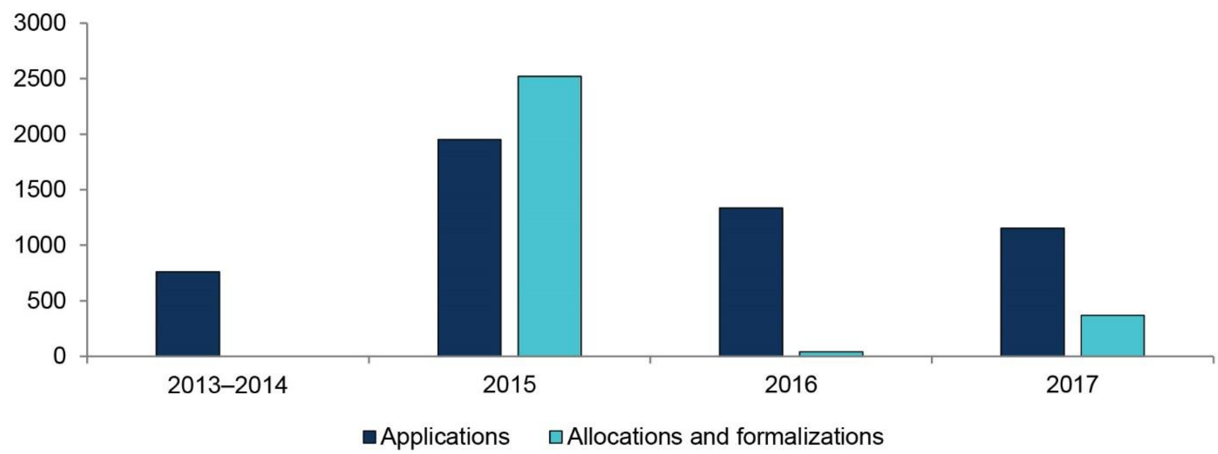
Requests for land rights fall into two broad categories: applications for the formalization of existing land holdings (*formalisation*) and applications for new land (*affectation)*. Before the project, most communes were receiving and processing small numbers of citizen applications for agricultural parcels each year; those numbers increased in certain years when national budget programs or international donor assistance was provided. The IWRM Project encouraged citizens to make applications and started receiving their forms in a few communes, including Gandon, in 2013. The project widened the program to include all nine of the project communes and sent teams to the field in the first half of 2015. Large numbers of applications were received and their documentation was processed and verified using the Land Information System (SIF), an electronic database of land transactions. During mid-2015, a substantial number of the applications were ready for Rural Council deliberations and received approvals, with subsequent affirmation by the subprefects. The citizens were then able to go to the pertinent registry office to receive the title document after paying a small fee.

After July 2015, when the IWRM Project ended, the field operations and SIF activities became difficult to sustain, as discussed below, and the processing of applications slowed or ended in the communes; however, citizens continued to bring applications to the registry offices. The backlogs of pending files that remained at the end of the project continued to mount during 2016 and 2017.

This pattern of activity can be seen in the numbers that were shown in the registry books during our visits to Gandon and Ronkh. In the period 2000–2012, Gandon processed an average of 29 allocations of new land per year, with a spike in allocations during a development project in 2008. The LTSA teams brought in 762 applications in 2013–2014 and 1,952 in 2015. Using the SIF, the project was able to process this large number of files and the Rural Council was willing to deliberate, acting in May/June 2015 to approve 716 land grants and in October 2015 to approve another 1,804.

Among these 2,520 new land titles issued in 2015, the distinction between new parcels (affectations) and formalized existing parcels was not clear, but a rough estimation made from the hardcopy registry books indicates that about 60 percent were residential plots (mostly formalizations) and 40 percent were agricultural parcels (including many new allocations). According to Gandon commune officials, the large drop-off in processing applications was caused by a lack of financial resources, including to cover the costs associated with deliberation meetings and transportation to land sites for verifications; post-project, the Rural Council decided to act only on agricultural parcels, with the small numbers of approved allocations and formalizations noted in Figure V.8. Since citizens continued to bring in applications for their house plots in large numbers, the backlog has become substantial. The Gandon officials anticipate that the PDIDAS project, funded by the World Bank and intended to carry forward the land tenure activities implemented by the LTSA, will help them to work through these pending application files.

Figure V.8. Land applications, allocations, and formalizations (Gandon, 2013–2017)

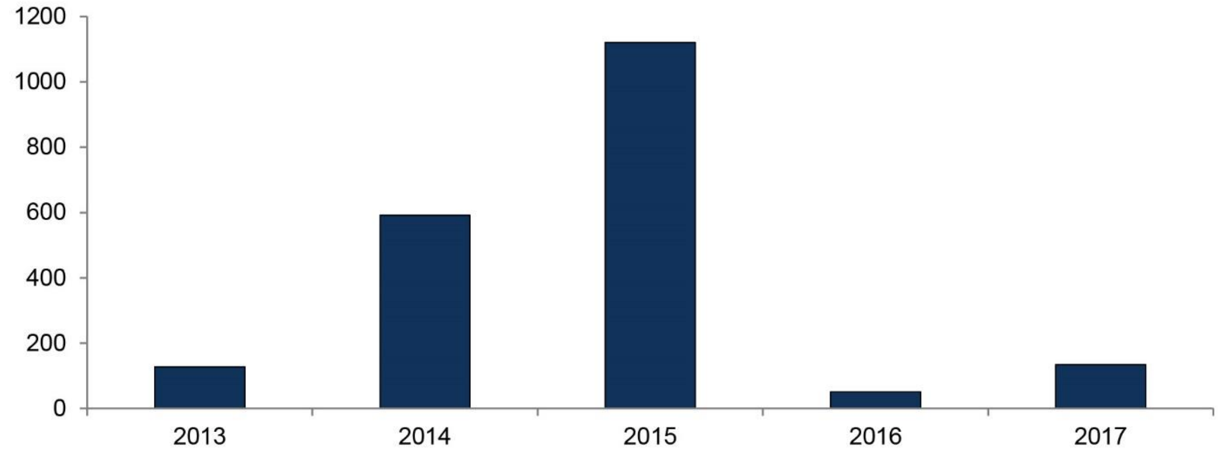


Source: Gandon Registry of Deliberations and Registry of Applications (reviewed December 5, 2017)

Note: From a review of the land registry, it was unclear if there were any land allocations or formalizations from 2013 to 2014

Ronkh also experienced an increase in demand for formalizations, from a handful per year prior to the 2013 LTSA inventory activity to the period when LTSA intervention began. The highest number of applications in Ronkh (1,102) was submitted during the LTSA consultant’s field operations in 2015. The Rural Council gave approval to 479 landholdings in July 2015. Of these, 34 were new allocations and 425 were formalizations of existing parcels.

Figure V.9. Land rights applications, Ronkh (2013–2017)



Source: Ronkh Registry of Deliberations and Registry of Applications (reviewed December 6, 2017)

Note: Ronkh granted 34 land allocations and 425 land formalizations in July 2015. Besides that, the only record of land allocations or formalizations between 2011 and 2017 involves two allocations in 2013 whereby the state, granted the company Senhuile up to 10,000 hectares, of which an initial 958 hectares was occupied in Ronkh (ActionAid 2014).

Figure V.9 shows a dramatic drop-off in applications after the compact closed; no applications for new land or for formalization were processed in Ronkh in 2016 or 2017. Additional applications received after closeout and in 2016 and 2017 have been waiting in stacks of paper files in the registry office.

According to the Ronkh communal officers, almost all of the affectations granted in 2015 and the subsequent applications were for lands of agricultural use. Ronkh citizens have not yet felt a need to regularize their rights to house plots. The same officers gave two reasons for the lack of recent Rural Council deliberations on new allocations and regularizations. First, they have not had resources to conduct the required field missions for either type of application and, second, there has been no reserve land under commune control for new affectations. Commune officials anticipate that PDIDAS will provide assistance in the near future to start up the review of this backlog of applications, although the limited human resource capacity might be a limiting factor.

Finally, the difference between Gandon's ability to continue some reviews and approvals and Ronkh's lack of continuation can be attributed to the fact that Gandon introduced a filing fee that must be paid by applicants at the time of application, to support the costs of processing applications. In Ronkh, no such fee exists.

d. Landholding data management (SIF) and registry office operations

During the compact, the LTSA project was able to process and move to completion the large numbers of land titling applications by using the modern methods of GPS parcel survey and mapping and document processing in the SIF. The project provided each commune registry office with the equipment and software to continue these operations, and offered training to technical staff or registry officers. After the project ended, however, the combination of limited budgets, inability to retain technically trained staff, and difficulties of equipment maintenance and reliable electric supply have hindered the continued use of the SIF.

We note apparent differences in capability between the communes. On our visit to Gandon, we observed a land bureau that appeared relatively well organized and had a knowledgeable staff. There was clear demand for land bureau services, with applicants waiting in line to submit requests for formalization or affectation and to check land bureau information against their own records. In Ronkh, the land bureau had lower capacity than Gandon in most aspects—physical premises and state of repair of equipment, human resources, and organization and storage of files. Although some residents have been submitting requests for formalization to the commune, it appears that many land decisions are settled informally by the powerful cooperative unions and growers (including agribusinesses), rather than the commune.

However, during our observations and conversations at the Gandon registry office, it was unclear whether Gandon has recorded any of the recently filed applications for grants of rights or transactions in the SIF. The office had a part-time technical assistant who was familiar with the software and the database installed originally by the LTSA. However, new data were not readily available as the computer was broken and it was clear that the Gandon land office registrar was relying on the paper dossiers on a day-to-day basis. These were kept in cardboard boxes marked as Application Dossiers, Granted Land Rights [Affectations], and Withdrawal/Re-affectations (for transfers of title). In Ronkh, the SIF equipment was not being used and paper files were placed in stacks around the office without an evident system of boxes or file drawers. On Ronkh's computers, the data entry interface does not link to the land data. Officials in both communes indicated that they had no earmarked funding for staffing and maintenance of the SIF. Commune officials also said that finding staff who can use the computer-based software has been a challenge, and that turnover is high.

It is worth noting that the SIF contains information only on agricultural land. In Gandon, this has limited the usefulness of the database system because the commune is adjacent to the city of St. Louis and much of its land transfer activity involves house plots and suburban projects. For compiling agricultural land titles and transactions, SAED planned to create the "*cossif*," a centralized database that will aggregate information from all communes. However, SAED reported post-compact that it does not communicate with the communes to obtain these data in a systematic way. Since most communes are using paper records and variable methods of recording and filing, SAED cannot rely on a standard method for compiling and communicating data.

2. Support for commune-level land institutions

In both Gandon and Ronkh, commune officials, members of the DC, and land bureau staff all indicated that the main barrier to implementing their responsibilities of land management and allocation, formalization, and POAS compliance is lack of sufficient municipal revenue. In particular, they cannot carry the costs of sending out teams and they lack vehicles. In both Gandon and Ronkh, revenue for land activities was supposed to come from the final fees that applicants were to pay when their new affectations or formalizations were granted and they came to the registry office to pick-up their certificates of title. However, in both communes, most landholders have decided that they do not need the title document for any immediate purpose, and have avoided coming in. Thus, in Ronkh, the commune received only a tiny fraction of the payments that should have added up to 25 million FCFA if all 459 landholders given grants in 2015 had claimed titles and paid the fees of 5,000 FCFA per hectare (interview, December 7, 2017).

Gandon has addressed the lack of revenue in part by requiring applicants to pay a small fee at the start, when they file their applications for new affectations or formalizations. This has generated some money for field operations in 2016 and 2017. However, the problem of costs can best be recognized in the context of the total communal finance: Ronkh's budget is about one-third the budget of Gandon for a larger land area and slightly smaller population.

3. Farmers' perceptions of land institutions' effectiveness

Farmers we interviewed in the communes where LTSA was implemented in the Delta, both independent and members of GIE or GPF, confirmed that commune officials and committees are involved in the administration and governance of land and that in the past few years these institutions have become more active. Individual farmers and GIE leaders indicated that the commune officials were, indeed, carrying out their land management duties. As the president of a GIE in Diama summed up: "If you need land, you make a request at the town hall with the location, they accept it, and it's good."—E2

In Gandon, farmers indicated that LTSA activities included educating farmers about the process, which helps them assess whether the land officials are doing their work properly. As a farmer in Gandon with large land holdings said: "MCA did a nice job of communicating the process to access land. We are all aware of the process…before, people didn't understand."—L1

Some farmers we interviewed considered land governance agencies effective, despite a few reports of delays in the processing of titres d'affectations. As one GPF president in Diama explained: "If you want land, you go to the commune. They give you a "deliberation." Once you've had that, the land is yours and you can rent it or cultivate it freely…We are happy with the way the commune manages land."—F3

However, farmers' perceptions of the efficiency of the land institutions vary depending on the commune. In general, in group and individual qualitative interviews, farmers in Gandon and Diama expressed satisfaction with commune officials' land management. Farmers in Ronkh found the process for formalizing land slow: "I know that it [formalizing land] is difficult because since I put in my application until now I have not had an answer. They [commune officials] just reassure me. They say that it is not easy to manage [the land formalization]."—L2

Another farmer complained: "The work of [the mayor] is not efficient at all. I don't know about other areas, but our mayor is not efficient [with land formalization]."—C2

Some stakeholders in focus groups and interviews also raised governance concerns such as corruption and patronage at the commune level, which has eroded community members' confidence in the effectiveness of local land agencies. Others noted what they consider to be lack of impartial treatment by local government agencies in adjudication of applications, noting private developers have obtained land while people who originate from the area await the processing of their files.

Although registry records in Gandon did not distinguish between new land allocations and land formalizations, land officials in Gandon and Ronkh indicated that increased demand during the project did not lead to substantial increases in new land allocation in either commune. In Gandon, constraints on the amount of unallocated agricultural land meant that requests for new affectations could not usually be granted in the regions that applicants requested. When offered land in other regions of the commune, applicants often declined the land because they felt it did not have good access to fresh water irrigation sources. In Ronkh, commune officials told us that no unallocated agricultural land was available and, therefore, no affectations were being granted. This is in part due to a scarcity of good land and also because in Ronkh the three large cooperative unions hold use titles to large amounts of the agricultural land, which they distribute through a more customary system known as the *Section Villageois* (SV). The SV system allocates land rights to cooperatives (or unions of cooperatives) that distribute land to villages within a commune and then to village members. The first problem that arises in this situation is how to determine who are cooperative members and verify the status of persons claiming rights in these lands. Second, many applicants received land grants in villages where they were not residents. Related to both problems, local residents in Ronkh said that there were many consolidated parcels that were not being occupied and used that ought to be broken up and redistributed to active producers.

Some farmers identified what they perceived as inequities in land allocation, particularly in Ronkh, where the large agribusiness Senhuile was granted rights to approximately 10,000 ha in 2013 (ActionAid 2014). Some stakeholders presume there is inequitable land allocation because 100–200 hectares might be given to some applicants whereas they themselves are assigned a maximum of 20 hectares:

> If the state or the mayor's office had been overseeing the commune, they'd have seen it is not normal, for example, to give one person 100 or 200 ha…He should get 50 ha or 20 ha and the rest should be shared. That way, if [the land] is shared, the people will have enough space to work. But that doesn't exist anymore. The land is all taken.—C1

As the above quote indicates, and additional interviews with farmers confirmed, little or no agricultural land or desirable land (that is, with access to water) is available for new allocation in some of the Delta communes. A female farmer in Ronkh, stated, "there are no more fields available in this zone. Men inherited from their parents and that which they have is not adequate for their wives and children."—E7

4. LTSA influence outside project areas

While our impact analysis does not permit a robust assessment of the LTSA project's impact outside of project areas, our qualitative research suggested that a number of principles and practices institutionalized by the IWRM Project may be taken up by communes outside of the nine communes included in LTSA, particularly in the departments of Podor and the department of Matam, to the east of Podor. More recent donor projects such as PDIDAS in the Delta Activity area (and AIDEP in Podor) are also planning or carrying out community stakeholder information and education sessions to obtain buy-in for land agreements and implementing a community-led process for land allocation and POAS usage, building on practices carried out by the LTSA. Further research is needed to understand whether and how the LTSA has influenced land management practices in nearby communes and elsewhere in Senegal.

F. Land security and land conflicts

In addition to supporting land administration and governance, the LTSA was designed to increase and improve land tenure security and thus increase investment in land, leading to increased crop yields and agriculture profits. In this section, we focus on how the IWRM Project affected land security and land conflicts. Our evaluation seeks to address the following research questions:

1. Has the extent of land formalization changed? Is there greater awareness of the process for formalizing land?
2. Have perceptions of land tenure security changed? Is there increased confidence in the land tenure system? If so, why?
3. Has demand changed for formalized land rights and are the costs of formalizing land rights perceived as reasonable?
4. Has the number or severity of land conflicts been reduced? Has the type or nature of land conflicts changed?
5. How has the IWRM Project affected women's access to land? How has it affected the landless?
6. How have changes in land security perceptions, formalization, conflict, or conflict management affected investments on land?
7. What have been the constraints or barriers to land access? Do these differ depending on gender, income levels, or age?

Main findings

- The IWRM Project had a positive impact on households' knowledge of the deliberation process for obtaining land rights and led to households obtaining use titles to their land.
- The project did not change households' concerns about losing their land, and had no effect on the number of land conflicts, which was already quite low.

1. Changes in the extent of land formalization

Our impact results support these qualitative findings. In the survey, we asked if the respondent knows the deliberation process to receive land title. On this self-reported measure, we find that treatment households were nearly three times as likely to report knowing the process to receive a title than comparison households (Table V.6). Treatment households also used this improved knowledge to apply for land. Specifically, using descriptive analysis, we see that one-third of households with farmland in the treatment group applied at the commune for a land title, compared to only 8 percent of households in the comparison group, a statistically significant difference.[26] Moreover, from matched-comparison group analysis, we find that the IWRM Project led to a large increase in titled land plots. Because of the IWRM Project, nearly one-third of treatment households' plots were titled, compared to only 13 percent of comparison households' plots (Table V.6).[27]

Our qualitative interviews with farmers illustrated their strong desire to formalize land when possible and their acknowledgement that the public process of identification and recording of land boundaries conducted as part of active formalizations has made them more knowledgeable about their land boundaries. GIEs, GPFs, and PDIDAS staff reported that residents with formalized land rights recognize they are in better bargaining positions should the commune or a private foreign investor try to take their land. In particular, they reported that landholders with formal rights are more likely to be paid—and to be paid higher sums—if outsiders (agribusiness or other farmers) attempt to obtain land in a commune. As a GPF member in Diama put it: "With the MCA (project), each household has its land and no one dares touch it."—L5

Table V.6. Impact estimates on land formalization, among households that have farm land (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimates	*p-value*	Sample (T)	Sample (C)
Household knows deliberation process to receive land title	56%	19%	37%**	0.00	690	755
Ratio of plots with any land title	32%	13%	18%**	0.00	848	821

Source: IWRM Project baseline and follow-up household surveys

Note: Sample sizes vary based on survey response. Sample contains households who reported having access to farm land. We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Farmers and GIE leaders described the costs of formalizing land title in Gandon; 10,000 FCFA/ha for residents and 50,000 FCFA/ha for nonresidents. For context, average annual agricultural investments in treatment households was 923,000 FCFA, and annual agricultural income was 981,000 FCFA. Ronkh did not establish such application fees. Farmers we spoke with did not find the costs unreasonable; however, land managers in both Gandon and Ronkh reported that only a minority of landholders who have been granted a *titre d'affectation* immediately pay the fee for documentation and pick up their hardcopy certificates. In our interviews, a number of individuals and GIE managers appear to be comfortable knowing their

[26] There is no baseline measure for applying for land at the commune level so we use a *t*-test to test for differences between the reported mean value for the treatment and comparison groups at follow-up.

[27] We find some evidence that the IWRM Project benefited titling for female-headed households in particular. Among those households in our sample, we find a 26 percentage point change in ratio of plots with any land title (*p-value* <0.01).

rights are registered with the commune and might pick up the title document and pay the fee only when the need arises.

2. Changes in perceptions of land tenure security

In interviews, many farmers described the value of obtaining certificates or papers as a means of protecting their land from others, meaning foreigners, outsiders, big agribusiness, people from Dakar, and the state. Our primary quantitative measure on land tenure security is a self-reported measure on whether the household is concerned about losing land. From our quantitative analysis, we find that the IWRM Project had no impact on this outcome among households who report having farm land (Table V.7).[28] Although this result might appear puzzling, we note that sentiment of tenure security is high; our qualitative interviews with farmers and GIE members reveal that farmers who successfully applied for formalization or who were in the process of applying tended to be those who were confident about their land claims and the security of their land. Further, we find a significant negative correlation of 0.13 among treatment households between ratio of plots with a title and being concerned about losing land (*p-value* 0.01). In other words, respondents that are more concerned about losing land are less likely to have titles to their plots.

Table V.7. Impact estimates on land security and land conflict, among households that have farm land (Delta)

Outcome measure	Treatment mean	Comparison mean	Impact estimates	*p*-value	Sample (T)	Sample (C)
Household is concerned about losing land	18%	21%	-3%	0.11	858	828
Household reported any land conflicts	5%	4%	1%	0.45	768	726

Source: IWRM Project baseline and follow-up household surveys

Note: Sample sizes vary based on survey response. Sample contains households who reported having access to farm land. We present the adjusted treatment mean, which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

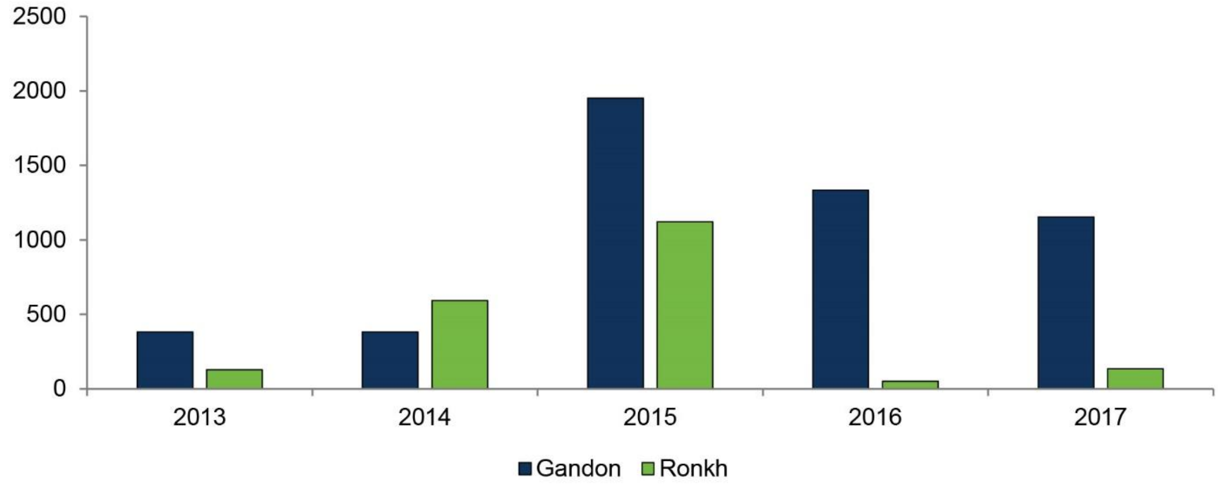
3. Demand for land formalization

Outreach and public education activities conducted under LTSA were successful in making residents aware of the benefits of having formal land rights, including land security and access to credit, and also improved public knowledge of the process for formalizing land. This led to an increased demand for formalization and allocation of land during the IWRM intervention, peaking in 2015, the final year of the compact. Significantly, citizens have continued to file applications in 2016 and 2017, even though they know that the IWRM Project ended and the Rural Councils are able to review and process only a very small number of files. This

[28] For the measure of whether a household is concerned about losing land, we also find no significant differences between households grouped by gender of the household head or poverty status of the household.

phenomenon can be illustrated by the number of applications reported by the land bureaus in Gandon and Ronkh from 2013–2017 (Figure V.10).

Figure V.10. Applications for formalization or allocation



Source: Land bureau records held at Ronkh and Gandon communes, viewed December 2017

[a] Values for Gandon in 2013 and 2014 are an average of the total applications in this two-year period.

During qualitative interviews, individual farmers, GIE members, and land managers in the Delta intervention zone confirmed that the project had led to great interest in and demand for formalization of land and for allocation of new land, both from individual farmers and from cooperatives and GPFs.

4. Changes in the number, severity, and type of land conflicts

Quantitatively, we find no change in the number of land conflicts using survey data from our matched-comparison group. Land conflicts were low at baseline and continue to be low at follow-up, with only 5 percent of the treatment group and 4 percent of the comparison group reporting any land conflict in the prior 12 months. We find no statistically significant difference between treatment and comparison groups.[29] We asked about seven types of land conflicts: heritage, investment, land boundary, land violation, government, regulation, and environmental. At follow-up, each type of land conflict was reported on by less than 2 percent of households with access to land, across the treatment and comparison groups.

Our qualitative interviews revealed that in the Delta area, farmers sometimes occupy areas that are not included in the POAS, which has resulted in some conflicts with SAED and between farmers and herders. But when asked about the number and severity of conflicts, individuals, GIE and GPF members and other stakeholders provided mixed answers, and none indicated a definitive increase in conflict. Members of a women's cooperative in Diama, when asked whether there had been changes in the number of land conflicts in the past three years, suggested

[29] We also find no significant differences when examining reported land conflicts by gender of the household head or poverty level of the household.

these have decreased because formal documentation serves to prevent disputes. The president said: “Arguments of land is over. It is obligatory to have documents now. On the documents you have the signature of the mayor, the counselors, the president, the vice president. This will serve me as proof in case of need.”—F3

According to land officials we interviewed, when conflicts arise, they are resolved quickly and are likely to be resolved at the village or commune level without escalating to the courts. A common theme in our qualitative interviews was the desire to avoid going to court to resolve a land dispute. Farmers and DC officials agreed that once a case gets to the level of the courts, resolution takes a long time and keeps land tied up and unproductive.

5. Women’s access to land

Women’s access to land varies among the communes in the Delta zone. To illustrate, we return to our in-depth study of Gandon and Ronkh. In Gandon, women attending our meeting with local GPFs reported that the outreach and education activities increased demand for land among women as well as men during the LTSA project period. Some women we interviewed reported being treated equally by the commune when they applied for formalized rights, and attributed this to the LTSA project requirements, although we do not have information on how women perceived their treatment when applying for land before LTSA.

In Gandon, the Domaine Communale (DC) indicated that the focus on land for women was present during the MCA project and that the DC provides information to residents about equality in land access. However, after the IWRM Project was completed, the number of women applying for land has been decreasing over time. Members of the DC were uncertain whether the reason was lack of information or some other social explanation. They estimated that women represent about 15–17 percent of land applications[30] and explained that officially there is no restriction for women to get land, but that formalization for agricultural use typically involves the male head of the household, who requests land for the family.

In Ronkh, women reportedly had less access to land than women in Gandon. As described in other sections above, commune officials in Ronkh explained that because Ronkh land is primarily suitable for growing rice, which women typically have not grown, there is little demand from women for land. This contrasts with responses from women we interviewed in Ronkh who indicated they would like to grow rice and noted that some land that was set aside for women was later claimed by the men of the village. The women were unable to meet with the visiting minister of agriculture to recover that land, and one GPF member in Ronkh told the interviewer: “Talking about land is dangerous, that’s why many people do not discuss it.”—F8

Commune officials in Ronkh also indicated that the reason that LTSA guidelines for land allocation, including the emphasis on women and the landless, are not being used is because they can only be applied when there is newly available land, of which they reported none at the time of interview (December 2017). But some women we interviewed indicated that they are not familiar with the process of land formalization or allocation, creating a barrier to accessing these

[30] We were not able to verify this estimate.

rights: “it is easier for a man than a woman to have land for herself”… “because men know better than women the procedures for requesting land.” —F9 & F10

6. How changes in land security have affected investments on land

A common theme in our qualitative interviews is the value of formalized land rights for accessing formal and informal credit. Land managers and commune officials reported that credit-related benefits were appealing to farmers for investment in their own fields and to attract partners for larger ventures. GIE members reported that landholders with formalized land rights had improved access to formal and informal credit for developing their land, since banks and other financial partners perceived less risk to their investments when partnering with landholders who held such rights. As one farmer in Ronkh said: “It’s necessary to have documents that are legal, of the sort that, if I show them to someone, he will at least be sure that this is a recognized inheritance/property and that it is recognized by the government. In addition, this document can serve as a guarantee for a loan.”—C2

Moreover, documents provide proof of ownership when farmers are interested in renting or even selling land to outside investors. In Diama, for example, a women’s GIE president described a foreign investor approaching the mayor looking for land with “Dior” soil, which is appropriate for farming market crops such as melons (a potential export crop). She described the value of having documentation:

> The commune … gives you a “deliberation” [*titre d’attestation*]. Once obtained, the land belongs to you, and you can rent it or cultivate freely. You can also look for partners if you don’t have a lot of means … [the mayor] put me in touch with the investor and it will be up to me to see if I rent or if I accept to sell. If we are in agreement on the price, I can sell it to him. At that time, I can [register the transaction].—F3

To investigate further how changes in land security may have affected investments on land and other agricultural production outcomes, we conduct a mediation analysis to decompose our impact estimates on agricultural outcomes from our survey data into a direct and an indirect effect. The IWRM Project has a direct effect on agricultural production through changes in irrigable land. The project also has an indirect effect as the project may affect changes in land tenure security, which in turn may affect agricultural investment and production outcomes.

For an indirect effect to exist, we first need to find a significant effect of the intervention on land tenure security. We find no significant impacts of the intervention on our measure of perceptions of land tenure security: household perceptions of being concerned about losing land (Table V.7). About 1 out of 5 households expressed concern about losing land, which was statistically indistinguishable from the comparison group. Therefore, changes in land tenure security perceptions did not affect agricultural investment or production. We also found no effect of the IWRM Project on reported land conflicts (Table V.7). Conflicts remained low as a result of the project—only 5 percent of the treatment group reported any land conflicts in the preceding year—and that number was statistically identical to the comparison group. Hence, changes in land conflict have also not affected agricultural investment or production.

We do, however, find that the project had a significant effect on measures of land formalization. We find significant increases in the share of households that now report knowing the deliberation process to receive a land title and in the average share of titled plots (Table V.6). We therefore examined whether that increase in land formalization due to the IWRM Project also affected outcomes for agricultural investment and production. To use the Ratio-of-mediator-probability weighting (RMPW) method (Hong, Deutsch, and Hill 2015), we use a binary mediator for land titles—whether the household has at least one plot titled—which is measures land formalization.[31] We tested the first-stage of this measure and found that treatment status significantly and positively predicted having at least one titled plot by 16 percentage points (p-value<0.00). We focus our analysis on agricultural production changes during the hot season, since we found the largest effects of the IWRM Project during the main growing season.

We decompose the effects of the project on the amount of land under production, whether a household cultivated any crops, and binary indicators for a positive increase from baseline in agriculture investment costs per hectare or revenue per hectare (Table V.8). We find that the indirect channel of the intervention that operated through increasing titled plots resulted in a significant increase in the amount of land under production. While overall, we find that the project increased land under production in the hot season by 0.56 hectares on average, 0.09 hectares, or 16 percent of the overall impact estimate, can be attributed to the positive effect on land formalization.[32] In other words, the increase in land titling caused by the intervention did positively affect a short term investment input (amount of land under production).

We next examined changes in overall investment inputs using a binary variable that equals 1 if there was positive change from baseline in reported agriculture investment costs per hectare and 0 otherwise. We find that the project made it more likely by 6 percentage points that households would decrease rather than increase their agricultural investment per hectare. When decomposing this affect, we find that changes in land formalization had no bearing on changes in agriculture investment. Farmers may have run up against credit limits in their ability to borrow money to farm land—particularly given the larger amount of land farmed on average at follow-up—irrespective of how secure they felt on that land. Our investment measures also only captures short term farming inputs for each agricultural season.

Table V.8. Direct and indirect effects of land formalization on agricultural production outcomes, hot season (Delta)

Outcome measure	Overall effect (p-value)	Direct effect (p-value)	Indirect effect (p-value)	Sample (T)	Sample (C)
Land under production (ha)	0.56** (0.00)	0.46** (0.00)	0.09** (0.00)	1,109	1,105
Change in agriculture investment costs per hectare	-0.06** (0.00)	-0.06** (0.00)	0.01 (0.29)	1,136	1,136

[31] We chose this measure over another possible binary indicator—household has titles to all plots—because the measure had more variation and better represented the expected increase in land formalization due to the intervention, as households that previously had no titles to land were able to obtain a title to at least one parcel.

[32] We checked this finding using the mediator “all plots titled” but found no significant effect, possibly owing to the mediator having less variation than the measure for “at least one plot titled”.

Outcome measure	Overall effect (p-value)	Direct effect (p-value)	Indirect effect (p-value)	Sample (T)	Sample (C)
Household reported cultivating	0.04* (0.04)	0.03 (0.15)	0.01* (0.05)	1,122	1,108
Change in agriculture revenue per hectare	-0.05* (0.01)	-0.06** (0.00)	0.01** (0.01)	1,136	1,136

Source: IWRM Project baseline and follow-up household surveys

Note: Sample sizes vary based on survey response. Sample contains all households in the matched analytic sample. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Measures for change in agriculture investment and revenue per hectare are binary. Households receive a value of 1 if the change was positive from baseline and a value of 0 otherwise. The indirect effect is the impact estimate for the causal pathway from the IWRM Project to a change in land tenure security (measured by having at least one plot titled) to a change in the outcome measure. The direct effect is the impact estimate for the causal pathway between the IWRM Project and the outcome measure, operating through other unspecified channels. The direct and indirect effects sum to the total effect aside from rounding.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

In terms of agricultural production outcomes, we find that changes in land titles did modestly contribute to the small change we found for households cultivating any crop. 1 percentage point of the 4 percentage point effect size can be attributed to changes in titled plots. And while the overall project led to a reduction in the likelihood that households increased their agriculture revenue per hectare by 5 percentage points, we find that increases in land formalization had a very modest opposite effect – increasing the likelihood that households would receive a higher amount of revenue per hectare by 1 percentage point. Overall, we find some evidence that improvements in land tenure security may have contributed to positive changes in agricultural production, particularly for cultivating on a larger tract of land.

7. Constraints and barriers to land access

As with women's overall access to productive land, the types of constraints and barriers to land access differ across Gandon and Ronkh. In Ronkh, as described above, the major constraint to land access is lack of availability. Almost all arable land is already used for farming and is allocated under customary land access systems. As a result, few parcels are available to women outside of the land allotted to GPFs. In Gandon, women may have easier access to available land, if they seek it. But although access to land might be easing for women in Gandon, they continue to report challenges gaining access to credit to develop and support farming activities because, according to women we interviewed, (1) credit is available only for rice (which, according to men and women we interviewed across all project zones, is traditionally cultivated by men, and women's land may be inappropriate for rice) and (2) women rarely have formalized land rights to use for collateral, even though the LTSA project may have helped to incrementally increase women's formal land rights.

G. Sustainability

Our evaluation focuses on the two years after the infrastructure and land tenure activities were completed in September 2015. However, stakeholders interviewed as part of the qualitative research also shared their perspectives on the sustainability of different aspects of the IWRM Project. Engineers focused on the need to maintain irrigation infrastructure, whereas farmers—

the primary beneficiaries of the project—focused on ways to build on the successes of the project by expanding access; investing in inputs, such as land grading equipment; and in commodification, such as building rice hulling plants. Local land management officials expressed the need to continue formalizing land rights. Each section below summarizes issues with possible effects on sustainability. We focus on answering the following research question: What are the prospects for the sustainability of project activities post-Compact?

Infrastructure requires consistent routine maintenance, and defects need to be addressed. In the Delta Activity area, follow-up work has been put in place to make the infrastructure sustainable for more than 20 years, or even 30 years, as pointed out by a SAED engineer. Recognizing the need for continued diligence, he said, "Concrete infrastructure can generally last more than 30 years, but some infrastructure is in the ground, requiring frequent care and maintenance to last."—S3 To this end, SAED procured multiyear contracts for maintenance of the canals and drainage system through 2020 (USACS 2018a).

In addition, defects have been noted in the infrastructure work in the Delta, such as the lack of grading of some land that has left mounds and ruts that do not allow for irrigation or drainage, and some canal banks have experienced erosion even in the first years of use. Other problems are a mixture of infrastructure flaws, an excess of water, and difficulty habituating animals to new watering locations. According to a leader of a union of cooperatives in Diama:

> The water overflows everywhere [outside the canals], the sluice gates are not secured, water troughs have been made at specific locations but it is not possible to make the animals go there to drink when they are left by the herders to wander; there are places where, in two (2) years, the canals will be broken.—W3

Even if the water is accessible with a motor pump in most areas, several farmers argue that a gravity system would have been a better and less expensive option for irrigation. According to the president of a WUA in Ronkh, "The gravity system is out of service in some areas that are now no longer irrigated. The OMVS [SAED] was supposed to take into account the gravitational works in its planning but did not do it."—W4

Constant budgetary shortfalls hamper maintenance efforts as well as SAED's ability to oversee the irrigation system. SAED funds maintenance, in part, through collection of water fees, which had only a 30% recovery rate pre-compact (MCC 2009a). It is not clear whether the recovery rate has improved post-compact and delays in funding from the GoS have slowed some maintenance activities (USACS 2018a). WUAs, a critical player in sustaining project activities as they assist in fee collection, state that they lack resources for the tasks that have been assigned to them. In considering what is to be asked and expected of WUAs, it is important to understand they are made up of volunteers.

Farmers want help to extend the irrigation system and to improve the crops' value chains. As interviews reveal, some plots that had relatively easy access to water before the project no longer have easy access, either because the original source is no longer available or because the new water sources (the compensatory canals) are blocked from the farmers' fields by newly built dikes or roads. Farmers want to find ways to make these fields accessible to the newly abundant water. Investing in equipment such as levelers would also potentially allow plots within the perimeter better access to water. In addition, because farmers are experiencing the increase in rice and other crop production, they want to build on the impact of the MCA project with infrastructure in the value chain, such as warehouses and rice hulling plants. They see the potential of increased yields and revenue with such additional improvements in the production chain. An increase in production inevitably impacts the value chain of each product, as explained by a SAED agricultural adviser in Diama, who says that it “creates many more players in the value chain by affecting the transporters, seasonal workers, traders, factory employees, processors, bag sellers, consumers.”—S1

Land tenure formalization applications have increased, but land offices do not have the capacity to complete processing. Farmers also expressed the need to continue formalizing land rights. Outreach and education efforts greatly increased demand for land allocation and land formalization, but land offices are not equipped or funded adequately to carry on the tasks associated with this process without outside funding at present. The apparent increase in the value of land with the newly abundant water in the irrigation system could lead to intense interest in buying or renting land; lingering backlogs of thousands of applications for formalization could create an environment where competing claims fester and conflict could increase.

Some LTSA activities continue to be implemented by local agencies and other donor projects. The IWRM Project has had an influence on the implementation of subsequent projects. PDIDAS has inherited a number of principles and practices from the IWRM Project, such as the process of working with the community to obtain buy-in for any land agreements, including letting the communities lead the process for land allocation and working with local government institutions to improve capacity for land formalization, conflict resolution, and POAS usage. However, the PDIDAS project has encountered delays in implementation as of the date of this report. The LTSA may also have had influence outside project areas, benefiting local technical groups with land allocation procedures and the establishment of a land information system, although the extent and outcome of these effects are unknown and there appears to be no centralized or standardized land information system in use.

H. Summary of Delta findings

In this section, we link our key findings for the Delta activity back to the project logic model to identify which parts of the logic model were or were not achieved at the time of this study and how that affected longer term outcomes. In Figure V.11, activity outputs, short term outcomes, and longer term outcomes are color-coded to level of achievement based on a synthesis of our findings. Green demonstrates clear evidence of achievement, yellow means we found mixed evidence of achievement, and red highlights there was a lack of evidence of achievement.

Figure V.11. Assessment of Delta activity logic model

Outputs (Years 1–5) 2010–2015	Short-term outcomes (Year 5) 2015	Medium/long-term outcomes (Years 6–10) 2016–2020
• 1,159 temporary jobs • 17 water control structures created • 181.3 km of canals are habilitated • 8 km of protective dikes constructed • 39.8 km of drains constructed	• Increase potentially irrigable land to 39,300 ha • Increase amount of land under production to 42,030 ha • Increase water flow (65m^3 per second) • Establish satisfactory drainage system	• Increased cropping intensity in the Delta (150%) • Increased agricultural production − 277,000 tons of paddy rice* − 115,000 tons of tomatoes* − 130,000 tons of onions* • Increased agricultural incomes • Strengthened job opportunities in farming sector • Infrastructure servicing and maintenance • Contribution to increased investments in agricultural sector

Evidence of achievement
Mixed evidence of achievement
Evidence of lack of achievement
Lack of evidence

*Amounts are combined for both the Delta and Podor activities, but the vast amount agricultural production increases were anticipated for the Delta because of its much larger intervention area.

As reported in MCC's compact close-out document, MCC met and exceeded all **output targets** for building and refurbishing irrigation infrastructure. This resulted in a large amount of potentially irrigated land, and land under production did increase as a result of the intervention, with an average of 0.56 hectares for our treatment group in the hot season (**short-term outcomes)**. Overall in the Delta, SAED reports that a total 20,891 hectares was under production during the three 2016-17 agricultural seasons. The vast majority of land under production occurred in the hot season with 14,512 hectares. That number increased slightly the following year to 16,630 hectares, bringing the 2017-18 seasonal total to 26,919 (USAC 2018b). While these overall numbers are lower than MCC's targeted amount of 42,030 hectares, our impact analysis coupled with SAED's reporting provides evidence that the project led to a growing increase in the amount of land under production.

While we do not have independent evidence on the irrigation system's water flow, SAED reported that the system achieved the targeted 65m^3 per second (MEFP 2016). However, there were challenges with ensuring the reliability and availability of water throughout the intervention area, limiting the benefits of newly irrigable land. While overall satisfaction with the availability of irrigation water remained high in our matched-comparison group sample, through our qualitative research we found that farmer satisfaction with the drainage system depended on plot proximity to the system.

Medium and longer term changes in production have so far mostly occurred during the main growing season (the hot season). As we concluded from our matched-comparison group analysis, newly irrigated land was used overwhelmingly for rice production. However, many farmers decided not to cultivate during the cold and rainy seasons and did not farm market vegetable crops like tomatoes and onions as anticipated in the program logic. Only 5,641 tons of tomatoes and 17,372 tons of onions were harvested in Delta's 2017-18 cold season (USAC 2018a), far below the 115,000 and 130,000 ton targets for tomatoes and onions respectively. Rice production did increase substantially with SAED reporting that Delta farmers harvested 162,460 tons of rice during the 2017-18 seasons. While this is still below the target of 277,000 tons of rice, the target could still be reached by the end of the 2020 as anticipated. We find that the project has yet to achieve its intended increase in cropping intensity (150 percent). In our matched-comparison group analysis, we found that the project resulted in a significant increase in rice yields during the hot season. However, rice production also increased at the expense of farming other crops during the cold and rainy season. For instance, SAED reported that cropping intensity in Delta was only 49 percent in 2016 and 75 percent in 2017. (USAC 2018a).

There was mixed evidence as to how the increase in rice production affected agricultural incomes, investment, and job opportunities. Overall, we find a significant increase in agricultural profit, particularly in the hot season. However, that change appears driven by the increase in the amount of land under production and is offset by an overall decrease in off-farm revenue. Farmers may also still be figuring out optimal land use with the new irrigation system. Qualitative data has shown that some groups, particularly women, report that the project has improved their well-being.

Finally, we find mixed evidence that the project achieved its outcome on infrastructure servicing and maintenance. SAED reported that it had signed contracts for maintenance of the infrastructure, which corroborates our own finding that that maintenance was being done regularly (Thiam 2018). However, through stakeholder interviews, we also identified maintenance limitations, namely that there is inadequate financing for the WUAs to ensure that cattails (*typha*) are not preventing water flow in the canals.

We link our key findings for the LTSA to the project logic model in section VIII, after discussing the results for the Podor Activity.

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VI. EVALUATION FINDINGS: PODOR

In this chapter, we present our key findings from the evaluation of the IWRM Project in the Podor Activity area. We estimate changes in outcome measures between baseline and follow-up for the intervention group in Podor. We did not have a comparison group in Podor, and therefore cannot present causal findings on the IWRM Project's impact, but we do present suggestive evidence on whether the project affected key outcomes. Factors outside the scope of the IWRM Project could have affected the changes found between baseline and follow-up, such as weather patterns, economic conditions, other social programs, or changes in government policy. Podor also has a drier climate than the Delta, is farther inland, and is poorer overall. It received a different package of activities as part of the IWRM Project—most notably a new irrigated perimeter built in Ngalenka, with the resulting newly irrigated land allocated to farmers in communities around the perimeter. Our analysis focuses on identifying changes in outcomes for those households who received newly irrigated land under the project.

We begin with a summary of our key evaluation findings. We then detail results in the following topic areas: water use and availability, agricultural production, agricultural profits and household income, land administration and governance, land formalization and conflicts, and project sustainability. We blend the findings from our quantitative and qualitative analyses to answer each project research question as fully as possible.

A. Summary of key findings

- The source of water used for irrigation after the IWRM Project was the same as the one used before: farmers still used local waterways to irrigate their fields. However, access to irrigation water in the main growing season seems to have improved with the project's creation of the Ngalenka perimeter.
- The average area irrigated for households that received land within the Ngalenka perimeter also was about the same after the IWRM Project as it was before. This may be because some households in the sample had irrigated land in the Ngalenka cuvette before the project, and have replaced that land with improved land within the new perimeter. However, we have no data to confirm whether that was the reason for this finding.
- Most women who received access to land within the new perimeter were very happy to have land allocated to them. However, many were challenged by the small size of the plots allocated to women, which inhibited them from realizing substantial profits. Others said their Ngalenka perimeter plots were unsuitable for rice cultivation, and this was a disappointing feature of the project.
- Water user associations in Ngalenka appeared to have mixed outcomes. Some leaders of WUAs reported making progress in their role in managing fee collection, overseeing maintenance, and participating in selecting maintenance contracts. Other interviewees said WUAs are less active than they should be, and see the role of SAED as remaining more prominent in determining fees and maintenance contracts.
- The IWRM Project was successful in providing new farm land to some households that didn't have access to farm land before. Among the intervention group, access to farm land increased by 24 percent during the hot season.

- There was no significant change in the amount of land under production for intervention households during the hot season. Households may be prioritizing production within the Ngalenka perimeter land due to its better water access, and therefore changing the land they are farming on instead of farming on more of it. There was a decline in the amount of land under production during the cold season, which is likely because the perimeter was not being irrigated then.
- A significantly larger share of households harvested crops in the hot season at follow-up compared to baseline. The land within the irrigated perimeter may have reduced the rate of crop failure—a key project objective.
- Improvements in agriculture production appeared highest among female-headed households and the poorest households. There were significant increases in the number of households reporting that they farmed land and in the amount of land under production. There were no changes in these measures for male-headed households or better-off households.
- The IWRM Project appears to have succeeded in increasing rice production during the main agriculture season. Relative to baseline, the intervention group saw increases in the percentage of households cultivating rice, the area of rice cultivated, rice investment costs, rice revenue, and rice yield. Among all intervention households, the average area of rice cultivated increased by 43 percent, and average rice yield quadrupled from its baseline average, as more households cultivated rice, and farmers harvested more rice per hectare.
- However, despite the improved rice production in the main growing season, there was no statistically significant change in profit in this season. Households tended to consume a large portion of the rice they harvested. In the cold season, there was an overall decline in agricultural profit relative to baseline, as well as a decline in off-farm earnings.
- The POAS is in use in Guedé and Ndiayène Pendao, and zone commissions are functioning in Guedé since receiving funding from a donor project.
- Customary land tenure remained dominant, thus land “allocation” still consists of formalizing customary claims, creating barriers to land access for those without such claims, such as women and landless residents.
- LTSA outreach, education, and land grants provided to GIEs (including GPFs) in the Ngalenka perimeter created strong demand for formalization, but the land bureaus are underfunded, and this led to a backlog of applications.
- The SIF database is in use by some land offices, but is not routinely updated; lack of human and material resources limit its use.
- On average, one-quarter of the plots had a land title before and after the intervention. Because the land allocation that was part of the LTSA and the Podor Activity delivered titles to the cooperatives and not to individuals, households do not seem to perceive the land was titled to them.
- Households with land in the Ngalenka perimeter were less likely to say they knew the process for obtaining land titles at follow-up than they were at baseline. Because an extensive educational outreach on new land titling procedures was part of the project, this outcome might reflect a decrease in confidence rather than a decrease in knowledge.

- Scant conflict over land was reported overall, and there was no change in this between baseline and follow-up.
- Decisions about investing in the perimeter did not appear related to land security or concerns about conflict. Farmers cultivate when they are most likely to have a good harvest; that is, in the hot season, when water flow can be well regulated, credit is available, and other communal actors with land in the perimeter (with advice from the local agricultural extension agent) decide to cultivate.
- Although the women and previously landless residents who received land in the Ngalenka perimeter regarded this as a very positive element of the project, women's groups have not been able to cultivate their preferred market garden crops because the price of inputs, especially electricity, exceeds any potential profit for the small land area they would be able to cultivate.

B. Use and availability of water

The Podor Activity differed from the Delta Activity in a few important ways. In Podor, the IWRM Project built an irrigated perimeter of 450 ha in the cuvette of Ngalenka. The cuvette is a shallow basin-like area of land that historically flooded in the rainy season when the Senegal River overflowed its banks. Historically, the cuvette (about 3500 ha) was a mixed-use area in which farmers cultivated recessional crops in the clay soil after the flood waters receded. Since the construction of the Manantali and Diama dams in the 1980s, the Senegal River no longer floods at the levels it did in earlier decades, and the Ngalenka cuvette has been only partially cultivated in areas close to the tributary Namarde and Ngalenka Creeks and other waterways in the area.

Residents of the villages around the Ngalenka cuvette are mostly farmers and herders. The majority of households interviewed at baseline in 2011–2012 had land in an irrigated perimeter; these are common along the waterways in the area. The IWRM Project built a 450 ha irrigated perimeter within the cuvette, which was completed in 2015. The perimeter includes concrete-lined primary canals, secondary canals, and associated sluice gates; elevated pathways; an intake channel connected to the Ngalenka Creek; water pumps connected to the electric grid; and a drainage station. During the first five years of operation, producers determined that only rice could be grown in the Ngalenka perimeter.

Our analysis of the effects of the IWRM Project is based on quantitative data collected before the project started as well as quantitative and qualitative data collected between 12 and 27 months after the project was completed, covering each agricultural season in a calendar year. In Podor, we compare changes in outcomes for households that received land in the new irrigated perimeter (the intervention group) before and after the project ("pre-post").[33] Because we do not have a comparison group for our quantitative analysis in Podor, factors external to the project that change over time, such as weather patterns, economic conditions, or government policy, could be affecting the changes in outcomes we observe. For example, if the overall economy improved during the project, any changes we find in agricultural production could be related to

[33] 249 households were identified as receiving land within the Ngalenka perimeter and responding to all three waves of surveys at baseline in 2011–2012 and at follow-up in 2017–18.

the changes in economic conditions instead of project activities. Our analysis therefore provides suggestive evidence on the IWRM Project's contribution to any changes discussed here, but it does not establish causality.

We begin our findings by examining how the IWRM Project affected the use and availability of water for households who received land in the Ngalenka perimeter. The evaluation was designed to determine whether water is more available to households and more land is irrigated as a result of the project. In this section, we answer four research questions:

1. Have there been changes in the sources of water used for agricultural production?
2. How has water availability changed, and have barriers or costs to accessing irrigation been reduced? Has the water supply become more reliable?
3. Has the amount of irrigated land increased?
4. Has the role of WUAs changed, and how do they impact the use and availability of water?

Main findings

- The source of water used for irrigation after the IWRM Project was the same as the one used before; farmers still irrigate their fields from the local waterways. However, the reliability of irrigation water in the main growing season seems to have improved with the project's completion of the Ngalenka perimeter.
- However, the average amount of land irrigated for households that received land within the Ngalenka perimeter did not change. This may be because some households in the sample had irrigated land in the Ngalenka cuvette before the project and have replaced that land with better land in the new perimeter, but we have no data to confirm the reason for this finding.
- Most women who received access to land within the new perimeter were happy that land was allocated to them. However, many said the small size of the plots allocated to women kept them from realizing substantial profits. Others said their Ngalenka plots' unsuitability for rice cultivation contributed to their disappointment with the project's outcomes.
- Water user associations in Ngalenka reported mixed outcomes. Some leaders of WUAs have seen progress with their role in managing fee collection, overseeing maintenance, and participating in selecting maintenance contracts. Other interviewees said WUAs are less active than they would like, and see the role of SAED as remaining more prominent in determining fees and maintenance contracts.

1. Source, availability, and access to water for agriculture production

The IWRM construction of the Ngalenka perimeter was designed to provide a reliable water source to a large tract of arable land in an area where the available water was already being used for irrigation, but primarily for small scale irrigation schemes. Therefore, it is not surprising that our quantitative survey data showed no changes in the *sources* of water that farmers used for agricultural production; they used creek water before the project and they used creek water after the project was completed.

What has changed is that irrigation water is now available from the creek through pumps and canals connected to the new Ngalenka perimeter, whereas before, land within the Ngalenka cuvette was not properly leveled for irrigation and did not have well-designed canals to bring water from the river to plots. However, farmers are still not accessing that water in all agricultural seasons. Conversations with farmers and SAED officials revealed that the new perimeter was not cultivated in the cold or rainy seasons that we collected survey data for. The reasons given for not using the perimeter were different depending on the season. Farmers did not cultivate in the cold season because the plots whose soil was appropriate for cold-season crops (tomatoes and onions) totaled only about 80 ha (of the total of 450 ha in the perimeter) and were scattered throughout the perimeter. The cost of using the electric pumps to pull water into the canals was deemed too high for this small scattered surface area.

Our quantitative data suggest farmers were unhappy about this: there was a significant decline of 15 percentage points in household satisfaction with the availability of water during the cold season (Figure VI.1). In the rainy season, only about one-quarter of farmers cultivated, and their reasons for not farming in the 2017–2018 rainy season related to factors external to the IWRM Project, including delays in receiving agricultural loans and a public notice that the Senegal River level would be lower than usual. We therefore focus here on pre-post changes for the cold and hot seasons; results for the rainy season are in Appendix C.

Figure VI.1. Change in satisfaction with the availability of irrigation water, among all households (Podor)

Source: IWRM Project baseline and follow-up household surveys.

Note: A household is considered satisfied with the availability of irrigation water if it reported it was either satisfied or very satisfied. Households are “unsatisfied” if they reported they were neutral, unsatisfied, or very unsatisfied with the availability of irrigation water. If a household decided not to farm, we define it as unsatisfied with the availability of irrigation water, because the lack of available water was a reason not to farm. Baseline sample size is 249 for both seasons. Follow-up sample size is 245 for the cold season and 249 for the hot season.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

We find no substantial change in farmers’ satisfaction with the availability of water during the hot season, the main growing season when they cultivated land within the irrigated perimeter. Our qualitative data, collected from farmers and other stakeholders in the area around the Ngalenka perimeter, reveal challenges with using the new irrigation system that help explain the lack of positive results in satisfaction with water availability. At the same time, our qualitative data reveal that stakeholders have favorable attitudes about the availability of water, even if they express reservations about how the new irrigation system is currently working.

Speaking in focus groups and individual interviews, farmers in the Ngalenka perimeter said they appreciated the new availability of adequate water for farming. Thanks to the new and renovated infrastructure, the problem of inadequate water for irrigation seems to be diminishing for many farmers. The change is nicely summarized by a SAED engineer in Podor:

> At Ngalenka, before [the IWRM Project] there were people who farmed flood-based crops. So if there is rain, there is water; if there is no rain, there is no water, and [the crops] do not grow; there is no reliability. But today, with the [perimeter], there is water throughout, all the time.—S3

However, our qualitative data also revealed that the greater availability of water has been accompanied by some technical and financial difficulties. Despite farmers' overall satisfaction with increased availability and access to water, they reported challenges in terms of reliability in the cold and hot seasons, access to water if they lived far from the source, and the cost and fees associated with accessing irrigation water.

Reliability in the cold and hot seasons. The farmers we interviewed told us there are still barriers to accessing water regularly. Many of them noted that water was available, but explained that it was harder to access in the cold and hot seasons because the water mixed with the dry soil or clay in the intake to the irrigation canals and became mud, which was more difficult and expensive to pump. They also reported that water was not available all the time because the canals are too narrow and small for enough water to get to all the plots when needed. The presence of the fast growing weed *typha* also clogged canals.

These problems with the irrigation canals escalated with the distance the water had to travel from the source to a farmer's plot. Users whose plots were far from the primary canal explained that they were forced to take turns irrigating their fields with the limited water that reached them, which sometimes led to disputes. In addition, a number of farmers, WUA leaders, and SAED engineers reported that the topology of some parcels in the Ngalenka perimeter prevents farmers from accessing irrigation water easily, because some are higher than the irrigation canals and there was not enough grading done to ensure gravity-fed irrigation to all plots. In addition to the problem of water supply varying depending on the location and grading of the field, the quality of the water and the cost of accessing it also vary, according to farmers.

Although water was made more available in the main growing season (the hot season), farmers said it was too expensive. They incurred costs from both the water access fees and the electricity—and sometimes diesel for smaller pumps used by some farmers within the perimeter—required to operate the pumps that brought the water to their fields. The cost of power appeared to be the biggest driver of cost concerns.

The new infrastructure and resulting higher cost of access to water prevented some farmers from using the available water. Describing his inability to pay the higher price of water in the irrigated perimeter, one farmer from Doulel Mbarick summarized his sentiments and those of other farmers who once cultivated in the cuvette:

> There are no more floods, the rivers have been closed. The floods came here. Since [the Manantali dam was completed], the river doesn't flood. We can't farm here anymore.—E8

Another farmer in a Podor GIE put it more concisely:

> With the floods, there were no invoices.—E9

Irrigation. To examine how access to and availability of water affected irrigation, we used our quantitative survey data to examine whether the IWRM Project changed methods of irrigation through the rehabilitation and construction of canals. We classify a system as simple gravity irrigation if no pump is used, and sophisticated irrigation if a household reported using a diesel or electric pump, a sprinkler system, central pivot irrigation, or drip irrigation. Because 90 percent of farming households reported farming on one or two plots in any agricultural season, we report on whether a household used an irrigation system on any of its plots.

Table VI.1. Pre-post changes for water and irrigation, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p-value*	Sample (post)	Sample (pre)
Cold season						
Used a simple gravity irrigation system	0.01	0.04	-0.03*	0.03	246	249
Used a sophisticated irrigation system	0.53	0.65	-0.12**	0.01	246	249
Percentage of farm plots that were irrigated	0.53	0.65	-0.12**	0.00	249	249
Total area of land irrigated (ha)	0.28	0.37	-0.10**	0.01	241	245
Hot season						
Used a simple gravity irrigation system	0.00	0.04	-0.04**	0.01	249	249
Used a sophisticated irrigation system	0.62	0.45	0.17**	0.00	249	249
Percentage of farm plots that were irrigated	0.62	0.46	0.16**	0.00	249	249
Total area of land irrigated (ha)	0.33	0.27	0.06	0.09	244	248

Source: IWRM Project baseline and follow-up household surveys

Note: Data were trimmed at +/- 3 standard deviations from the median. A household used a type of irrigation system if it reported its use on at least one of its farm plots. We classify a system as simple gravity irrigation if no pump is used, and sophisticated irrigation if a household reported using a diesel or electric pump, a sprinkler system, central pivot irrigation, or drip irrigation. Beyond these two types of irrigation, farmers could report using a watering can for irrigation, no irrigation, or some other form of irrigation identified by the respondent. Sample sizes vary based on survey responses, item-level missing data, and outlier trimming. Households that did not farm received a value of 0 for each measure.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

As could be expected from the configuration of the Ngalenka perimeter, which relies on electric pumps to pull water into a primary canal, a scant number of farming households reported using simple gravity irrigation, either at baseline or follow-up. Most households used—and continue to use—a form of sophisticated irrigation such as a diesel or electric pump (Table VI.1). We find a drop in sophisticated irrigation from baseline during the cold season, when households were unable to farm on land within the Ngalenka perimeter. In the hot season, we find an increase from baseline in the use of sophisticated irrigation (by 17 percentage points), likely the result of households taking advantage of the new irrigation system within the Ngalenka perimeter. These findings are consistent with those found in examining the share of plots that a household irrigated. There again, households in the cold season irrigated fewer plots, on average, than they did at baseline, but irrigated more plots during the hot season. Irrigation decisions in the intervention group seemed to be dictated by farming availability within the Ngalenka perimeter.

2. Amount of irrigated land

We used survey data to compare the reported amount of irrigated land households farmed at baseline and follow-up. As expected, in the cold season, there was a significant decrease in the amount of irrigated land, from an average of 0.37 hectares at baseline to an average of 0.28 hectares at follow-up among all households in our sample, including those that did not farm. In the hot season, there is a small but suggestive increase in the amount of irrigated land, though it is not statistically significant.

Although these results are consistent with the findings on changes in irrigation for the cold and hot seasons, the results for the hot season are still unexpected. Households might have been expected to report a significant increase in irrigated land in the main agricultural season, because they were given land with access to irrigation as part of this intervention. However, there are several plausible explanations. First, as reported in the qualitative findings, the costs of farming are a barrier to expanding agricultural production. So even though households may now be farming on more productive land thanks to the IWRM Project, they may lack the resources to farm on a larger area of land, or choose to focus the same effort on more productive land. Second, the principles used for allocating land in the perimeter might have privileged households that already had irrigated land before the project (see Section VI.E), that is, households with other irrigated land, or households that had irrigated plots on the land where the Ngalenka perimeter was then built. Farmers' Ngalenka perimeter land might have been, in part, replacing irrigated land that was incorporated into the perimeter. Third, the land that was allocated could have been too small to register as a significant increase in irrigated land on a per household basis. Although the Project initially planned to give parcels of one hectare to each beneficiary household, many communities actually divided up these parcels to give smaller plots to more households.

Women's access to water. Our qualitative data offer some insight into how men and women in the intervention group had different perceptions about the changes in irrigated land. Almost all of the community members we interviewed said that increased availability of water through the development of the agricultural perimeter by MCA was one of the main drivers of change in agriculture production in Podor. Most of them, particularly small producers and women, stated that before the coming of the project, they were faced with many technical and financial challenges with irrigation infrastructure, which impacted their agriculture productivity.

During the interviews, both male and female beneficiaries, in notable numbers, declared that they appreciated the project's presence in their community because it made water more available to them. Women in particular were able to access land, many for the first time, and this was a very positive change. However, many farmers, especially female farmers, reported that the newly available irrigated land was not distributed equally between men and women, and women did not benefit as much from newly distributed lands. Some women farmers explained that the land allotted to their GPFs was too small to subdivide, and that profits would be too small to share if they all worked the land together. For example, one GPF president in Tivaoune explained how land allocation to GPFs worked in their shared situation:

> We are 25 women, and we all cultivate the same plot. Because this is the case, sharing is difficult, but if we had more land, this wouldn't pose a problem.—F4

Many female farmers we interviewed in our focus groups and individual interviews between 2016 and 2018 reported receiving land that was of lower quality or less suitable for rice cultivation than the land men got. Members of GPFs reported that the irrigation infrastructure did not provide enough water to their fields to grow rice, and that the soil in their plots was unsuitable for rice cultivation (*sols carreaux*). One group noted that the lack of water has led to three failed rice crops for them.

3. Water management and the role of the WUA

WUAs have existed informally in Podor since at least 2002. As part of the IWRM Project, and similar to the activities carried out in the Delta project area, WUAs became more formalized through restructuring, obtaining permits of association, and establishing an office in Podor. The IWRM strengthened WUAs' technical capacities for maintenance of the irrigation infrastructure, assisting with billing, fee collection, and logistics. The WUAs' purpose is to help communities use and sustain the irrigation infrastructure by collaborating with SAED, and thereby ensure the availability of water in all seasons.

In the Ngalenka perimeter, WUAs have two main responsibilities. They are responsible for collecting the fees that are charged to GIEs (or individuals) for accessing water. The fees are meant to fund maintenance, equipment, and staff who maintain the irrigation infrastructure. Second, the WUAs are responsible for the maintenance of the primary and secondary canals, drainage canals, and pumping station, with technical help the *Direction Autonome de la Maintenance* (DAM) of SAED. WUAs are also responsible for planning the water distribution schedule that allows irrigation water to flow to different parts of the perimeter, and for, clearing the waterways of weeds or debris. After the end of the IWRM Project, WUAs were expected to carry on managing these responsibilities. Our qualitative research yielded conflicting perspectives on how satisfactorily WUAs have stepped into these roles.

Some stakeholders we interviewed noted that the work of the WUAs is more and more visible, and fee collection has become smoother. Other positive changes mentioned by respondents include that the current WUAs were better integrated into SAED's administrative management for infrastructure maintenance contracts. A member of the WUA of the Ngalenka Canal noted its new participation in procurement by mentioning that WUA members observe the opening of tenders for the selection of service providers.

Other interviewees said the situation has not changed, and WUA members do not take on the maintenance, participate in decision making (even in the selection of companies for the maintenance contracts), or collect fees. These stakeholders also reported that the WUAs are not receiving funding from the fees to do maintenance work and are more commonly only observers of the maintenance work, which SAED leads.

Despite some differences of opinion on the effectiveness of WUAs, virtually all WUA leaders and several other stakeholders said that WUAs lack the financial means to fully ensure maintenance of the irrigation infrastructure and thereby ensure a good supply of water to the agricultural fields.

The WUAs depend entirely on SAED for technical support, and function only with subsidies from the state and/or from *le Fonds de Maintenance des Adducteurs et Emissaires de Drainage* (FoMAED), which was created under the authority of the Ministry of Agriculture. MCA's efforts to empower WUAs during the IWRM Project are still perceived as important by WUA leaders. However, the funds intended for maintenance work are managed by SAED, and WUA leaders, who think SAED's control is a barrier to their full functioning, are seeking more control over the money. As explained by one WUA member, the WUAs' lack of control over resources limits their ability to do the tasks they are responsible for.

> We already have offices in [the regional offices of] SAED, equipped with a computer and equipment…, we have Invoicing and Collection commissions, but SAED has them…. If I want to use my car, I have to make a request ... We are working on the weekend, we do not have a holiday. If their [farmers'] needs are felt, we [the WUA] are obliged to intervene …[but] there is a small barrier [to full functioning].—W6

C. Agricultural production

This section's focus is on whether farming households are using more land for agricultural production as a consequence of the IWRM Project, and whether the project had any effects on farming households' decisions to cultivate and invest in rice production, which was its primary focus in Podor. We answer four research questions:

1. Have there been changes in the amount of land used for agricultural production? Is land being used for production in different seasons than before?
2. Has crop production improved? Have production methods, including the choice of inputs, changed? Have there been changes to the types of crops produced?
3. What factors are contributing to or constraining changes in agriculture inputs and production? Why are households changing or not changing agriculture production decisions, and how do those reasons vary depending on crop type, growing season, or income level?
4. How have changes differed by gender and among different income levels?

Main findings

- The project was successful in giving new farmland to some households that didn't have access to farmland before. Among the intervention group, access to farmland increased by 24 percent during the hot season.
- There was no significant change in the overall amount of land under production for intervention households during the hot season. Households that previously had land may be farming on different land versus farming on more of it-prioritizing production within the Ngalenka perimeter due to its improved water access. We did find a decline in the amount of land under production during the cold season, which is likely because the perimeter was not irrigated in that season: few producer groups planned to farm, and the costs were too high to irrigate only a small portion of the perimeter.
- We find evidence that improvements in land use were greatest among female-headed households and the poorest households, where significantly more of the respondents said they farmed land, and where the amount of land under production in the hot season also increased significantly. There were no changes in these measures among male-headed households or better-off households.
- A significantly larger share of households harvested crops in the hot season at follow-up compared to baseline. The land within the irrigated perimeter may have reduced the rate of crop failure-a key project objective.
- The project was successful at increasing rice production during the main agriculture season. Relative to baseline, the intervention group saw increases in the percentage of households cultivating rice, the area of rice cultivated, rice investment costs, rice revenue, and rice yield. Among all intervention households, the average area of rice cultivated increased by 43 percent, and average rice yield quadrupled from baseline as more households cultivated rice and farmers harvested more rice per hectare.
- Farmers generally appreciated the project and considered the availability of water through the new perimeter to be one of the main drivers of agricultural change in the region. Despite the significant improvement in yields, however, many farmers said there was much room for improvement in agriculture production in the perimeter.

1. Changes in land use

We begin by exploring whether the greater availability of water for irrigation resulted in changing the average area of agricultural land under production. Given that the intervention group received new farmland within the Ngalenka perimeter as part of the IWRM Project, we might expect land under production to increase.

Almost all intervention households—over 90 percent—reported having farm plots in the hot and the cold seasons, a significant increase from baseline of 12 percentage points (15 percent of the baseline value) in the cold season and 18 percentage points (24 percent) in the hot season (Table VI.2).[34] This is evidence that the IWRM Project was providing new land to households that did not have access to farmland before. However, there was no statistically significant change in the amount of land *under production* for the hot season, the main agricultural growing season. At both baseline and follow-up, intervention households reported farming about one-third of a hectare on average. For the cold season, there was a statistically significant *decline* in the area of land under production of 0.1 hectares, or a 26 percent decrease from the baseline value.

[34] A household had farm plots if it reported that it possessed, borrowed, used, rented, or managed any farmland.

Table VI.2. Pre-post changes for agricultural production, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p-value*	Sample (post)	Sample (pre)
Cold season						
Land under production (ha)	0.28	0.38	-0.10**	0.01	245	245
Household has farm plots	92%	81%	12%**	0.00	248	249
Household farmed land	54%	71%	-17%**	0.00	249	249
Household harvested crops	49%	64%	-15%**	0.00	249	249
Hot season						
Land under production (ha)	0.33	0.28	0.05	0.13	245	248
Household has farm plots	93%	76%	18%**	0.00	249	249
Household farmed land	63%	55%	7%	0.10	249	249
Household harvested crops	60%	34%	27%**	0.00	249	249

Source: IWRM Project baseline and follow-up household surveys.

Note: Results are among all households surveyed in each season.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

To understand why there were no apparent increases in the land under production, we examined changes per season in the share of all households that farmed land (Table VI.2) along with other evidence. In the cold season, when farmers traditionally grow vegetables, fewer households farmed land than at baseline. At the same time, more households had farm plots, probably because they were allocated land by the project. However, the new farmland allocated within the Ngalenka perimeter was not irrigated in the cold season, because it was expensive to run the pumps for the minority of plots on which vegetables could be grown, and those plots were scattered throughout the perimeter. The reduced amount of land under production in the cold season of 2016-2017 appears related to the decision not to irrigate the new perimeter in that season.

In the hot season, we find that *more* households farmed land compared to baseline. This is evidence that households were actively taking advantage of the new irrigated perimeter land during the main growing season. More evidence that these households were farming on land within the perimeter was presented in Table VI.1, which revealed that in the hot season, more households were using a sophisticated irrigation system relative to baseline. At the same time, the share of households that harvested any crops significantly increased from 34 percent of households at baseline to 60 percent at follow-up, a much greater increase than the increase in the number of new households farming. Thus, farming land within the irrigated perimeter may have reduced the rate of crop failure, which was a key objective of the project.

As noted, however, at follow-up there was no increase in the area of land under production for the hot season in comparison to baseline. One possible explanation is that households were prioritizing farming within the Ngalenka perimeter land due to its better water access, thereby changing the land they were farming on instead of farming on more land. Consistent with this explanation, there was no change in the average number of plots farmed per household between baseline and follow-up among our intervention group (data not shown). Also, our interviews with GIE (including GPF) members and other stakeholders revealed that although the project was designed to give households half-hectare plots in the Ngalenka perimeter, many communities divided up those plots into smaller parcels of land in order to provide more households with newly irrigated land. These smaller plots farmed by more households seem to have left the average land under production unchanged.

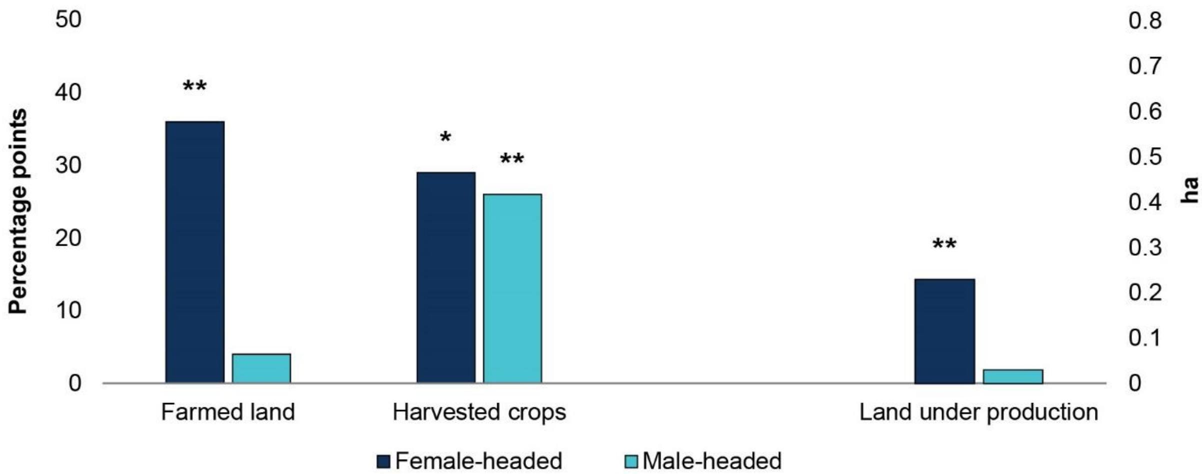
We also examined results by the gender of the household head and the poverty level of the household—using the Poverty Probability Index (Schreiner 2016) to estimate the likelihood that a household is living on less than $2.50 a day and dividing the sample into three groups based on this index.[35] An important limitation in our analysis of gender group changes is that, because 90 percent of the households in our sample were headed by men, and there were only 28 female-headed households in the sample, the resulting estimates have wide confidence intervals. Dividing the sample by the poverty-level of the household also resulted in three small subgroups. The subgroup findings are suggestive evidence only on whether one group could be driving overall results.

We focus our subgroup analyses on three key agriculture production variables during the main growing season: whether a household farmed any land, the amount of farmland under production, and whether a household harvested any crops. There were large changes in these three outcomes for female-headed households (Figure VI.2). The share of those households that farmed land increased by 36 percentage points, a significant difference compared to the results for male-headed households. Although there were no overall changes in the area of land under production for the hot season, there was a significant increase of 0.23 hectares for female-headed households, which is also significantly different from the change for male-headed households.[36] Both groups of households had comparably significant changes from baseline in terms of whether they harvested crops during the hot season.

[35] There was no statistical difference in the share of female-headed households by income group (*p-value* 0.37). In other words, female-headed households were found in each economic strata in our sample.

[36] As mentioned, our subgroup estimates, especially for female-headed households, have wide confidence intervals. The 95 percent confidence interval for the change in female-headed households that farmed land ranges from 11 to 60 percentage points; the confidence interval for the change in land under production for female-headed households ranges from 0.09 to 0.37 hectares.

Figure VI.2. Agriculture production changes by gender of household head (hot season, Podor)



Source: IWRM Project baseline and follow-up household surveys

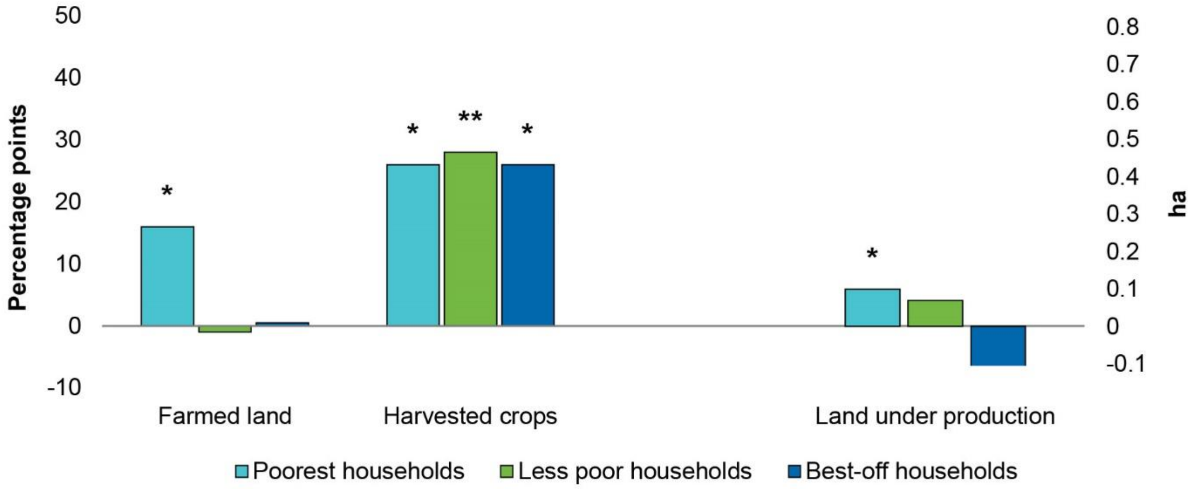
Note: Changes between baseline and follow-up for agriculture production outcomes are presented by subgroup for the gender of the household head for the main growing season (hot season). Change in outcomes are in percentage points unless otherwise noted. A household farmed land if it reported that it cultivated any crops. Sample sizes for female-headed households varied between 27 and 28; sample sizes for male-headed households varied between 217 and 221. There was a significant difference between the groups in the amount of farmed land (*p-value* 0.02) and land under production (*p-value* 0.02).

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

The poorest households had significant positive changes in agricultural production between baseline and follow-up (Figure VI.3), with a 16 percentage point increase in the share of households that farmed land in this group. In contrast, there was little change in the other two economic strata. The poorest households also saw a significant increase in land under production from baseline—a change of 0.1 hectares. There is suggestive evidence that the better-off households actually saw a decrease in land under production from baseline, but the sample is not large enough to detect a statistically significant change. All income groups reported a similar increase in the share of households that harvested crops. Overall, these findings provide suggestive evidence that the project may have been successful in targeting its land allocation withinthe Ngalenka perimeter to needier households, and those households reaped the largest benefits from the intervention. Complete subgroup results are in Appendix C.

Figure VI.3. Agriculture production changes by poverty level (hot season, Podor)



Source: IWRM Project baseline and follow-up household surveys.

Note: Changes between baseline and follow-up for agriculture production outcomes are presented by subgroups that indicated the household poverty status, determined by using the Poverty Probability Index for Senegal (Schreiner 2016). Changes in outcomes are given for the hot season and are in percentage points unless otherwise noted. A household farmed land if it reported that it cultivated any crops. Sample sizes were 120 or 121 for the poorest households, 80 or 81 for the middle group, and 45 to 47 for the best-off households. The differences between all three groups for each measure were not statistically significant.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

Our qualitative data in Podor revealed the evolution that occurred between the baseline and follow-up and produced the results found in the quantitative study. Farmers we interviewed were nearly unanimous in recognizing that there was one season right after the MCA project was completed that resulted in a very good rice harvest. Most farmers we interviewed throughout the Ngalenka perimeter reported that after the first year, rice yields per hectare gradually fell, and there were rice crops that were entire failures. The president of a GPF in Tivaouane II gave this report:

> In [that one] season, we had a satisfactory harvest, but [in] the two that followed, we did not have a harvest … It was only once that we had success.—F4

A member of the community of Wouro Mbarick echoed this:

> The first crop resulted in good yields, but they plunged the following seasons.—C3

And the president of the Ndiayène Pendao GIE corroborated:

> We have only done three crops. It is the first crop that was good. But the second and the third did not go well. We did not have good yields.—E10

Farmers attributed the drop in yields after the first year to bad rice seed, a lack of water in the parcels farthest from the main canal, plots that were higher than the canal elevation, and plots with unsuitable soil for rice. Many of the plots whose soil was sandier and therefore more suited to market vegetable crops were assigned to GPFs, leading to widespread discouragement when the women's groups were unsuccessful in their attempts to grow rice.

Aside from the first year after the completion of the perimeter, in which two seasonal crops of rice were cultivated, in all other years most farmers grew only one crop of rice. Many farmers expressed hesitation about cultivating in back-to-back seasons because of the failures during the second season of the first year. Because so many were hesitant, less land was irrigated the next off-rice season, and the farmers who wanted to grow rice had to consolidate their fields to reduce the area that would need to be irrigated. Those who could not grow rice in those smaller, consolidated areas were not able to cultivate rice for lack of water. Eventually, the majority decided the perimeter would not be irrigated at all in the off seasons (rainy and cold seasons), because it was too expensive when all the land wasn't being cultivated. This is in contrast to assumptions made in the ERR and project logic, which anticipated farmers would cultivate in all three seasons. In addition, farmers were advised by the agricultural extension service to grow only rice. The chairman of the GIE Doulel Mbarick explained:

> We must cultivate only rice, as imposed by SAED, during the first five years to combat salinization of the soils … two seasonal crops were initiated the first year with varying fortunes. And as soon as the second season was over, we were limited to one season in the hot-dry season. –E8

A SAED agent in Podor suggested that farmers in the Ngalenka perimeter based the decision to plant only one season of rice on financial and logistical difficulties:

> All conditions are met for a dual crop [of rice], but the farmers are experiencing difficulties putting them together. They are limited to just one crop [per year].−S3

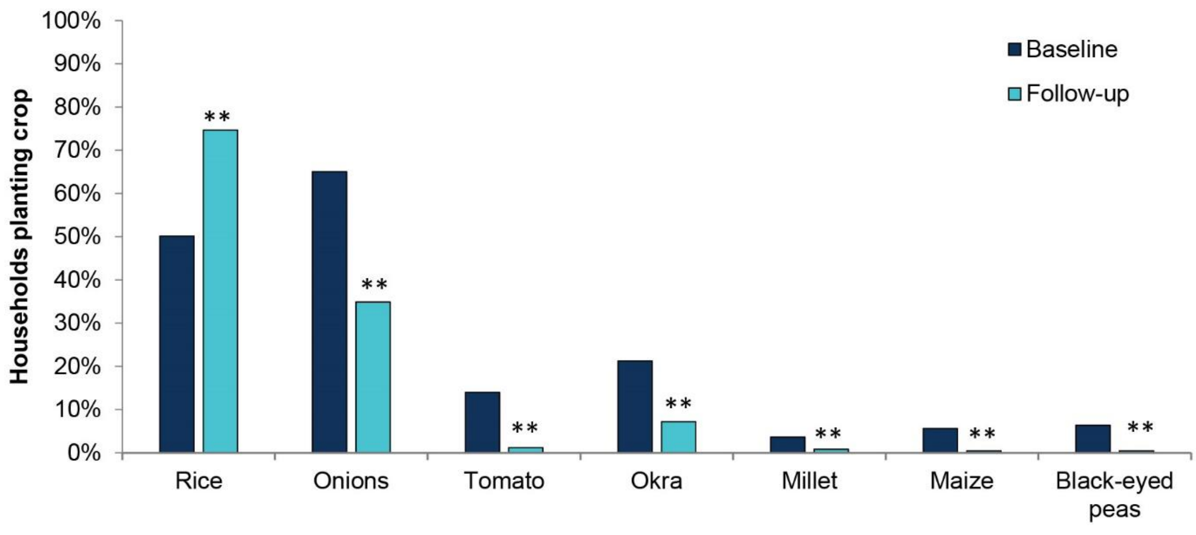
Many farmers reported that during the hot season (only), they were able to grow rice with higher yields than they could achieve before the new perimeter was built, but yields were not high enough for them to consider the harvests great successes. Some farmers described their need to learn how to cultivate in the irrigated perimeter—especially how to cultivate irrigated rice. There are farmers who had never had access to land before, and others were new to rice cultivation. They are managing a learning curve in growing rice as well as dealing with the quality of their inputs and the water, plots, and soils in the new perimeter. Many elements have come together, but yields are not yet a resounding success.

2. Crop choices and diversification

The IWRM Project also anticipated it would change farmers' crop cultivating decisions by encouraging rice production—particularly during the hot season—and vegetable production, particularly during the cold and rainy seasons. We used survey data for a descriptive analysis of whether there have been changes to the types of crops produced at baseline and follow-up. We examined crops for which at least 3 percent of all surveyed households in Podor cultivated that crop at baseline and/or follow-up, in any season. Seven crops fit that criterion: millet, maize, rice, black-eyed peas, onions, tomatoes, and okra.

Crop selection changed over time, and this change was statistically significant (*p*-value <0.01). Specifically, there was an increase in rice cultivating and a decrease in cultivating each of the seven other crops (Figure VI.4). For instance, 35 percent of households cultivated onions in any season at follow-up, compared with 65 percent of households that cultivated them at baseline. Only 1 percent of the households grew tomatoes at follow-up, whereas 14 percent had grown them at baseline. Okra farming decreased by two-thirds, with 21 percent growing it at baseline and 7 percent at follow-up, and very few if any households reported farming millet, maize, or black-eyed peas at follow-up, although some did at baseline. Part of the drop in cultivating vegetable crops is likely due to households' not being able to cultivate on land within the Ngalenka perimeter during the rainy or cold seasons, as it was too expensive to only irrigate the smaller areas suitable for cultivating vegetables. Overall, although the project was successful in increasing the share of households that cultivated rice, it was not successful in encouraging households to diversify the crops they cultivated. As noted previously, MCC's ERR calculation assumed that farmers would cultivate non-rice crops during the rainy and cold seasons. Without these additional farmer benefits, MCC may not be able to justify its investment costs ex-post.

Figure VI.4. Crop selection over time, any season (Podor)



Note: Figure shows the percentage of intervention households that reported cultivating each crop during any season for the baseline and follow-up years of data collection. Crops listed are the seven most popular crops cultivated by the entire surveyed sample in Podor. Sample size at both baseline and follow-up was 249 households. The crop mix was significantly different between baseline and follow-up (*p-value* <0.01).

*Significantly different from baseline value at the .05 level, two-tailed test.
**Significantly different from baseline value at the .01 level, two-tailed test.

Qualitative data also revealed that because the new perimeter was being used to grow rice, a number of farmers changed away from other crop choices and grew rice instead. One example of this change was explained by a WUA member in Ndiayène Pendao who was happy with it. He noted a shift from millet, a typically rainfed crop, to rice, an irrigated crop:

> Before, we grew millet, but today with the irrigation infrastructure, we are able to grow rice.—W7

Both focus group participants and interviewees noted that irrigated rice was the most widespread crop in the area. A SAED agent in Podor corroborated this:

> They grow rice, onion, and tomato in the low-lying areas. But, in the *casiers* (irrigation plots), they principally grow rice and a little okra.—S3

Farmers confirmed that typically, in addition to rice, they also cultivated garden crops such as onion, tomato, okra, chili pepper, eggplant, carrot, cabbage, and turnip. However, their choice of crop was strongly influenced by the availability of water and agricultural inputs. With the irrigated perimeter being focused on rice, less diversification of crops was a likely outcome.

3. Rice production, revenue, and investment

The Podor Activity was specifically designed to accelerate rice production. In the hot season, the main growing season for rice, there were positive significant changes on all measures of rice production, including increases in rice yield and revenue from rice sales (Table VII.3). The share of households that planted rice increased from 41 percent before the intervention to 59 percent during the follow-up survey round. The area of land under production for rice also grew from an average of 0.21 hectares among all households at baseline to 0.30 hectares at follow-up, an increase of 43 percent. This is in contrast to the finding that there was no change in the area of overall land under production (Table VI.3). This apparent contradiction is explained by households switching from farming other crops to farming rice. (We do not report on cold season rice production as the variety available is not suitable for production at that time of year, as described in section IV.C.1.c).

Households were also investing more in rice inputs per hectare during the hot season than they were at baseline, after adjusting for inflation, by about 129,000 FCFA on average, an increase that more than doubles the baseline average.[37] This includes costs for fertilizer, pesticides, manual labor, machinery, and other farming expenses. Although farmers were spending more for production, they were also getting more out of their land at follow-up: rice yields increased significantly from baseline, by an average of 2,813 kg/ha among all households in our sample (regardless of whether they farmed rice), quadrupling from baseline to follow-up. Among just households that farmed rice, the median crop yield increased from 3,750 kg/ha at baseline to 5,177 kg/ha at follow-up. This is evidence that the newly irrigated land is better for

[37] We inflation-adjusted all monetary outcomes to account for changes in Senegal's Consumer Price Index between baseline and follow-up.

rice farming than the land rice-farming households were using at baseline: more households cultivated rice, and farmers harvested more rice per hectare. As expected, because rice yield increased, there was a corresponding increase in rice revenue per hectare and in total rice revenue. Total rice revenue increased by an average of 73,000 FCFA per household in the hot season, or about $130 (which includes revenue from both selling and trading rice).

Table VI.3. Pre-post changes for rice production, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p-value*	Sample (post)	Sample (pre)
Hot season						
Household planted rice	59%	41%	18%**	0.00	249	249
Area of rice planted (ha)	0.30	0.21	0.09**	0.00	245	248
Rice investment costs per hectare (‘000 FCFA)	240	110	129**	0.00	245	247
Rice yield (kg/ha)	3,698	885	2,813**	0.00	248	248
Rice revenue (‘000 FCFA)	83	11	73**	0.00	247	248
Rice revenue per hectare (‘000 FCFA)	166	23	143**	0.00	246	247

Source: IWRM Project baseline and follow-up household surveys

Note: Sample sizes vary based on survey response rates, item-level non-response, and outlier trimming. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Follow-up data were inflation-adjusted using change in the consumer price index in Senegal from 2012 to 2017. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables. We do not report results for cold season rice production as the rice variety available is not suitable for cold season production. Our survey results found that some farmers reported cultivating rice in the cold season but call-back interviews revealed that this referred mainly to harvesting late rice that had been planted during the rainy season, as detailed in section IV.C.1.c.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

Beyond selling rice (either for money or in-kind trades), many farmers are consuming the rice that they are harvesting. Among households that harvested rice, they are consuming, on average, 49 percent of their harvest, which is more than the average amount farmers reported selling (24 percent) and trading (14 percent) combined.[38] Selling rice directly for income constitutes a smaller share of what farmers do with their harvest than consuming or trading rice.

We do not have evidence that the increase in rice production in Podor affected market prices for rice. In Senegal, a commission composed of representatives from producers, distributors, farmers’ bank, SAED, and other stakeholders sets a target wholesale price for rice. That price does vary in practice based on local market conditions, rice quality, quantity being bought/sold, and other factors. In 2018, SAED reported a target price for paddy rice of 130 FCFA/kg.

Farmers we interviewed stressed that the availability of quality agricultural inputs such as seeds and fertilizers was crucial for improving agricultural production in Podor. Some farmers in GIEs use self-financing through contributions of group members to cover these costs, whereas

[38] Farmers also give away part of their harvest and other parts of their harvest can be lost to pests.

other farmers use credit. With the project's completion, more households grew rice, and the cost of production per hectare was higher; therefore, more farmers used credit. . Farmers obtain inputs for their crops using credit contracted from the *Caisse Nationale de Crédit Agricole du Sénégal* (CNCAS). One member of the GIE Doulel Mbarick said:

> The cost of investments depends on the needs identified by the agricultural advisors from SAED. They [the investments] are funded by the bank, which issues purchase orders that we use to obtain [inputs] from suppliers. —E8

Some farmers criticized the quality of the agricultural inputs, saying they led to a decline in agricultural yield. Several were particularly critical of the seed used in the 2016–2017 season. They indicated that the variety of seed they had access to was uncertified and contained impurities harmful to seedlings. Others also reported that the fertilizer provided was inappropriate for rice. For example, one farmer remarked:

> Last year (2016), we came upon bad seed. If it grows, there is wild rice that also grows. We were provided fertilizer that was not fertilizer for rice, but fertilizer for peanuts or corn. —C4

Despite their reports of poor performance on some elements of the rice production system in the new perimeter, farmers reported that overall production in the area was improved, and that yields in the hot season were higher than they were before the project. Nonetheless, in general farmers were not deeply satisfied with the yields.

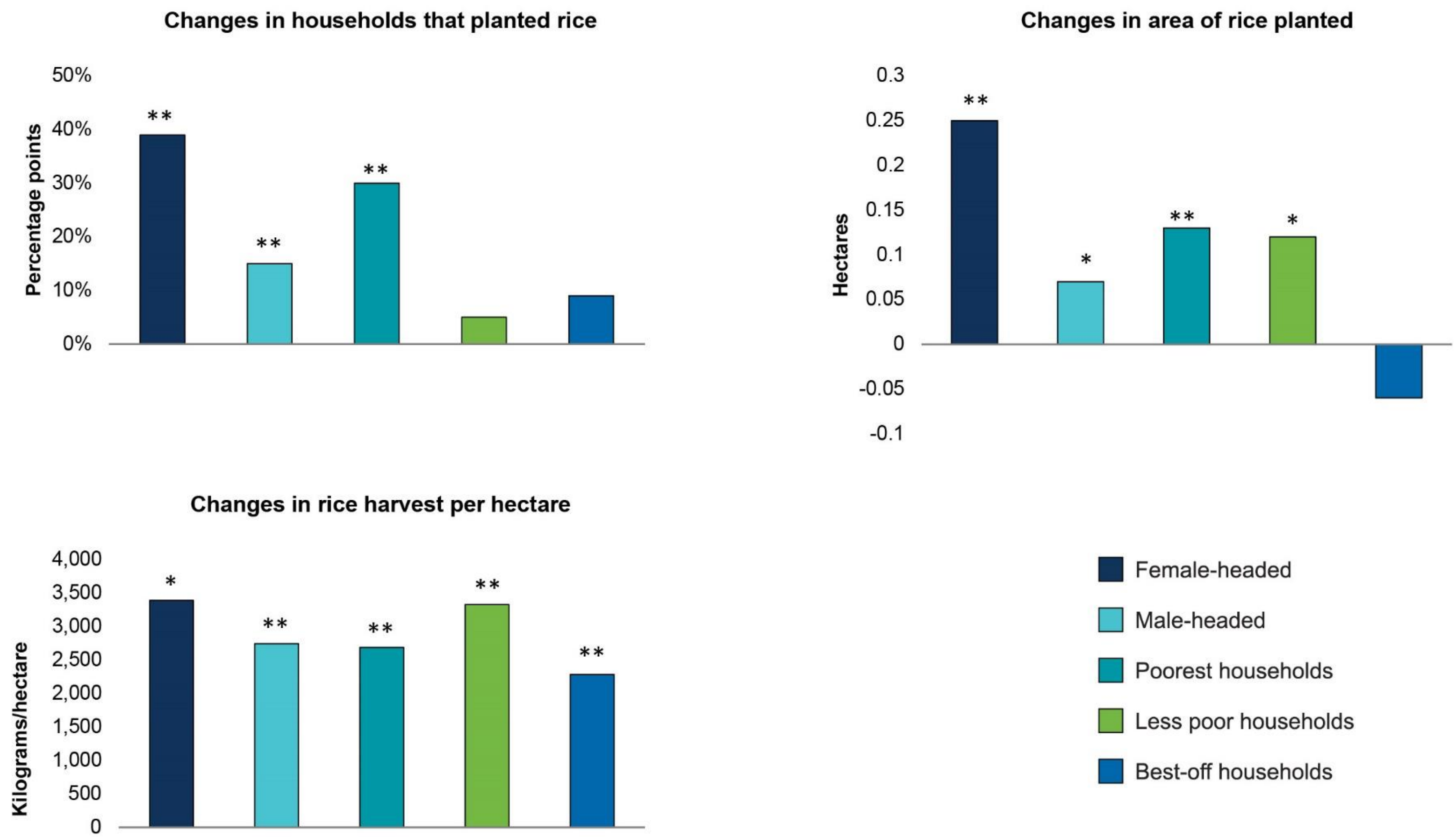
4. Agricultural production for women, the poor, and the landless

We conducted subgroup analyses on rice production by gender of household head and poverty level. With only 28 female-headed households, the estimates for gender differences have wide confidence intervals. We focused on rice production during the hot season—the main growing season—among all intervention households (Figure VI.5). As was the case in examining agriculture production, there is evidence that female-headed households expanded their rice production more than male-headed households did. Although both male- and female-headed households had significant increases in the share of households that cultivated rice, a significantly larger share of female-headed households cultivated rice (39 percentage point change) compared to male-headed households (15 percentage point change). The change in the area of rice cultivated, while significant for both groups, was also larger for female-headed households, a difference of 0.18 hectares between the groups.[39] Both groups saw similar significant increases in rice yield from baseline.

[39] Due to the small sample size of female-headed households, the 95 percent confidence interval for each subgroup estimate is large. The change in female-headed households that cultivated rice ranges from 16 to 63 percentage points; the change in area of rice cultivated ranges from 0.11 to 0.39 hectares.

It appears that poorer households drove some of the positive changes in rice production for the hot season, because it was only for those households that there was a significant change in the proportion of households cultivating rice—a 30 percentage point increase. The two poorest groups of households saw a positive increase in the average area of rice cultivated, but there was no change in rice area cultivated for the best-off group of households. Yield benefits were again widespread, with households at all income levels enjoying similar significant increases in the amount of rice they harvested per hectare. Complete subgroup results by gender of household head and poverty group are included as Appendix C.

Figure VI.5. Changes in rice production measures by subgroup (hot season, Podor)



Source: IWRM Project baseline and follow-up household surveys

Note: Changes in rice production from baseline are shown for the main growing season (hot season) by the gender of the household head and the poverty level of the household. Poverty status of the household was calculated using the Poverty Probability Index for Senegal (Schreiner 2016). Sample sizes for female-headed households were 27 or 28, and for male-headed households they were between 217 and 221. Sample sizes were 120 or 121 for the poorest households, 80 or 81 for the middle income group, and 45 to 47 for the best-off households. There were significant differences by gender for area of rice cultivated (*p-value* 0.02) and by income level for share of households that cultivated rice (*p-value* 0.03).

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

5. Total production, including other crops

Our findings on overall agriculture production are consistent with our findings on rice production and understanding on which seasons farmers cultivated within the perimeter (Table VI.4). During the hot season, there were significant positive increases from baseline in total and per hectare agricultural investment costs and agriculture revenue.[40] These increases appear driven by the large increases in rice production.

During the cold season, there were significant negative changes from baseline on all four measures of investment costs and revenue among farming households. This is likely because they were not able to cultivate in the irrigated perimeter during the cold season: doing so has not proved to be profitable when balancing the cost of irrigation and other inputs with the potential revenue.

Table VI.4. Pre-post changes for total agriculture investment and revenue, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p-value*	Sample (post)	Sample (pre)
Cold season						
Agriculture investment costs (‘000 FCFA)	106	188	-82**	0.00	244	244
Agriculture investment costs per hectare (‘000 FCFA)	196	353	-158**	0.00	240	236
Revenue all crops (‘000 FCFA)	144	288	-144**	0.00	215	235
Revenue all crops per hectare (‘000 FCFA)	254	510	-256**	0.00	214	228
Hot season						
Agriculture investment costs (‘000 FCFA)	113	67	47**	0.00	245	246
Agriculture investment costs per hectare (‘000 FCFA)	218	146	72**	0.00	245	245
Revenue all crops (‘000 FCFA)	94	54	40*	0.02	225	214
Revenue all crops per hectare (‘000 FCFA)	161	82	79**	0.00	223	210

Source: IWRM Project baseline and follow-up household surveys.

Note: Results are based on all intervention households. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Follow-up data are inflation-adjusted using change in the consumer price index in Senegal from 2012 to 2017. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables.

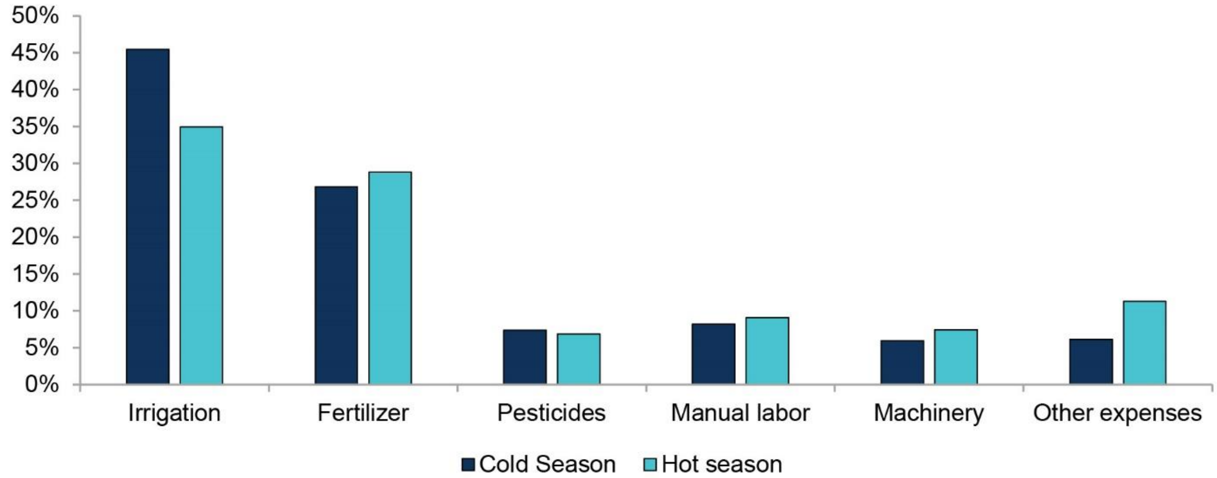
*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

[40] We define investment as the total amount spent by a household on fertilizer, pesticides, machinery, labor, and other farming expenses, such as transportation, management fees, storage and warehouses, and financial fees. We define revenue as the total amount received from selling all cultivated crops plus the value of traded crops, using the median price for each crop in our survey data.

When examining the component parts of agriculture investment, we find that the main expenses for farmers were irrigation and fertilizer costs (Figure VI.6). Those components combined accounted for 72 percent of total investment costs in the cold season and 64 percent of total investment costs in the hot season.

Figure VI.6. Composition of agriculture investment costs, among farming households (Podor)



Source: IWRM Project follow-up household survey

Note: Figure displays the share of total agriculture investment costs that farming households in the Podor intervention group spent on each cost component during the cold and hot seasons for the follow-up year of data collection. The sample represents 133 households in the cold season and 154 households in the hot season. A comparison to baseline values is not possible due to differences in survey questions.

D. Agriculture profits and household earnings

This section explores how the changes in agricultural production described above are reflected in changes in agricultural profits and household earnings in the Podor Activity area. We examine the following research questions:

1. Have agricultural profits changed?
2. Have household income levels changed, including changes in components of household income, and has income shifted between agricultural and nonagricultural sources?
3. Do farmers perceive an improvement in their living standards?

Main findings

- Despite the improvement in rice production in the main growing season, there was no statistically significant change in agricultural profit in this season, likely driven by an increase in agricultural investment costs.
- We find a decline in agricultural profit in the cold season relative to baseline. While it was profitable to farm in the cold season at baseline on land in the Ngalenka cuvette, at follow-up, households were not able to continue the same activities on the new farm land within the perimeter.
- We find no significant change from baseline in off-farm earnings during the hot season. Households were able to maintain their off-farm activities at the same time that they were expanding rice production on land within the perimeter. However, we find a significant decline in off-farm earnings during the cold season.

1. Changes in agricultural profits

We begin our analysis by examining changes in agricultural profit. Agricultural profit is the difference between reported agriculture revenue and agriculture investment costs (reported in the previous section in Table VI.4). For the cold season, we find a significant decline from baseline in agricultural profits of roughly 57,000 FCFA, or $102 (Table VI.5). We also find a significant decline in profit per hectare. This is not surprising, since households did not farm in the new perimeter in the cold season as it was not cost-effective to irrigate parcels for vegetable farming, as described earlier. Although it was profitable to farm in the cold season at baseline on land in the Ngalenka cuvette, at follow-up, households were not able to continue the same activities on the new farm land within the perimeter.

In the hot season, we find no significant change in agricultural profit or profit per hectare. Recall that we found more rice production in the hot season, including higher rice yields and revenue per hectare; however, it appears that this did not translate into an overall positive change in agricultural profit. At both baseline and follow-up, average hot season agriculture profit is negative, compared to positive values at baseline and follow-up in the cold season. Although households shifted their farming focus to the hot season, it remains unprofitable to farm then. Farmers may still be learning how to optimize production in their newly irrigated land within the Ngalenka perimeter. Since we have information only from before and after the project, with no counterfactual such as a comparison group, factors external to the project could also influence the results. For example, the lack of improved agricultural profit despite increased rice production in the hot season might be influenced by high credit payments. We do find that total agricultural investment costs increased in the hot season more than total agricultural revenue increased, meaning that increased investments by farmers did not result in a more profitable rice harvest, on average. However, farmers are also consuming more rice than selling rice at follow-up. So while that consumption is not accounted for in agricultural profit, the household’s food security may have increased with improved rice yields. Overall, although they have all received land in the Ngalenka perimeter, households in our sample have not yet seen a positive change in their agricultural profit across seasons.

Table VI.5. Pre-post changes for household earnings and agricultural profits, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p-value*	Sample (post)	Sample (pre)
Cold season						
Agricultural profit (‘000 FCFA)	37	94	-57*	0.02	247	235
Agricultural profit per hectare (‘000 FCFA)	27	155	128**	0.00	245	233
Household earnings, off-farm, (‘000 FCFA)	83	126	-43*	0.02	247	245
Hot season						
Agricultural profit (‘000 FCFA)	-19	-13	-6	0.58	248	213
Agricultural profit per hectare (‘000 FCFA)	-29	-51	22	0.14	246	208
Household earnings, off-farm, (‘000 FCFA)	171	147	25	0.62	248	245

Source: IWRM Project baseline and follow-up household surveys

Note: Sample sizes vary based on survey response and whether the measure contains all households or just farming households. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Follow-up data are inflation adjusted using change in the consumer price index in Senegal from 2012 to 2017. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables. Sample sizes vary based on survey responses, item-level missing data, and outlier trimming.

*Significantly different from the baseline value at the .05 level, two-tailed test.

**Significantly different from the baseline value at the .01 level, two-tailed test.

Our qualitative data give us insight into the opportunities and challenges farmers found in improving their income and living standards through farming. The men and women we interviewed who belonged to GIEs and GPFs in the Ngalenka perimeter reported changes in their profits from agriculture in the time since the perimeter’s completion. Many reported that the first season of rice in the perimeter was very productive, with reports of excellent harvests and good prices for harvested rice. Of that, farmers estimated a high amount—40 to 50 percent—went to repay credit, still leaving acceptable profits. However, the majority of farmers, both men and women, described experiencing increasingly lower profits due to lower yields in the seasons that followed.

Farmers who described lower yields identified several different causes, as mentioned in the last section. These include the small size of their parcels, problems with the perimeter’s irrigation infrastructure that prevent water from flowing to their fields, soils that are not well suited to rice cultivation, erosion of soils, the system of leveling fields, and fields whose elevation is higher than the canals, preventing gravity-fed irrigation. Overall, there were many reports of poor and failed harvests during the three years since the completion of the perimeter.

Other farmers reported that the lack of improved profit was mainly due to the high costs inherent in rice agriculture. For some of these interviewees, a main factor was the high cost of farm inputs; for others it was that bank interest rates were too high. Still others mentioned high costs for irrigation, both the fees and the costs for electricity and diesel for pumps. A final category of high costs mentioned for rice cultivation includes transportation of crops, payments for storing and processing including hulling, manual labor for planting and harvesting, and the like.

Whether farmers experienced declines in profit due to low yields, high costs, or both, those who have experienced a decline in profits reported that this leads to difficulties in accessing inputs for subsequent seasons and repaying the banks, often because the little revenue earned is used for the needs of their households. One farmer eloquently summarized both sides of the profit equation, explaining how female farmers in her GPF dealt with both low yields and credit challenges in changing to a high-input crop in the perimeter. She reported, "Before, we cultivated millet and watermelons. With MCA, we launched into rice. Everything that we harvest is used to reimburse the bank. Sometimes you are even obliged to sell a part of your cattle, if you are willing, to repay the credit."—F6

Some farmers we spoke with undertook market gardening of crops such as okra, eggplant, tomato, or onion in small sections of the perimeter or on suitable land outside the perimeter. These farmers found that market gardening during this change in agricultural production in their area allowed them to maintain a separate stream of revenue that those who solely cultivated rice did not have. There were GPFs, GIEs, and members of the community who were not affiliated with such groups who reported that it was the sale of market garden products and other diversification in the composition of their incomes, such as animal husbandry, fishing, farming multiple crops, and small businesses, that allowed them to feed their families and/or repay a portion of their rice debts. The IWRM Project's efforts to increase diversification of agricultural production through crops like vegetables had the opposite effect, likely because irrigating the perimeter did not make economic sense in the cold and rainy seasons.

2. Changes in household earnings and living standards

Although there was no positive change in agricultural profits from baseline, farming is just one component of a household's income. We estimate the change in households' off-farm earnings as well, since households can reallocate labor toward agricultural production or off-farm labor, depending on opportunities and risks presented by the irrigation and land tenure security interventions of the project, or other factors. We calculate household off-farm earnings from reported labor income; that is, payment to household members for work outside of farming their own land, including salaried positions, non-agriculture labor (like tailoring or catering), agriculture labor on a farm outside of the household (like a day laborer), and business revenue.[41]

Since households cultivated less agriculture in the cold season, we could expect them to increase their off-farm revenue. However, we find a significant decline from baseline in off-farm earnings during the cold season of roughly 43,000, FCFA or $77 (Table VI.5). It is unclear what is driving this change. It could be that households expected to farm within the perimeter and it was too late to shift to off-farm labor when they realized that irrigation pumps would not be used for vegetable farming that season. As this is pre-post analysis, factors that are external to the project could be driving the decline in off-farm earnings and our discussions with farmers did not

[41] Due to differences in how consumption was measured at baseline and follow-up, we are unable to estimate the pre-post change in consumption for Podor as an overall measure of household well-being. Instead, we focus on our qualitative findings in this area.

reveal an explanation for this finding. We find no significant change from baseline in off-farm earnings during the hot season. Households were able to maintain their off-farm activities at the same time that they were expanding rice production on land within the perimeter.

Although profits and earnings have not increased, some women interviewed reported the project has improved their well-being because women have been able to access land for the first time. Some female farmers argued that even if the land they now have is typically 0.40 to 0.50 hectares, this is a positive change, as it has enabled some to have an income-generating activity and many to produce rice for their families' consumption. They note that before the project, they had virtually no access to agriculture. With this land, respondents noted an improvement in their quality of life, as many more of them are now able to cultivate, harvest, transform, and/or even sell products in the market and meet the needs of their families. The president of a GPF stated this well when she said:

> Prior to the creation of the GPF, it was very difficult for us. But since its creation through MCA, our conditions of life have improved. Before, we were in poverty. Our incomes were dispersed. At present, there is a framework that allows us to pool our incomes so each of us can benefit.—F7

A female member of a GIE in Podor, expressed a similar sentiment:

> The arrival of MCA has been an advantage because before MCA we had no income, we had no field, nor anywhere to cultivate our rice. But with their arrival we really had a change because at least we have rice to feed our children.—E6

E. Land administration and governance

In this section, we describe institution-level outcomes of the LTSA for the Podor project area and address the following research questions:

1. Have local government agencies become more effective at land management, including land allocation, land formalization, and conflict resolution?[42]
2. Do institutions receive adequate support to carry out their functions?[43]
3. Is there greater confidence in the efficacy of these institutions?
4. What impacts did the project have outside of project areas?[44]

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[42] We note that our qualitative data collection among individuals and in focus groups and our case study research found resistance to frank discussion of land conflicts, so our results for this outcome are limited.

[43] Discussion of the results for this research question is folded into discussion of research questions 1 and 3.

[44] Project impact outside of project areas cannot be measured rigorously but will be the subject of additional study in the final phase of the evaluation. We provide in Section VI.E.3 preliminary information on recent projects that consciously mirror some of the implementation of LTSA.

To answer these questions, we conducted an in-depth case study in Guedé and Ndiayène Pendao (NP), two of the five Podor communes that received the LTSA. The case study involved speaking with officials involved in land administration, land tenure committee members, and land management technicians, as well as members of GIE and GPF in these two communes and managers of other land-related projects in the area. To learn more about the beneficiary perspective on the effectiveness of local institutions in land management, we later interviewed farmers and additional GIE and GPF leaders in NP, which received a different set of interventions than the other eight communes included in the LTSA. Specifically, activities in NP included the construction of a 450 ha irrigated perimeter at Ngalenka, a participatory process of land allocation within the perimeter, and the delivery of use titles to the Ngalenka perimeter to 53 GIEs and 13 GPFs.

Main findings

- LTSA outreach, education, and land grants provided to GIEs and GPFs in the Ngalenka perimeter created strong demand for formalization in Podor department and formalizations increased during the project but lack of funds to cover the costs of land surveys, and Rural Council administration have led to a backlog of applications since project end.
- The POAS is in use in Guedé, and Ndiayene Pendao and zone commissions are functioning in Guedé since receiving funding from a donor project.Thus, donor funding helps support commune land institutions' implementation of the LTSA principles and practices post-compact.
- The SIF database is in some use by the land office in Ndiayene Pendao, with assistance from an external funder. It is not functional in other communes; lack of human and material resources limit its use.
- Farmers, when asked in qualitative interviews, expressed increased confidence in the land institutions since the LTSA project.

1. Effectiveness of local government land management and conflict resolution

As described in Chapter II, the LTSA inventoried commune land and provided communes with technical assistance, operationalization of land management procedures, and demonstrations of five improved tools related to land policy and management. In NP, the LTSA also implemented a participatory process for land allocation and titling of land in the new Ngalenka perimeter.

In order to determine whether the tools introduced by the LTSA have proven effective and have been sustained, we conducted follow-up visits in December 2017 in the two communes selected for the case study in the Podor region: Guedé and NP. Both communes received the standard LTSA interventions, and NP received the land allocation sub-activity. Below, we report outcomes for each of the communes and describe commonalities and differences in intervention outcomes.

Guedé, located to the east and south of the regional capital of Podor, is bordered by the Senegal River to the north, and about two-thirds of its area extends south of National Route 2. The commune covers 149,000 ha of land and has a population of about 48,000 (SAED 2010). About 21,000 ha of Guedé's land are potentially irrigable, with 4,500 ha of land located in four shallow depressions known as "cuvettes," which had been improved in the past for irrigated agriculture (POAS 2005). NP is located south and west of the regional capital of Podor, covers 126,000 ha, and has a population of about 19,800. For the NP area, 24,400 ha are cultivable and 5,400 ha were under irrigated cultivation at the start of the IWRM project, including about 74 ha of the 1,087 ha cuvette of Ngalenka.

a. Spatial planning and land use regulation-POAS

The principles for land use, like those in the Delta area, are understood by commune officials in Guedé and NP. Guedé and NP began work on the POAS in 2003; NP adopted the first version in 2003 and Guedé adopted the first version in 2004. It included regulatory maps showing the areas of designated land uses such as zones for cultivation, herding and mixed activity, forest zones, water and rangeland protection. The LTSA provided training, public education, and materials to support the commune's enforcement of the POAS, including manuals and maps, signage, a registry book to record conflicts, and a film demonstrating ways to solve herder/farmer conflicts. In NP, the LTSA gave assistance to implement the POAS in the form of public education activities and support of the work of the zone commissions, which are responsible for identifying potential land conflicts and helping to mediate them. For the most part, the agricultural zones and herding zones in NP are separated by the National Route 2 (*Route Nationale n°2* or RN2) road, and the water points and livestock herding corridors are indicated in both French and Arabic on the LTSA-provided signage. In NP, the LTSA trained individuals in POAS principles and financed DC members' visits to villages to hear about land management problems, obtain information, and help out with any land conflicts in the villages.

In our visit to Guedé and NP in December 2017, we found that the POAS was being used more actively in both Podor communes we visited than in the Delta area. Commune officials in Guedé described using the SIF and records produced during the LTSA implementation to resolve a land conflict, indicating that the documentation resolved the conflict. In contrast with the two communes we visited in Delta, zone commissions were functioning and active in NP and Guedé. The commissions had been revived with support from the *Agence Francais du Developpement* by way of the AIDEP project. The reason for the period of inactivity post-MCA and before AIDEP was budgetary: having regular meetings with zone commission members is expensive and not earmarked within the regular budget of the communes.

b. Principles and procedures for the allocation of land rights

As in all communes included in the LTSA, activities in Guedé and NP began with a land inventory, carried out in 2011. In Guedé, the inventory revealed the persistence of customary land tenure and little activity by the Rural Council in taking control of landholding through formalization. Similarly, data on recording of land transactions revealed that most land transactions remained intra-family or informal, and the majority of landholdings were less than a hectare in size. LTSA consultants helped the Rural Council to draft and adopt procedures for land allocation and redistribution. Guedé set an order of priority for the different classes of landholders who might apply for land allocation or formalization. Customary landholders were given first priority, followed by individuals who held use rights but were not actively using a land parcel. Lowest priority was given to new applications from small or medium farm entities (20 ha limit). No provision was made for granting land to large scale farming projects. The quota for women was set at 5 percent; this limit was described as a mandated minimum for any commune-sponsored perimeter and not as a limit on the number of women presenting applications for land grants, although applications received by the LTSA consultants nearing the end of the project showed only 3.3 percent from women.

In Ndiayène Pendao, the combination of the activities of inventory and formalization along with the creation of a new irrigated perimeter, gave the only opportunity in the IWRM Project to withdraw some of the land under customary control of specific families in order to accommodate the requests of some landless farmers and women producers. The 2011 inventory in NP covered both the specific Ngalenka perimeter and the nearby villages, which made it possible to determine the status of all potential claimants to land rights in the new perimeter, including those with previously established customary claims, those who had claims outside the perimeter, or those who were landless. In the finalized 2011 agreement, 60 percent of the planned Ngalenka irrigated perimeter was given back to the three familial groups that exerted historical claims on the land (whether they were actually farming it or not), 20 percent of the land went to local landless populations, and 10 percent went to women's groups. Stakeholders reserved the remaining 10 percent for farmers who were occupying and farming about 79 ha of the 450 ha perimeter before its development (MCC 2015c).

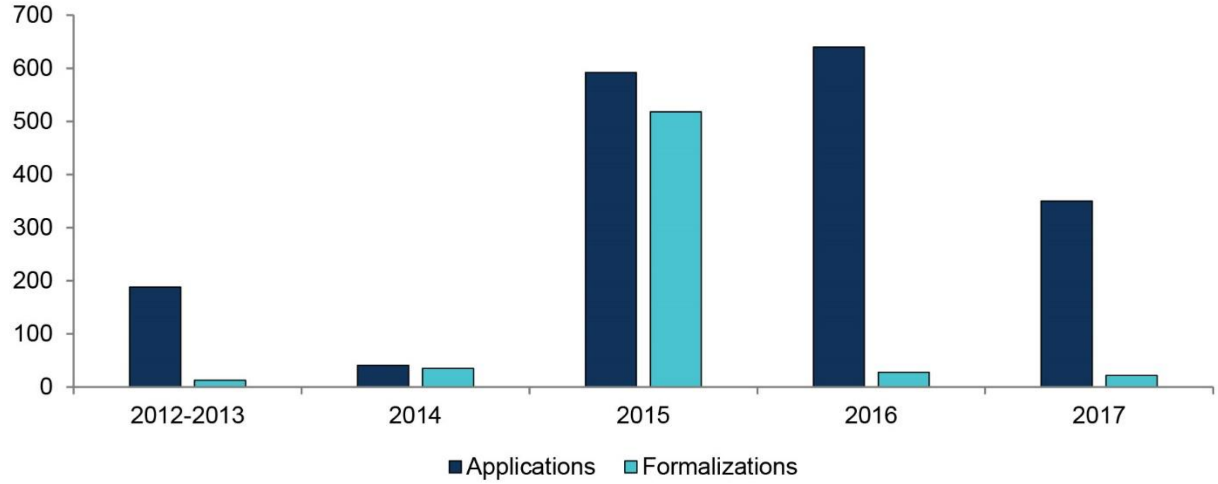
NP and other communes have found it more difficult to apply such policies and procedures since LTSA ended because whereas formalization of customary claims is relatively easy, grants of new land is not. For individuals with customary claims, the technical work of measuring the parcel is not costly and the verification of the landholder status and agreement with neighbors is straightforward. In contrast, to grant land to a landless applicant, the municipality would have to acquire rights to a vacant parcel if the municipality did not already control one. As a result, in 2015 the Rural Councils in Guedé and NP mostly formalized existing parcels while only granting a few new parcels. Similarly, in 2016 and 2017, the Rural Councils had only moved forward and given grants to applicants who had requested formalization of existing customary rights. In Guedé, the Domain Commission members explained this as both a practical and policy matter: the municipality has had no reserve lands to create new parcels and the local community has had a strong respect for traditional rules and practices, in particular the maintenance of customary lineage rights in the land.

In both Ndiayène Pendao and Guedé, the Domain Commission members expect that, when the AIDEP and other international assistance projects are undertaken, they will again be able to offer newly-arranged and improved land parcels to a variety of local citizens, and the Principles and Procedures will guide division of lands.

c. Changes in number of applications for land titles and land allocation

LTSA fieldwork began in earnest in Guedé in February 2015 and continued through July 2015. The LTSA received and helped prepare 546 applications for review by the Guedé technical committee and the Rural Council, who approved 518 grants of formalization in June 2015. Among the applications, 504 were for individual and family landholdings, and 14 were for farm enterprises. The public interest in formalizing landholdings, generated by the IWRM Project, continued after the closeout of the project and during 2016–2017 citizen applications continued. However, the Rural Council has reviewed and taken action on only a small number of these requests (Figure VI.7)

Figure VI.7. Land formalization applications and grants: Guedé



Source: Guedé/NP Registry of Deliberations and Registry of Applications (reviewed December 11-14, 2017)
Note: From 2007 to 2011, there was an average of 21 formalizations a year

The Guedé DC members we interviewed in December 2017 explained that the formalization activities of the IWRM Project gave rise to a higher demand for land titling. When the project teams arrived in the village, and the landholders saw their neighbors' fields being measured with the GPS, they were eager to file applications and get a precise measurement of their parcels with an accurate placement of boundary markers. These actions gave them a strong sense that they could protect their land against encroachment.

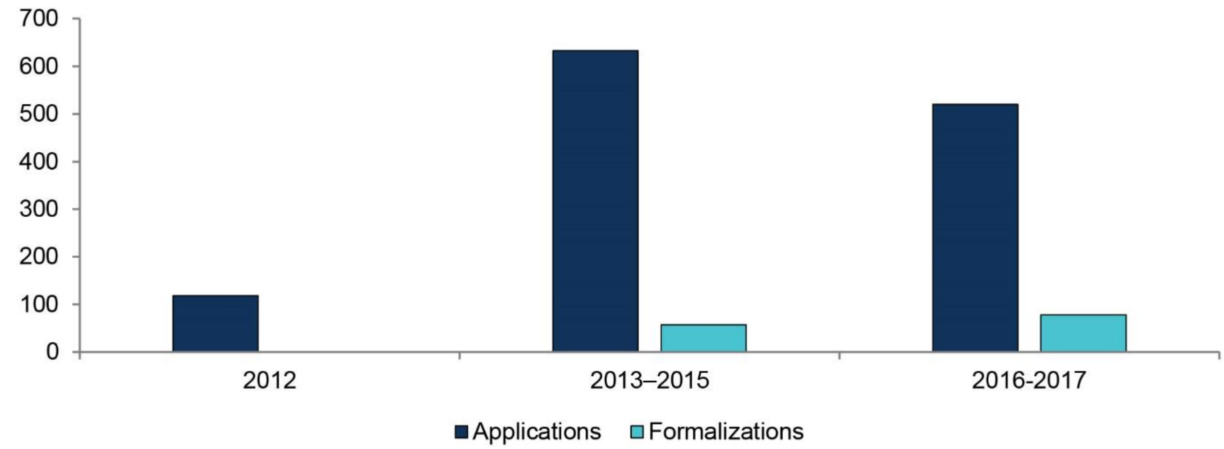
The ability of the commune to keep up with the inflow of applications since the end of the LTSA project has been hindered by the lack of resources to cover the costs of reviews. Nevertheless, the Rural Council has made the effort to complete and review some files in both 2016 and 2017, as shown by VI.7. In September 2016, it granted formalization for 28 agricultural parcels, covering 130 ha. In September 2017, it issued formalization for 22 parcels covering 516 ha, which had been prepared under the state sponsored project *Rizicole de Guia.*

The lack of funds for land management has been caused, in part, by nonpayment of fees by citizens who have received land rights grants but have not claimed their title documents. The DC members explained that most local citizens feel secure enough once their land rights have been recorded in the registry. However, the DC members also noted that one group of land grant recipients who had earlier been displaced feared a conflict over their new land parcels. These landholders quickly paid their fees and took their title documents.

In December 2017, there were over 1,000 application files pending in the registry office, and the DC members were hoping that a new project, AIDEP, funded by the *Agence France de Developpement* would help them process many of these.

Land formalization procedures in NP follow processes like those in other communes we visited: land applications are made using the standard forms, and commission members undertake field missions to measure and precisely locate each parcel (using GPS) and to engage with the village chief to clarify the status and eligibility of the applicant. Importantly, the Rural Council accepts only applications from individuals who are already established as customary proprietors, and only for the specific parcels they control. Unlike Guedé, no applications in NP are processed and acted on if the applicant simply asks for a grant of land without specifying a parcel. In 2015, the Rural Council in NP processed a smaller number of parcels because of the focus of the project on Ngalenka. In July 2015, the Rural Council granted rights of *affectation* to 57 parcels, covering 769 hectares, and it followed in 2016 and 2017 with 16 and 62 more grants of *affectation* for agricultural parcels and another 350 grants of *permis d'habitation* for village house plots.

Figure VI.8. Land formalization applications and grants: NP



Source: Guedé/NP Registry of Deliberations and Registry of Applications (reviewed December 11-14, 2017)
Note: From 2007 to 2011, there was an average of 3 formalizations a year

Like the other communes, the DC has found itself stretched beyond capacity by the numbers of applications and is proceeding slowly. The main obstacle in carrying out the formalization procedures effectively is the difficulty of scheduling and paying for the field missions that DC members must make in order to measure and precisely locate each parcel using GIS and to verify the status of the applicant with the chief and neighbors.

The DCs in both Guedé and NP use LTSA-introduced procedures for formalizing land rights, but these procedures are interpreted differently than in other communes. In interviews, members of the DC in NP clarified that they focus on applications that request the formalization of existing land rights. When the DC considers an application, the village chief is invited to sit with the DC and to certify the applicant and the appropriateness of the application. The DC explained that they interpret their role in a different way than in other communes, where applicants may request land without specifying a parcel and without asserting eligibility based on past customary rights. The DC in NP strongly expressed their adherence to customary rights, whereas the DC in Guedé explained their approach in terms of practical limitations, such as costs and unavailability of lands. Moreover, the DC in Guedé stated that when assisted by AIDEP or other future projects they would seek to apply the principles and procedures that would allow more inclusive participation by the landless and women. In NP, the DC was not similarly optimistic.

d. Landholding data management (SIF) and registry office operations

As noted in Section VI.e., the LTSA project was able to process large numbers of land titling applications by using GPS parcel survey and mapping and document processing in the SIF. The project provided each commune registry office with the equipment and software to continue these operations and train technical staff or registry officers. As in the Delta communes, the combination of limited budgets, inability to retain technically trained staff, and difficulties of equipment maintenance and reliable electric supply have hindered the continued use of the SIF post-compact in the Podor communes.

LTSA provided technical training for use of the SIF to Guedé's municipal secretary and the SIF was used for LTSA applications during 2015. However, at the closeout date of the IWRM, the SIF in Guedé contained only the data set of the applications made in 2015. The previous records of land grant applications and Rural Council deliberations, approving *affectations*, and other rights or transactions had not been incorporated into the system. Similarly, the applications made by citizens after June 2015 were not entered into the SIF.

During our December 2017 visit to Guedé commune headquarters, the registry office was under construction, and the computer hardware and software were not being used. The registry books were kept in the office of the deputy mayor and were up to date, but the system for keeping and retrieving paper applications and transaction documents could not be observed because of the construction.

NP's land office is functioning, and a technician enters applications for land formalization into the SIF, although it is not fully updated with information on the completed formalizations. The technician available during the visit was a temporary hire, and commune officials said turnover is high in this position. As in other communes, the main files consist of paper dossiers of applications and the results of deliberation processes and formalizations. Commune officials confirmed that land titling fees are rarely paid, and that the fees are waived for the poor.

2. Farmers' perceptions of land institutions

To understand beneficiary perspectives on the effectiveness of land institutions, we interviewed individual farmers and GIE and GPF leaders and asked their perceptions of these institutions and the processes of land formalization over time. We found that respondents had a difficult time comparing these institutions pre-LTSA to the present and largely focused on their perceptions at the time of the 2017 or 2018 interviews. Respondents reported that commune officials and land managers are carrying out land-related tasks in their communes, although the specific responsibilities of different bodies seemed to differ somewhat between communes. In NP, a single DC deliberates and manages attribution of land. Guedé has two DCs which operate in the eastern and western portions of the commune to manage land-related matters. In general, respondents reported that they have confidence in their local land authorities due to a more efficient and professional land allocation process since LTSA. As one farmer in NP stated, "The Domaine Committee (DC) came with procedures to help us. We are pleased with the president of the DC."—C9

As in the Delta project areas, the main outcomes of the LTSA are increased knowledge about and demand for land formalization. Farmers we interviewed indicated that, before the

LTSA project, they were fully aware what land belonged to them, but that the education outreach of the LTSA led them to seek formalization their land rights. One farmer, talking about the new procedures for land formalization, said,

> *"*I believe that it is better [now]. Whatever is the portion of land that you have, you should arrange to get your documentation. This should be done in the same manner as when you own a house.*"* —C5

3. Impacts outside project area

As mentioned in the sections on the Delta Activity and LTSA, the principles and practices around land tenure regularization, formalization, deliberation and allocation that formed much of Phase II of the LTSA have been adopted by donors and local governmental agencies, particularly in the department of Podor. IPAR, a Senegalese land-focused think tank, in conjunction with the Food and Agriculture Organization (FAO) and funded by the German federal government, began training commune-level land agencies, creating dominal land committees and related bodies to implement more formal land tenure security activities in 22 communes in Podor (IPAR 2019). Representatives of communes in the department of Matam and, notably, from Mauritania, Senegal's northern neighbor whose population along with Senegal's has historically shared customary claim on lands near the river, have participated in outreach and education meetings on these principles and practices.

F. Land security, land conflicts and investment in land: Podor

In the previous section, we discuss outcomes of the LTSA on land administration and governance, as well as farmer perceptions of the effectiveness of land institutions. In this section, we focus on how the IWRM Project affected land formalization and land conflicts. Our analysis is restricted to households that were part of the Podor Activity as well as the LTSA; thus, our sample includes only the households that received land in the Ngalenka perimeter. We answer the following research questions:

1. Has the extent of land formalization changed? Is there greater awareness of the process for formalizing land?
2. Have perceptions of land tenure security changed? Is there increased confidence in the land tenure system? If so, why?
3. Has demand changed for formalized land rights and are the costs of formalizing land rights perceived as reasonable?
4. Has the number or severity of land conflicts been reduced? Has the type or nature of land conflicts changed?
5. How has the IWRM Project affected women's access to land? How has it affected the landless?
6. How have changes in land security perceptions, formalization, conflict, or conflict management affected investments on land?
7. What have been the constraints or barriers to land access? Do these differ depending on gender, income levels, or age?

Main findings

- Examining the percentage of plots that are titled for each household, we find that, on average, one-quarter of plots have a land title before and after the intervention.
- Households with land in the Ngalenka perimeter were less likely to report knowing the process for obtaining land titles at follow-up than at baseline. Since the project included an extensive educational outreach on new land titling procedures, it is possible this outcome reflects a decrease in confidence rather than in knowledge.
- Very little conflict over land was reported overall and there was little change in conflicts between baseline and follow-up.
- Decisions about investment in the perimeter do not appear related to perceptions of land security or concerns about conflict. Rather, farmers cultivate when the likelihood of a good harvest is highest-which is the hot season in Ngalenka, when water flow can be well regulated, credit is available, and other communal actors with land in the perimeter, under advice from the local agricultural extension agent, are also farming there.
- Women and landless residents received land in the Ngalenka perimeter: 10 percent of the land was allocated to each group. This is viewed as a very positive element of the project. However, women's groups have not been able to cultivate their preferred market garden crops, because the costs for inputs, especially electricity to run pumps, exceed any potential profit for the small land area that would be cultivated.
- Customary land tenure is dominant, thus land "allocation" most often consists of formalizing customary claims, which creates barriers to land access for those without customary claims, such as women and landless residents.

1. Changes in the extent of land formalization

To understand changes in the extent of land formalization in the area where the Ngalenka perimeter is located, we examined whether the extent of land formalization had increased between baseline and follow-up and whether households indicated that they knew the process for obtaining titles to their land. Using survey data, we find no change between baseline and follow-up for the proportion of parcels for which households have titles (Table VI.6). We examined the percentage of plots that are titled for each household and find that, on average, one-quarter of plots have a land title both before and after the intervention. Both before and after the project, we asked respondents whether they knew the deliberation process to receive a land title. We find that significantly fewer households reported knowing the process to receive a land title after the project than prior to the project, a drop from 38 percent at baseline to 16 percent at follow-up. Since the project included extensive educational outreach in villages throughout the cuvette area, and the process, as explained, involved a number of new steps such as capturing GPS coordinates and site visits, this change could be an effect of the IWRM Project informing them about new processes, or the project could have reduced respondents' confidence in their knowledge of the process to obtain land titles.[45]

[45] Further examination of the reason for these changes is warranted.

Table VI.6. Pre-post changes on land formalization, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p-value*	Sample (post)	Sample (pre)
Ratio of plots with any land title	0.24	0.25	-0.01	0.77	238	249
Household knows deliberation process to receive land title	0.16	0.38	-0.22**	0.00	235	249

Source: IWRM Project baseline and follow-up household surveys

Note: Sample sizes vary based on survey responses and item-level missing data. Sample contains households that reported they received land within the Ngalenka perimeter as part of the IWRM Project.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

Some farmers in Ndiayène Pendao indicated an interest in formalizing land rights during interviews in early 2018, but others did not see a need to do so. Several indicated that to access land requires having customary rights to the land or, if one has no customary rights to land, negotiating land use with the individual or family who retains these rights. One farmer expressed a common theme found in our interviews in the Podor area, that residents had been generally content with customary rights prior to the project and were a bit uncertain about the need for formalization,

> We had [so many] deliberations. We had even gone to the courts because there were so many deliberations. It used to be that there was no formalization. I was born and I found my ancestors cultivating the field, then my father and then me. Therefore this field, fundamentally, has had no formalization and no deliberation.—C7

2. Changes in perceptions of land tenure security

Our primary quantitative measure on land tenure security is a self-reported measure on whether the household is concerned about losing land. We examined whether households in Ndiayène Pendao were concerned about losing land both prior to the IWRM Project and after. We found that, among households who received land in the Ngalenka perimeter, households are more concerned about losing land at follow-up (32 percent) than they were at baseline (22 percent). This difference of 9 percentage points is statistically significant (Table VI.7). The increased share of households that are concerned about losing land could be an unintended effect of providing land to households that were not historically customary claimants. We find differences in whether a household is concerned about losing land based on poverty status and gender of the household-head. The small sample of female-headed households in our intervention group expressed significantly more concern about losing land than male-headed households. Almost half, 44 percent, of female-headed households reported being concerned about losing land at follow-up, whereas only 11 percent of female-headed households expressed such a concern at baseline. The poorest group of households also expressed an increase in their concern of losing land; the wealthier groups saw no significant change on that measure.

Table VI.7. Pre-post changes on land conflict, among all households (Podor)

Outcome measure	Post mean	Baseline mean	Difference	*p-value*	Sample (post)	Sample (base)
Household is concerned about losing land	0.32	0.22	0.09*	0.02	241	249
Household reported any land conflicts	0.05	0.04	0.01	0.46	242	249

Source: IWRM Project baseline and follow-up household surveys

Note: Sample sizes vary based on survey responses and item-level missing data.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

3. Demand for land formalization

The outreach and public education activities of the LTSA in the Podor communes had a similar effect on public interest in obtaining formal land rights as it had in the communes near the Delta Activity. According to the Guedé Domain Commission members, when the project teams arrived in the village and the landholders saw their neighbors' fields being measured with GPS, they were then eager to file applications. Getting a precise measurement of the size of their parcels with an accurate placement of boundary markers provided them with a strong sense that they could protect their land against encroachment. In Ndiayène Pendao, the preparatory work for the irrigated perimeter generated demand for land as well as for formalization of land rights. As shown in Chapter VII, section E, applications for formalization continued in 2016 and 2017 in Guedé and Ndiayène Pendao, even though the capacity of the communes to process the applications has been limited. The advent of the AIDEP project is anticipated to help processing of applications during its period of performance, 2017–2022. Residents we interviewed in early 2018 expressed continuing interest in formalizing their land claims as a means of ensuring access to their land; they did not see the cost of formalizing as a deterrent. During the project, LTSA covered many costs for the land titling process and AIDEP is expected to cover some of the costs as well.

4. Changes in land conflict

Although concerns about land security have increased among households with land in the Ngalenka perimeter, very few land conflicts were reported at baseline or follow-up, which is consistent with reports from commune officials and leaders of GIE in the area. These data are presented above in Table VI.7. (We also find no significant changes when examining results by gender of household head or poverty status of the household). Our qualitative data suggest that, though few conflicts occurred prior to the IWRM Project, the number of conflicts has nevertheless declined since its implementation. One community member reported that:

> There is a decrease [in conflict] in some areas, even if it has not completely disappeared. There are still some who take land from others, and that gives rise to conflicts. Before, there was no farmland. It was all forest. There are certainly conflicts, but they are reduced. —C10

As noted above, however, frank discussion of land conflicts was often deflected by respondents in focus groups, individual interviews and group interviews, so actual changes in number, type or severity of land conflict cannot be ascertained with our data.

5. Women's access to land

The creation of the Ngalenka perimeter and the participatory process for allocating land within the perimeter have been heralded by commune officials as well as GIE and GPF members as an important success of the project. Key features of the allocation process include dedicating at least 10 percent of the newly built perimeter to women's cooperatives and 20 percent to landless residents in the area near the Ngalenka cuvette.

In preparation for the allocation of land in the perimeter, LTSA took care to identify the meaning of some key terms, such as "landless." In particular, LTSA consultants carried out workshops in villages in the eligible zones around the cuvette to focus on the question of how to define landless. It was resolved that applicants could be people who had no land rights as well as people with some land outside the zone. Seventeen villages were identified as containing primarily landless residents who could be eligible for land in the perimeter, and additional landless households or individuals within other villages were also included in the allocation process.

Several GPFs existed before the IWRM intervention, and these groups were included in the allocation process. Additional GPFs were created specifically to access land in the perimeter. After deliberation in the villages in the area, the final outcome included 14 GPFs, which represented the three major lineage groups with customary claims in the area and landless groups.

Our qualitative interviews reveal a widespread appreciation for the allocation of land in the perimeter to women. However, many women and some of the men we interviewed expressed frustration that despite having land in the perimeter, women are not able to cultivate the crops they expected—that is, market vegetable crops such as onions and tomatoes—since they cannot cultivate during the cold season. As one interviewee said:

> There has been no progress. You know when you harvest you can earn, but to cultivate and lose and to put in your money and you earn nothing, there is really no improvement. The only positive aspect is that we have land whereas before we did not have land. But now, thank God, we have land. This is progress. But in terms of the agricultural cycles, we haven't had any income except once. The past three years we haven't had any profits.—C8

6. Investments in land

To explore how the LTSA affected investments in land, we leveraged both our survey data with intervention households as well as in-depth interviews with leaders of GIEs and GPFs that had been allocated land in the Ngalenka perimeter and individuals who may have lived in eligible villages but were not members of the 53 GIEs and 14 GPFs that received land in the perimeter.

As shown in Tables VI.6 and VI.7, we find no significant change in the number of reported land conflicts or share of titles plots from baseline. Land conflicts remain low and around a quarter of plots are titled. Therefore, the IWRM Project does not appear to have affected agricultural investment through reductions in land conflicts or increases in land titling. However, we do find that fewer households report knowing the deliberation process to receive a land title and more households are concerned about losing land compared to baseline. An increase in a concern for losing land could negatively affect agriculture investment and production.

To check this, we correlated the change in a household’s concern about losing land with the change in measures for agriculture investment and production. We found a small positive and significant correlation of 0.15 (p-value 0.02) between a change in concern about losing land and the amount of land under production. In other words, becoming more concerned about losing land is related to a change in having more land under production. This does not make intuitive sense until you consider the context of the intervention. The Podor activity provided newly irrigable land to households. Households used that land to farm in the hot season. However, access to this new land did lead to some households being more concerned about losing the land, though the magnitude of the correlation is small. We found no significant correlation between a change in concern about losing land with changes in agriculture investment per hectare or revenue per hectare.

Our qualitative interviews shed additional light on the challenges that the LTSA had in affecting investments on land. GIE and GPF leaders focused on the cost of inputs for cultivating in the perimeter and the revenues that these investments are likely to produce, when making the decision to invest. A common theme among interviewees with land in the perimeter was the high cost of electricity to use the pumps. GIE leaders weigh the costs of inputs against the likelihood of a good harvest when deciding, as a group, whether a GIE will cultivate its parcels in the perimeter. In addition, the GIEs and GPFs must collaborate to make the decision whether to cultivate at all in the perimeter during a given season, as the cost of running the pumps and managing the water flow is too high to be borne by a small number of cooperatives.

After the Ngalenka perimeter was completed in 2014–2015, GIEs and GPFs cultivated their first agricultural cycles in the fields. Problems managing the water flow into different parts of the perimeter, inexperience with rice cultivation (particularly among the GPFs), and poor parcel leveling (the soil of rice parcels should have a consistent height to ensure correct water levels) led to losses during the first season of production. MCA’s funds for project-affected persons reimbursed the GIEs and GPFs for losses in these early seasons. In the first seasons after the project ended in September 2015, the cooperatives, with advice from the SAED extension agent, decided to focus their attention and investments on the main agricultural season (the hot season) to grow rice. The first full hot season resulted in very good production, with 2,943 tons of rice produced in the perimeter (USACS 2018a). Following the hot season, the perimeter was under production for the rainy season in 2016 and produced 1,115 tons of rice. This drop-off in production was not remarked upon by interviewees as particularly unusual. Rainy season rice is subject to additional stresses due to less regular irrigation and to losses at the time of harvest due to weather- or pest-related problems.

Since the first seasons post-compact, the Ngalenka perimeter has been under production only in the hot season. The reasons are multifold, but mainly due to the cost of inputs and the risk associated with farming the perimeter in the off-seasons (rainy and cold seasons). Interviewees, including GIE and GPF leaders, SAED extension agents, and commune officials, indicated that (1) the credit bureau (CNCAS) funds inputs primarily for rice, which is most easily grown in the hot season with appropriate and well-managed irrigation; (2) only a small portion of the perimeter has appropriate soil for market vegetable production (sandier soil than the clay preferred by rice) and the cost of using the pumps to water this small portion of the perimeter would eliminate any profit from production; (3) in 2017 specifically, a number of Ngalenka GIEs did not receive financing from CNCAS in time to prepare their fields for the rainy season, and (4) OMVS alerted the public prior to the 2017 rainy season that the Senegal River delta would have lower water levels than normal, which could affect the availability of water in the source for the Ngalenka perimeter.

The above discussion highlights the importance of risk and communal decision-making in farmers' decisions to invest in cultivating land, even when the land is well suited to agriculture and infrastructure has been provided without cost to the users. For the Ngalenka perimeter, each agricultural season requires a cooperative-level assessment of risk (with input from an extension agent), which is carried out among members of each cooperative, and a communal decision among GIEs and GPFs to undertake the risk of farming. Decisions to cultivate in the Ngalenka perimeter in off-seasons cannot be made by individuals or by specific GIEs/GPFs because the key input, water, is communally owned and managed. Thus, land investment decisions are not driven by individual interests or even group interests, as they might be in the Delta Activity area, and the outcome of group decisions affects all members of not just the specific GIE/GPF but also all GIEs/GPFs with claims in the Ngalenka perimeter.

7. Barriers to land access for women, the poor, and the landless

Given the strong reliance on customary land rights in the Podor project areas, women, the poor, and the landless encounter substantial barriers to land access. The exception is land specifically allocated to women, the poor, and the landless in the Ngalenka perimeter. In Guedé, the efforts of the IWRM to encourage women to become landholders and to participate in the activities of POAS and land management did not produce a strong response. As noted in the discussion on principles and procedures, many of the Guedé Rural Council members did not see a rationale for a priority of land allocations for women, and the quota was set at only 5 percent, compared with 10 percent in the other communes. When LTSA consultants analyzed the data in May 2015 from the applications filed by individuals and families for formalizations, they found that only about 3 percent of the then-pending applications identified women as landholders in Guedé, whereas the average across LTSA communes was 15 percent. Despite efforts to raise the level of women's participation, few women participated in LTSA training activities in Guedé (CIRAD/FIT/SONED 2015b).

In our December 2017 meeting with Guedé DC members, there were no women present, but the Guedé council members reported that women had been recipients of land grants in 2015, 2016, and 2017, although it was not clear how many women received land or the size of their land grants. In 2017, the French assistance project AIDEP provided support and technical assistance to four women's groups to apply for and receive 5-ha parcels which were then subdivided into parcels of 1,250 m^2 for their members.

In NP, heads of GPFs reported that the 2011–2014 land allocation process for the Ngalenka perimeter marked the first time that all-female GPFs could access land in the commune. They also remarked on the value of financial training they received. Previously, they had to rely on others to calculate agricultural output quantities and divide them among GPF members; now, with the training they received through the IWRM Project, they could do these calculations themselves. However, GPF members also noted that scant land was given to women in the Ngalenka perimeter. In an example given of a typical GPF, 44 women shared 3 ha of land, whereas each male member of a GIE in the perimeter were to receive at least .5 ha (the actual land allocated per male GIE member could not be verified). In addition, women mentioned that the land they were given was better suited for vegetables than for rice, but that they were required to grow rice by SAED and the Ngalenka WUA.

The principles emphasized by MCC to increase land access for women and the landless when allocating land do not appear to have had much effect outside of Ngalenka; as noted, neither commune we visited has been granting allocations for new land or otherwise allocating land in new perimeters for non-customary claimants. When asked how an individual without land could obtain it, commune officials in Guedé reported that they would need to first approach the customary landholder and work out an agreement. Then, the commune would formalize the agreement. This suggests that it would be difficult for women, the landless, or other groups that do not typically have customary land claims to obtain land.

In our individual and focus group interviews with women in the Podor area, women told us they are often relegated to lowest priority in the allocation of land. According to the women we interviewed, before the IWRM Project arrived, very few of them had access to land. Instead, they spent their time on household chores and other tasks in the agricultural value chain, such as hulling and marketing of agricultural products. Women who received access to land through the Ngalenka perimeter expressed appreciation for the opportunities provided by access to land; as one woman put it:

> If it was not [for] the MCA we would not have land. It has come, it has bought us land so that we can make a living, and when we grow and pay our debts, what is left we bring home to live on. —C6

However, a number of GPF members indicated that the small amount of land they were allocated, the location of their plots, the type of soil of their plots, and the requirement to cultivate rice limit the benefits of having access to the land.

G. Sustainability

As with Delta, our evaluation focuses on the two years after the infrastructure and land tenure activities were completed in September 2015. The challenges posed to sustainability in the Podor Activity area are similar to those in the Delta Area. However, because of the specifics of the Podor activity, these challenges manifest differently than they do in Delta. Each section below summarizes issues with possible effects on sustainability. We focus on answering the following research question: What are the prospects for the sustainability of project activities post-Compact?

Infrastructure requires consistent routine maintenance, and defects need to be addressed. As with the Delta, SAED is procuring multiyear contracts for maintenance of the canals and drainage system of the Ngalenka perimeter, to make the infrastructure sustainable for 20-30 years. Before each agricultural season, the WUAs and GIEs, with SAED's assistance, engage teams to carry out maintenance on the canals and pumps and to re-level the fields. However, WUAs face the same lack of resources they do in Delta, which hamper their ability to sustain project activities and ensure optimal irrigation for production in the area.

Producer groups and SAED engineers, discussing the Ngalenka irrigation and drainage system, said more work is needed for the infrastructure to be fully useful, particularly for parcels whose elevation is too high for the gravity-fed system and for parcels whose distance from the primary canal leads to uneven and inadequate water supply. GIE and GPF leaders also described problems with the size, condition, and extent of roadways in the perimeter, explaining the need for bridges to make access to the fields possible for farmers and livestock and to make it easier to transport inputs and collect harvests.

Farmers want help to extend the irrigation system, reduce or subsidize the cost of pumping, and to improve the crops' value chains. Stakeholders are eager for additions and improvements to be made to the infrastructure and assistance to afford the electricity to use the irrigation pumps. Households are currently unable to cultivate crops within the new perimeter in the rainy and cold seasons, and have consequently become less productive in those seasons. Farmers, including women, have expressed interest in market gardening, and the IWRM aimed to increase gardening in the cold and rainy seasons, but fields are currently not being irrigated because it is not cost-effective. This is a particular problem for the women's cooperatives, which were allocated land more suitable for farming vegetables than rice and whose parcels are dispersed throughout the perimeter, making water distribution costly and inefficient. Addressing these barriers to project sustainability would help the project create longer-term economic benefits. Beyond irrigation infrastructure improvements, GIEs and GPFs have expressed the need for factories, infrastructure, and equipment for rice processing, storage, transport, and marketing, which would intensify the impact of the MCA project.

The number of applications to formalize land tenure have increased, but land offices do not have the capacity to process them all. As in Delta, commune land offices were not adequately equipped, staffed or funded to carry out the tasks associated with the increase in demand for land allocation and land formalization after the project ended. Lingering backlogs of thousands of applications for formalization could create an environment where competing claims between households fester and increase conflict. In addition, the electronic land database system is not routinely used or updated in all communes, limiting land managers' ability to ensure that duplicate claims are identified and handled.

Government agencies, donors, and farmers are committed to continue and build on IWRM activities. Farmers and SAED have created an action plan for continued maintenance and development of the perimeter. While many farmers are committed to continue exploiting the perimeter, a minority of farmers reported that they were unable to continue doing so, as they were unable to repay loans.

The IWRM Project has also had an influence on the implementation of subsequent projects. SAED reported that it is updating the POAS in other communes with additional *Agence Francais de Developpement* funding from AIDEP. Further, according to interviews with SAED, AIDEP is implementing land tenure activities based on LTSA principles, although stakeholders did not mention whether AIDEP was planning any new land allocation. AIDEP is also working to increase access to irrigated agriculture.

H. Summary of Podor findings

In this section, we link our key findings for the Podor activity back to the project logic model to identify which parts of the logic model were or were not achieved and how that affected longer term outcomes. In Figure VI.9, activity outputs, short term outcomes, and longer term outcomes are color-coded to level of achievement based on a synthesis of our findings. Green demonstrates clear evidence of achievement, yellow means we found mixed evidence of achievement, and red highlights there was a lack of evidence of achievement.

Figure VI.9. Assessment of Podor activity logic model

Outputs (Years 1–5) 2010–2015	Short-term outcomes (Year 5) 2015	Medium/long-term outcomes (Years 6–10) 2016–2020
• 7.7 km of protection dikes constructed • 24.4 km of primary and secondary canals constructed • 14 km of access paths constructed • 2 pumping stations created	• Construction of a new irrigated perimeter with 450ha of cultivable land	• Increased cropping intensity in the Ngalenka basin (80%) • Increased agricultural production – Paddy rice – Tomatoes – Onions • Increased agricultural incomes • Strengthened job opportunities in farming sector • Improved land access • Infrastructure servicing and maintenance • Contribution to increased investments in agricultural sector

Evidence of achievement
Mixed evidence of achievement
Evidence of lack of achievement

MCC achieved its **output** and **short-term outcome** targets for the Podor activity, successfully constructing a new irrigated perimeter with 450 hectares of cultivable land. The project had mixed success in achieving its **medium and longer-term outcomes**, though still has several years before the targeted completion date in 2020. The project was successful at expanding rice production among beneficiary households thanks to the new irrigation system. Rice yields and revenue increased from baseline for the intervention group. SAED reported that Ngalenka farmers harvested 1,740 tons of rice during the 2017-18 agricultural seasons. However, that is a decline from 2016-17 where farmers harvested 4,058 tons during the hot and rainy seasons (USAC 2018a). The project did not expand tomato or onions production. SAED reports and our survey data supports that no market vegetable cultivation occurred within the Ngalenka perimeter and that the perimeter was not even irrigated in the cold season. As households that received access to land within the perimeter are still figuring out the best way to utilize the land in all three seasons, we find mixed evidence as to whether the project achieved an increase in crop intensity. In 2016, SAED reported cropping intensity at 145 percent, exceeding MCC's target of 80%. However, the following year cropping intensity dropped to 70 percent without the perimeter being irrigated in the cold or rainy seasons. And as a result, we do not find positive increases in agricultural profit so far.

We find mixed evidence that the project strengthened job opportunities in the farming sector. While a larger share of the intervention group is farming at follow-up during the main growing season, because the perimeter is not being irrigated in the cold and rainy season, farming opportunities dropped for both of those seasons. We find that the project did support improved land access. Households targeted by the intervention for land within the perimeter did have greater access to land and, during the hot season, were more likely to farm relative to baseline.

We find mixed evidence on whether the project contributed to increased investments in the agricultural sector. Reported investment among farmers in the perimeter did increase from baseline during the hot season, though investment declined in the cold season as the perimeter was not irrigated.

Finally, we find mixed evidence on the project achieving proper infrastructure servicing and maintenance. Our qualitative analysis finds that SAED did conduct repairs to water pumps after the perimeter was completed. However, while it appears that SAED plans on servicing the pumps on a yearly basis, it is not clear to what extent this will be achieved.

VII. EVALUATION FINDINGS: LTSA

In this section, we link our key findings for the LTSA back to the project logic model to identify which parts of the logic model were or were not achieved and how that affected longer term outcomes. In Figure VII.1, activity outputs, short term outcomes, and longer term outcomes are color-coded to level of achievement based on a synthesis of our findings. Green demonstrates clear evidence of achievement, yellow means we found mixed evidence of achievement, and red highlights there was a lack of evidence of achievement. Gray indicates we were not able to observe the outcome. We note that the LTSA was implemented in a larger geographical area than the Delta and Podor activities but was intended to provide preconditions, ongoing support and mitigation for outcomes associated with the Delta and Podor activities and to result in outcomes independent of the Delta and Podor activities, as well. We discuss the results of the LTSA specific to the Delta and Podor activity areas in more detail in the results chapters above.

Figure VII.1. Assessment of LTSA logic model

Outputs (Years 1–5) 2010–2015	Short-term outcomes (Year 5) 2015	Medium/long-term outcomes (Years 6–10) 2016–2020
• 10,003 plots corrected or incorporated in the Land Information Service • 8,655 plots with formalized titles • Mapping of 60,151 ha • Land rights are formalized for 3,440 ha • Land rights of vulnerable groups are strengthened. • Nine support technical committees are strengthened and functional. • 7 land registers and 2 land books, update of land occupancy plans, land information system, and set-up of procedures manuals for lands distribution • 5,018 people are trained on land-tenure security tools. • 33 water use organizations are created.	• Improved local land governance • Continued use of improved land security tools • Fewer land conflicts • Remaining land conflicts are managed and resolved. • Land authorities have access to ongoing technical support and tools.	• Improved land access • Security for investments • Contribution to increased investments in agricultural sector

Evidence of achievement
Mixed evidence of achievement
Evidence of lack of achievement
Lack of evidence

As described in compact close out docs, the LTSA met or exceeded most of its **output objectives** (we did not observe the strengthening of land rights for all vulnerable groups). LTSA Phase I mapped over 60,000 hectares of land across the Delta and Podor Activity areas, which included nine communes: Ross Bethio, Ronkh, and Diama in the Dagana Department in the

Delta; Gandon in the Saint-Louis Department in the Delta; and Gamadji, Podor, Ndiayène Pendao, Guedé Village, and Dodel in the Podor Department. 8,655 farmers, GIEs, or corporate entities in the intervention area received land use rights titles covering 15,246 hectares of land (MCC 2015c). This total includes 53 GIEs that received land titles in the new 450 ha Ngalenka irrigated perimeter in Podor. 5018 individuals were trained to use the land tenure security tools, which included support to the development and domain communal and zone commissions within the nine communes targeted by the LTSA project. The project produced manuals, land registries, and public education materials that were distributed across the nine communes. The project created and trained 33 water user associations. In addition, for the 53 GIEs[46] in Ngalenka, the LTSA also helped the groups obtain loans they needed to buy seeds, fertilizers, and pesticides.

The formalization of land requests and stakeholder assessment of land institution efficacy provides evidence that the **short term outcome** of improved local land governance was achieved by the project. We find mixed evidence regarding the continued use of the improved land security tools. In communes with active external funders supporting use of the tools, land officials continue to implement the principles and practices implemented by the LTSA while in communes without such support, the costlier tools, such as visits to the field and deliberations are less present.

Our quantitative data show no increase in conflicts and our qualitative data suggest either no increase in conflicts or, possibly, reduced land-related conflicts. We categorize this outcome as mixed since we found that respondents preferred to avoid discussion of land-related conflict and we are unsure of the validity and reliability of our qualitative findings on this topic. Moreover, the logic model posited a reduction in conflicts, which we did not observe. We do not have evidence on the disposition of lingering land conflicts.

Across the LTSA project area we found that human and material resources lack for updating the SIF registry and we found no evidence that an updated *cossif* is maintained by SAED.

For **longer term outcomes**, we found mixed evidence for improved land access for farmers. Some communes appear to be at capacity in land allocation (Ronkh) while others continue to allocate land (Gandon). In the Podor area, to our knowledge, land allocation took place only via the IWRM Project in the Ngalenka perimeter. All other land requests in the Podor department are for formalization of customarily-held land.

As shown in the mediation analysis we carried out in the Delta activity area, the project had a positive impact on land titling which, in turn, had a positive impact on the amount of land under production. Approximately a quarter of the increase in land under production is attributable to farmers' titling of their land. The relationship between land security and investment in land was not clearly evident. In the Delta impact evaluation we found no relationship between perceptions of security and investment in land and while farmers' perceptions of land security were unchanged in the Delta activity area, farmers in Podor expressed an increased sense of insecurity regarding their land after the project.

[46] As mentioned, thirteen of these GIEs were women's groups, also known as GPFs.

VIII. NEXT STEPS AND FUTURE ANALYSIS

The findings reported here help build the limited evidence base for agricultural interventions in West Africa. We find that the IWRM Project met a number of its objectives in the first years after the compact, particularly those focused on making water more available for farming in the Delta Activity project area and providing land to underrepresented groups in the Podor Activity area. These early evaluation results also highlight some outcomes that have not yet been attained. For example, although the better water availability in the Delta Activity area has led to improvement on several targeted outcomes in the main growing season, such as land under cultivation, rice production, and farmers' agricultural profits, we do not find the increase in cropping intensity that the project expected. There was a decline in the production of market vegetable crops in the cold and rainy seasons. This is in contrast to Kuwornu and Owusu (2012) study in Ghana that found irrigation access increased cropping intensity. Understanding why this is so will require further examination of farmers' economic behavior, and identification of barriers such as access to credit or markets. This finding also confirms Connor et al (2008)'s model of SRV agriculture that suggests an increase in cropping intensity is necessary for households to receive widespread income benefits from agricultural investments.

We find some supporting evidence to Comas et al.'s (2012) conclusion that the costs of inputs for rice production exceed returns in the SRV. While we find that through improved irrigation the intervention led to an increase in rice yield, revenue, and overall agriculture profit in the hot season, the increase in profit appears mainly driven by an increase in land under production. Rice revenue per hectare did not change in the hot season. The increase in agricultural profit was also off-set by a decline in off-farm earnings and we found no change in overall household consumption. This finding contrasts to Dillon (2011b), which found that access to irrigation resulted in 20 to 30 percent increase in consumption. The reduction in cropping intensity may again be a key difference between what occurred in the SRV and in other areas of West Africa that received irrigation interventions.

As farmers become accustomed to the greater availability of water, policymakers may identify opportunities for complementary interventions such as downstream improvements in the rice value chain. Further, we do not find evidence that women have benefited broadly from the Delta Activity. Women we interviewed nearly universally expressed interest in having access to land and in farming, yet barriers to accessing land in the SRV seem high; there is little agricultural land available for allocation in some areas, customary land tenure inhibits women's' titling and women cannot access credit due to their lack of land titles and collateral. Examining more deeply the barriers that women face to accessing land or farming could provide input for policies around land titling and credit.

The Podor Activity was viewed very favorably by many interviewees, both for the infrastructure of the irrigated perimeter and for the participatory process used to allocate land in the perimeter. Women and formerly landless residents expressed satisfaction with gaining access to land. Yet the high cost of inputs prevents the perimeter from being used in off-seasons and women, in particular, express frustration that they are unable to irrigate their plots to grow market vegetables in the cold season. Studying cropping decisions and costs of inputs in the coming seasons will reveal whether the Ngalenka perimeter can eventually be put to use with enough efficiency to lead to an intensification of cropping and better economic outcomes for households.

Finally, the LTSA led to high demand for formalization and allocation of land, and the POAS is in some use, but local land institutions are overburdened with land requests and require more funding and resources to manage the titling process. As the application backlog grows, it will be important to continue examining how titling affects farmers' decisions to invest in their land and to monitor whether land conflict increases. We find that the increase in land under production in the hot season, a short term investment input, was positively affected by changes in land tenure security as part of the LTSA. This finding supports claims by Goldstein and Udry (2008) and Deininger et al. (2008) that formal land tenure and titling will promote agricultural investment. In the coming years, it will be important to assess whether the processes for land titling are sustainable without external donor intervention.

We summarize our interim evaluation results in Table VIII.1 by presenting key findings separately for Delta and Podor for each research question on use and availability of water, agriculture production, household income, land formalization and conflicts, land administration and governance, and sustainability. For the next and final phase of our evaluation of the IWRM Project, we will revisit the medium and long term outcomes to observe changes at four-plus years post compact and we will calculate the IWRM Project ERR. We will carry out a final round of data collection in early 2020 and present a final evaluation report in November 2020.

Table VIII.1. Key interim evaluation findings by research question

Research question	Interim Delta findings	Interim Podor findings
Use and availability of water		
Have there been changes in the sources of water used for agricultural production?	No, the main source of water remains the Senegal River through irrigation canals or other waterways in the Delta.	No, water used for irrigation after the IWRM Project was the same as the one used before; farmers still irrigate their fields from the local waterways.
How has water availability changed, and have barriers or costs to accessing irrigation been reduced? Has the water supply become more reliable?	Overall, the project increased water availability and reliability through the rehabilitated irrigation infrastructure, particularly for farmers closer to the infrastructure. However, costs for the new mechanized irrigation were higher than previous irrigation costs and farmers farther from water sources and canals noted barriers to accessing irrigated water.	The reliability and availability of irrigation water in the main growing season seems to have improved with the project's completion of the Ngalenka perimeter.
Has the amount of irrigated land increased?	The project led to a statistically significant increase in the amount of irrigated land among farming households in all three agriculture seasons, on average between 0.86 and 1 hectare.	The average amount of land irrigated for households that received land in the Ngalenka perimeter did not change.
Has the role of WUAs changed, and how do they impact the use and availability of water?	Through the project, WUAs took on new water management responsibilities but members argued they did not have the resources to fulfill them.	Water user associations in Ngalenka reported mixed outcomes.
Agriculture production		
Have there been changes in the amount of land used for agricultural production? Is land being used for production in different seasons than before?	Land under production increased significantly in the hot season, the main growing season, and also the rainy season. There was no change in the cold season.	There was no significant change in the overall amount of land under production for intervention households during the hot season. In the cold season, the average amount of land under production declined, as the perimeter was not irrigated: few producer groups planned to farm, and the costs were too high to irrigate for only a small portion of the perimeter.
Has crop production improved? Have production methods, including the choice of inputs, changed? Have there been changes to the types of crops produced?	Farmers are spending more money on agriculture inputs for their larger tracts of land and receiving more revenue, but maintaining a similar level of per-hectare agriculture investment and revenue during the main growing season. Most of the changes in agriculture production were driven by increases in rice farming, including a significant increase in hot season rice yields. At the same time, households cultivated fewer market vegetable crops in the rainy and cold seasons. Fertilizer and irrigation costs continue to be the largest shares of investment costs for each agriculture season.	The project was successful at increasing rice production during the main agriculture season, as overall investment and revenue increased from baseline. However, farmers are cultivating fewer market vegetable crops in the cold season and investment and revenue dropped during that time. Fertilizer and irrigation costs continue to be the largest shares of investment costs.

Research question	Interim Delta findings	Interim Podor findings
What factors are contributing to or constraining changes in agriculture inputs and production? Why are households changing or not changing agriculture production decisions, and how do those reasons vary depending on crop type, growing season, or income level?	Farmers' choice of crops is largely guided by the availability of water and agricultural inputs. After the project, private structures such as banks facilitated an increased availability of seed and fertilizer inputs. However, farmers found inputs cost more given the increased land under production and because of the additional expenses for mechanized irrigation.	Farmers generally appreciated the project and considered the availability of water through the new perimeter to be one of the main drivers of agricultural change in the region. Despite the significant improvement in yields, however, many farmers said there was much room for improvement in agriculture production in the perimeter.
How have changes differed by gender and among different income levels?	Land under production and area of rice cultivated in the hot season increased for all gender and income subgroups. Almost all subgroups saw significant increases in hot season rice yield, though the small group of female-headed households saw the largest increase.	We find evidence that improvements in land use were greatest among female-headed households and the poorest households, where significantly more of the respondents said they farmed land, and where the amount of land under production in the hot season increased significantly. Poorer households drove some of the positive changes in rice production for the hot season, though all subgroups saw significant increases in average rice yields.
Household income		
Have household income levels changed, including changes in components of household income, and has income shifted between agricultural and nonagricultural sources?	Among farming households, we find a trade-off between off-farm earnings and agricultural profit. The project resulted in a shift in labor allocation with more farming in the hot season and more off-farm revenue activities in the cold season. For all three farming seasons combined, we find a reduction in off-farm household earnings.	We find no significant change from baseline in off-farm earnings during the hot season. Households were able to maintain their off-farm activities at the same time that they were expanding rice production on land within the perimeter. However, we find a significant decline in off-farm earnings during the cold season.
Do farmers perceive an improvement in their living standards?	Reports of improvements in living standards varied by beneficiary group. Women who gained new access to land reported being particularly better off. Farmers who lived further from water sources remained frustrated with water costs and reliability.	Perceptions on changes in living standards vary by beneficiary group. Some women reported the project has improved their well-being because women have been able to access land for the first time.
Have agricultural profits changed?	Agriculture profit increased for all three farming seasons combined, with the largest increase during the main growing season. The increase in agriculture profit appears mainly driven by an increase in land under production.	Despite the improvement in rice production in the main growing season, there was no statistically significant change in agricultural profit in this season. Households tended to consume a large portion of the rice they harvested. We find a decline in agricultural profit in the cold season relative to baseline. While it was profitable to farm in the cold season at baseline on land in the Ngalenka cuvette, at follow-up, households were not able to continue the same activities on the new farm land within the perimeter.

Research question	Interim Delta findings	Interim Podor findings
Land formalization and conflicts		
Have perceptions of land tenure security changed? Is there increased confidence in the land tenure system? If so, why?	There was no change in perceptions of land tenure security due to the project in the Delta project area. Qualitative interviews with farmers suggested some increased confidence in land tenure management due to the public outreach and evidence that land titles were being produced by the communes during the project.	Perceptions of land security worsened from before the project to post-project among recipients of land in the Ngalenka perimeter (our Podor analytic sample) but we were unable to determine why this was the case. Other respondents in the greater Podor and LTSA areas expressed a moderate increase in confidence in land tenure bodies during and after the compact.
Has the extent of land formalization changed? Is there greater awareness of the process for formalizing land?	Land formalization increased across the nine communes included in the LTSA, including in the communes also covered by the Delta Activity. The IWRM Project had a positive impact on households' knowledge of the deliberation process for obtaining land rights and led to households obtaining use titles to their land.	Land formalization increased in LTSA zones in the department of Podor. Recipients of land in the Ngalenka perimeter reported a decreased understanding of the steps for formalizing land from before the project to after the project. We were unable to determine the cause of this change.
Has demand changed for formalized land rights, and are the costs of formalizing land rights perceived as reasonable?	Demand for formalized land rights and for new land allocation increased across the project area and remained high after compact close. Perceptions of the costs for formalizing land rights were mixed; the continued high demand for formalization post-compact might suggest that the costs are considered acceptable. However, some farmers chose to not pay the final fees to pick up their land titles from the commune land office, which might suggest the cost is considered high, but our qualitative data did not reveal strong trends regarding perceptions around the cost of formalization.	Demand for formalized land rights increased across the project areas during the project and continued at a higher rate after compact close than before the project. Our qualitative data did not suggest that applicants perceive the costs for formalizing land excessive, but we were unable to obtain much data on this question.
Has the number or severity of land conflicts reduced? Has the type or nature of land conflicts changed?	There was no change in the number or type of land conflicts as a result of the project. Land conflicts remain low.	Land conflict was reported as low both pre and post-compact by survey respondents in Podor. We found that in some instances interviewees in focus groups and in-depth interviews preferred to avoid discussion of land conflict or replied that there was little conflict around land.
How has the IWRM Project affected women's access to land and irrigation? How has it affected the landless?	Women's access to land and irrigation differed substantially across communes in the Delta activity area. In Gandon, women applied for and received land titres d'affectation during the project. Two years after the project, land officials estimated that 15-17% of land applications during the project came from women, but that this number was decreasing post-project. In Ronkh, neither women nor men nor other groups found improved access to land via the project, as all land in the commune had already been allocated.	The IWRM Project led directly to improved access to land for women in the Podor (Ngalenka) project area as a portion of the 450 ha perimeter was allocated to women's groups. Additionally, some women gained access to land in the perimeter through mixed-gender GIE or through household membership in GIE. Additionally, 10% of the perimeter was allocated to previously landless residents of the neighboring villages.

Research question	Interim Delta findings	Interim Podor findings
How have changes in land security perceptions, formalization, conflict, or conflict management affected investments on land?	We found that land titling had a positive impact on area of land under production, which may be understood as a short term investment input for agricultural production.	In the Podor project area, land security perceptions worsened from before the project to after the project and while formalization increased, we cannot draw a clear link between formalization of land and investment in the land due to the project.
What have been the constraints or barriers to land access? Do these differ depending on gender, income level, or age?	In the Delta activity area land access varies by geographic location with some communes at capacity for land allocation while others have land available. The IWRM Project actively sought to lower barriers to women and poor access to land through public education campaigns and assistance to individuals and groups applying for land at the commune level. Aid to women's groups for obtaining credit for agricultural production was cited by several women's groups in the Delta as key to making productive use of their land. Gaining access to land for these groups and for all groups appears to be slower post-compact in the absence of outside funding and support.	In the Podor activity area women and the poor received land as part of the Ngalenka perimeter land allocation. We note that this group represents a very small portion of the overall population in the department of Podor. Land access in Podor is largely concentrated in customary land holders and barriers to accessing land for women and poor appear to be high post-project in the absence of external funders.
Land administration and governance		
Have local government agencies become more effective at land management, including land allocation, land formalization, and conflict resolution? Is there greater confidence in the efficacy of these institutions?	Several of the local government agencies in the Delta continue to implement the POAS and to allocate or formalize land requests and to mediate land conflicts, albeit at a lower rate than during the IWRM Project. There is wide variation in the extent to which commune land institutions are functioning per their mandate. Farmers expressed a general sentiment of confidence in some of the institutions, and this varied by commune.	At least some local government agencies in the department of Podor continue to implement the POAS, to formalize land requests and to mediate land conflicts (we did not obtain data directly from some LTSA communes in Podor). Farmers expressed some improved sense of confidence in the efficacy of these institutions.
Do institutions receive adequate support to carry out their functions?	Local land institutions are underfunded and are not able to carry out all of the functions of land allocation and formalization per the LTSA project without external support (by external, we mean support other than through tax levies or fees to residents and commercial entities within the commune). The Gandon land office's innovative fee for land applications appears to aid in the sustainability of the office's operations. Gandon differs markedly from many of the other communes that received the LTSA project, however, as it lies close to the major municipality of St. Louis and has high demand for residential and commercial land titles.	Local land institutions are underfunded and are not able to carry out all of the functions of land allocation and formalization per the LTSA project without external support (by external, we mean support other than through tax levies or fees to residents and commercial entities within the commune).

Research question	Interim Delta findings	Interim Podor findings
Sustainability		
What are the prospects for the sustainability of project activities post-Compact?	Prospects for the sustainability of the irrigation system impacts on rice production and for any eventual increase in agricultural production intensification (if any) are highly dependent on the maintenance of the irrigation infrastructure, the continued adequacy of water in the system (dependent on the level of water in the Senegal river) and the ability of farmers to achieve positive returns on their production (which is dependent on costs of inputs, access to credit, market conditions and other factors). We find some positive indicators for sustainability related to the condition of the canals and infrastructure as observed in early 2018 and the completion of nearly all canal maintenance tasks in the Delta (and Podor) Activity irrigation system that were planned for 2018 (USACS 2018b). It is worth noting that Senegal has entered into a second compact with MCC (signed December, 2018), which requires as a precondition follow-through on first compact obligations. The LTSA demonstrates mixed prospects for sustainability as all land agencies we interviewed had large backlogs of land applications due to lack of funding to clear these backlogs. At the same time, the principles for land conflict resolution and land allocation appear sustained and are being replicated in areas outside the project.	Approximately 70% of Ngalenka perimeter was in use in the hot season in 2016 and 2017 for rice production but the perimeter was not cultivated in the hot season in 2018 (USACS 2018b). This lack of intensification of cultivation runs contrary to the expected outcomes of the project and risks the project's sustainability. We find mixed prospects for sustainability in the Podor Activity for agricultural production. Farmers are cultivating more rice in the hot season but are not cultivating in the cold season. The most recent data from SAED on production in 2018 shows that 374 ha of the perimeter were cultivated in the rainy season of 2018. Means to support women's cultivation during all seasons and intensification of cropping across seasons are likely needed for the Ngalenka perimeter to achieve the expected results.
What impacts did the project have outside of project areas?	The successful creation of principles for land conflict resolution and land allocation appear sustained and are being replicated in areas outside the project (see Podor column). PDIDAS, a World Bank-funded project in the Delta Activity area, rehabilitated and improved canals in an area adjoining the Lampsar canal, which is expected to improve rice production in areas adjacent to the IWRM infrastructure zone.	The successful creation of the Ngalenka perimeter provided some inspiration for project activities being carried out by AIDEP in the Podor region. This includes investment in an irrigated perimeter and application of some of the principles of land allocation and formalization. IPAR and FAO, with funding from GIZ, are expanding use of the MCA model for education and outreach, land use and allocation to 22 communes in Podor and sharing lessons learned with representatives from other departments in Senegal, notably Matam, and from neighboring countries, including Mauritania.

Research question	Interim Delta findings	Interim Podor findings
Who benefitted from each IWRM activity? Where and when did each activity occur?	The Delta Activity was implemented in delta of the SRV, in the departments of St. Louis and Dagana. The activity benefited farmers connected to the rehabilitated irrigation infrastructure who now reliably irrigate their plots, as well as those employed in temporary jobs to refurbish the infrastructure. The total area of agricultural land with improved irrigation infrastructure increased from 11,800 hectares to 38,391 hectares.	The Podor Activity was implemented in Ngalenka, an area south of the departmental capital town of Podor. The activity benefited farmers who received newly irrigable land within the Ngalenka perimeter, particularly women and previously landless farmers. The activity created 450 hectares of irrigated land.
	LTSA occurred in nine contiguous communes in the departments of St. Louis, Dagana, and Podor. 8,655 farmers, GIEs, or corporate entities in the intervention area received land use rights titles as part of the activity. In addition, 5,018 stakeholders were trained in the use of land tenure security tools, including registries, procedures manuals, and databases. LTSA Phase I lasted from 2010 to the beginning of 2012; the Delta Activity and LTSA Phase II occurred from 2013 to 2015.	LTSA occurred in nine contiguous communes in the departments of St. Louis, Dagana, and Podor. 8,655 farmers, GIEs, or corporate entities in the intervention area received land use rights titles as part of the activity. In addition, 5,018 stakeholders were trained in the use of land tenure security tools, including registries, procedures manuals, and databases. LTSA Phase I lasted from 2010 to the beginning of 2012; the Delta Activity and LTSA Phase II occurred from 2013 to 2015.

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APPENDIX A

TECHNICAL DETAILS ON MATCHED COMPARISON GROUP DESIGN

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This appendix provides additional technical details on our matched comparison group design. We discuss results of our baseline equivalence analysis and describe our imputation approach for missing baseline data.

A. Baseline equivalence

Before examining our matched comparison group, we first examined baseline equivalence among the *full sample* of households that were surveyed in all 3 waves at baseline and were surveyed at follow-up. This provides us an understanding of how comparable the groups are before we conducted propensity score matching. We examined equivalence on all variables available for inclusion in the matching model in Table V.2 as well as all 3 waves of variables for measures on irrigation, agriculture investment, crop revenue, and land tenure security, and an annual measure of household consumption. In total, we looked at baseline equivalence on 53 variables related to the outcomes measured. We examined absolute effect size differences between group means at baseline whereby an effect size difference of greater than 0.25 standard deviations does not satisfy baseline equivalence (Ho et al. 2007).

Table A.1 shows baseline equivalence results among the full sample prior to matching. We bold effect size differences that are greater than a quarter standard deviation between treatment and comparison households. With testing equivalence on 53 variables, we would expect to find statistically significant differences on 2 to 3 by chance alone. We find, however, 10 variables that have effect size differences greater than 0.25 standard deviation units, meaning that there are significant differences at baseline on the overall sample prior to matching. We also find differences between 0.20 and 0.25 standard deviations on an additional six variables.

Through propensity score matching, we attempted to improve baseline equivalence on our analytic sample. Appendix Table A.2 shows the baseline equivalence results on our matched sample, weighted to account for comparison households being matched to multiple treatment households, among the same set of variables as in Table A.1. We find only one baseline difference greater than a quarter standard deviation out of 53 baseline measures, a difference we would expect to find based on chance alone. That difference is on a measure of land tenure security (household knows the deliberation process to receive a land title) during the final wave of baseline data collection when some of the land security activities had begun implementation. The intervention could have possibly affected responses among the treatment group for this measure. We find no differences on any baseline measure between 0.20 and 0.25 standard deviations. Based on our analysis, we achieved baseline equivalence on the matched sample, vastly improving baseline equivalence from the overall treatment and comparison groups.

Table A.1. Baseline equivalence results for unmatched sample (Delta)

Variable	Treatment mean	Comparison mean	Difference	Effect size difference	Sample (treatment)	Sample (comparison)
Household size	10.01	10.76	-0.74	-0.12	1361	1179
Age of household head	49.47	50.27	-0.80	-0.06	1361	1179
Household head is male	0.82	0.81	0.00	0.01	1361	1179
Household head received some formal education	0.32	0.38	-0.06	-0.12	1361	1179
Poverty likelihood (<$2.50/day)	0.69	0.65	0.05	**0.30**	1361	1179
Household consumption	2,702,859	2,787,346	-84,488	-0.06	1361	1179
Cold season						
Household has farm plots	0.82	0.75	0.06	0.16	1361	1179
Household farmed land	0.62	0.70	-0.08	-0.17	1361	1179
Total amount of land used (hectares)	1.80	1.43	0.37	0.10	1361	1179
Household used a gravity irrigation system	0.57	0.67	-0.10	-0.21	1361	1179
Agriculture investment costs per hectare of land farmed	258,901	322,704	-63,803	-0.10	1361	1179
Household harvested any crops	0.28	0.39	-0.11	-0.22	1361	1179
Revenue per hectare of land (inclusive of all crops)	131,691	182,617	-50,926	-0.12	1361	1179
Area of rice cultivated	1.53	1.10	0.43	0.12	1361	1179
Rice yield (kg per hectare)	671	267	404	0.22	1361	1179
At least 1 plot that has access to a river/lake	0.61	0.67	-0.06	-0.13	1361	1179
Total amount of land irrigated	1.63	1.44	0.19	0.05	1361	1179
Household expressed concern about losing land	0.34	0.46	-0.12	-0.25	1361	1179
Percentage of plots with any title	0.27	0.27	0.00	0.01	1361	1179
Household knows the deliberation process to receive a land title	0.45	0.35	0.10	0.20	1361	1179
Hot season						
Household has access to farm plots	0.85	0.71	0.14	**0.34**	1361	1179
Household farmed land	0.62	0.57	0.05	0.10	1361	1179
Total amount of land used (hectares)	1.56	0.99	0.57	0.19	1361	1179
Household used a gravity irrigation system	0.56	0.54	0.01	0.03	1361	1179
Agriculture investment costs per hectare of land farmed	203,927	134,186	69,742	**0.29**	1361	1179
Household harvested any crops	0.55	0.57	-0.02	-0.03	1361	1179
Revenue per hectare of land (inclusive of all crops)	350,108	296,013	54,095	0.09	1361	1179
Area of rice cultivated	1.39	0.88	0.52	0.17	1361	1179
Rice yield (kg per hectare)	3,005	3,666	-662	-0.13	1361	1179
At least 1 plot that has access to a river/lake	0.58	0.56	0.03	0.06	1361	1179
Total amount of land irrigated	1.29	0.44	0.85	**0.26**	1361	1179
Household expressed concern about losing land	0.32	0.35	-0.03	-0.06	1361	1179
Percentage of plots with any title	0.20	0.26	-0.06	-0.16	1361	1179
Household knows the deliberation process to receive a land title	0.43	0.31	0.12	0.24	1361	1179

Variable	Treatment mean	Comparison mean	Difference	Effect size difference	Sample (treatment)	Sample (comparison)
Rainy season						
Household has access to farm plots	0.84	0.72	0.12	**0.30**	1361	1179
Household farmed land	0.43	0.51	-0.07	-0.15	1361	1179
Total amount of land used (hectares)	0.88	0.75	0.13	0.05	1361	1179
Household used a gravity irrigation system	0.31	0.50	-0.19	**-0.38**	1361	1179
Agriculture investment costs per hectare of land farmed	103,024	182,534	-79,510	**-0.28**	1361	1179
Household harvested any crops	0.24	0.26	-0.02	-0.05	1361	1179
Revenue per hectare of land (inclusive of all crops)	82,686	113,157	-30,471	-0.11	1361	1179
Area of rice cultivated	0.66	0.62	0.04	0.02	1361	1179
Rice yield (kg per hectare)	438	1,204	-766	**-0.37**	1361	1179
At least 1 plot that has access to a river/lake	0.32	0.50	-0.19	**-0.38**	1361	1179
Total amount of land irrigated	0.27	0.50	-0.23	-0.08	1361	1179
Household expressed concern about losing land	0.33	0.36	-0.03	-0.07	1361	1179
Percentage of plots with any title	0.21	0.23	-0.02	-0.06	1361	1179
Household knows the deliberation process to receive a land title	0.49	0.35	0.15	**0.30**	1361	1179

Source: IWRM Project baseline household survey data

Note: Effect size differences greater than 0.25 standard deviation units are in bold.

Table A.2. Baseline equivalence results for matched sample (Delta)

Variable	Treatment mean	Comparison mean	Difference	Effect size difference	Sample (treatment)	Sample (comparison)
Household size	9.97	9.82	0.15	0.03	1136	1136
Age of household head	49.47	49.67	-0.20	-0.02	1136	1136
Household head is male	0.81	0.80	0.01	0.03	1136	1136
Household head received some formal education	0.32	0.38	-0.06	-0.12	1136	1136
Poverty likelihood (<$2.50/day)	0.69	0.67	0.01	0.08	1136	1136
Household consumption	2,687,468	2,660,377	27,091	0.02	1136	1136
Cold season						
Household has farm plots	0.79	0.76	0.03	0.08	1136	1136
Household farmed land	0.62	0.60	0.02	0.04	1136	1136
Total amount of land used (hectares)	1.68	1.78	-0.10	-0.03	1136	1136
Household used a gravity irrigation system	0.58	0.56	0.02	0.04	1136	1136
Agriculture investment costs per hectare of land farmed	263,193	285,917	-22,724	-0.04	1136	1136
Household harvested any crops	0.28	0.25	0.04	0.08	1136	1136
Revenue per hectare of land (inclusive of all crops)	123,814	145,404	-21,590	-0.06	1136	1136
Area of rice cultivated	1.43	1.57	-0.14	-0.03	1136	1136
Rice yield (kg per hectare)	567	690	-123	-0.06	1136	1136
At least 1 plot that has access to a river/lake	0.61	0.60	0.02	0.04	1136	1136
Total amount of land irrigated	1.51	1.79	-0.28	-0.07	1136	1136
Household expressed concern about losing land	0.36	0.38	-0.02	-0.04	1136	1136
Percentage of plots with any title	0.27	0.28	-0.01	-0.04	1136	1136
Household knows the deliberation process to receive a land title	0.41	0.41	0.00	0.00	1136	1136
Hot season						
Household has access to farm plots	0.82	0.79	0.03	0.08	1136	1136
Household farmed land	0.61	0.60	0.01	0.03	1136	1136
Total amount of land used (hectares)	1.38	1.47	-0.09	-0.02	1136	1136
Household used a gravity irrigation system	0.56	0.53	0.03	0.07	1136	1136
Agriculture investment costs per hectare of land farmed	187,092	202,595	-15,503	-0.06	1136	1136
Household harvested any crops	0.56	0.56	0.01	0.01	1136	1136
Revenue per hectare of land (inclusive of all crops)	340,386	313,655	26,731	0.04	1136	1136
Area of rice cultivated	1.25	1.38	-0.13	-0.04	1136	1136
Rice yield (kg per hectare)	3,087	3,096	-10	0.00	1136	1136
At least 1 plot that has access to a river/lake	0.58	0.57	0.01	0.02	1136	1136
Total amount of land irrigated	1.10	0.93	0.16	0.04	1136	1136
Household expressed concern about losing land	0.32	0.36	-0.04	-0.09	1136	1136
Percentage of plots with any title	0.20	0.18	0.02	0.06	1136	1136
Household knows the deliberation process to receive a land title	0.40	0.31	0.09	0.19	1136	1136

Variable	Treatment mean	Comparison mean	Difference	Effect size difference	Sample (treatment)	Sample (comparison)
Rainy season						
Household has access to farm plots	0.81	0.77	0.04	0.10	1128	1133
Household farmed land	0.41	0.36	0.05	0.11	1128	1133
Total amount of land used (hectares)	0.81	0.91	-0.10	-0.03	1128	1133
Household used a gravity irrigation system	0.34	0.33	0.01	0.03	1128	1133
Agriculture investment costs per hectare of land farmed	105,905	130,616	-24,710	-0.10	1128	1133
Household harvested any crops	0.21	0.19	0.02	0.05	1128	1133
Revenue per hectare of land (inclusive of all crops)	74,740	93,733	-18,993	-0.06	1128	1133
Area of rice cultivated	0.67	0.82	-0.15	-0.05	1128	1133
Rice yield (kg per hectare)	499	653	-154	-0.09	1128	1133
At least 1 plot that has access to a river/lake	0.35	0.34	0.01	0.03	1128	1133
Total amount of land irrigated	0.26	0.61	-0.35	-0.11	1128	1133
Household expressed concern about losing land	0.34	0.35	-0.01	-0.02	1128	1133
Percentage of plots with any title	0.22	0.24	-0.02	-0.05	1128	1133
Household knows the deliberation process to receive a land title	0.47	0.33	0.14	**0.28**	1128	1133

Source: IWRM Project baseline household survey data

Note: Effect size differences greater than 0.25 standard deviation units are in bold. Comparison sample sizes are weighted to the number of times a household is matched to treatment households

B. Missing data imputation strategy

To maximize our sample size for the matched comparison group design in Delta, we imputed missing data for baseline variables among households that were surveyed prior to matching. Missing data was due to item non-response or skip patterns in the survey. In order for the matching model to consider all surveyed households, each household had to have a non-missing value for each variable used for matching. Further, our impact estimation equation controls for the baseline value of each outcome measure. In order for no households to be dropped from the estimation equation that have valid outcome data, each baseline measure needed to contain only non-missing values. We imputed baseline data using the following imputation strategy:

- When data was missing data due to a skip pattern in the survey, we imputed 0 for that missing observation and include the gateway question that led to the skip pattern in the matching model. For example, respondents only answered questions on land titles if they reported having farm plots. Respondents who did not report having farm plots received a 0 for this question but we also included a binary variable of whether a household has farm plots in the matching model. Households that did not farm rice will have a 0 for all variables asking about rice investment, harvest, and revenue. In general, households who reported not farming last season have a 0 imputed for all agriculture variables in that season for the matching model.

- When data was missing for **binary variables** even though a respondent was supposed to answer that question, we imputed a 0 for that value, interpreting a non-response as a negative response to the question.

- We found that 1.4% of observations were missing for the Poverty Probability Index for Senegal. This is a 10-question index that maps a likelihood of living in poverty to each household (Schreiner 2016). If a household did not answer all 10 questions, the index has a missing value. To correct for this, we scaled the index for the questions the respondents answered to provide a poverty score for all surveyed households. For instance, if a household was missing a response to 1 question with a maximum value of 10 points, then that household’s poverty score was calculated out of 90 points instead of 100 points (the maximum score for a household that answered all 10 questions).

- When data was missing for **continuous variables** even though a respondent was supposed to answer that question, we imputed a nonzero value using single stochastic regression imputation with the ice command in Stata. Using a regression framework, this approach uses non-missing baseline data of key measures (the variables listed as available for inclusion in the matching model in Table V.2) to predict missing baseline values (Azur et al. 2011). A stochastic component is randomly selected from the set of residuals from the imputation equations and added to the imputed values to ensure that variance of the overall sample for each variables does not change with the imputed values. Imputation was conducted separately for the treatment and comparison group. A missing data analysis found that only a small number of observations for continuous variables were missing (around 1% to 2% of the data). For a few variables, this affected around 4% to 5% of the data.

We created a missing value binary variable that equaled 1 if a household had more than 10 imputed baseline values across all 3 waves of baseline data (for continuous variables), and 0 otherwise. This missing value flag was included in the Delta matching model and also as a control variable in our impact estimation equation. As a sensitivity test to our imputation approach, we estimated impacts among a matched-comparison group sample without imputation for missing continuous variables. Those results were similar to our primary analysis with imputed baseline data. Complete results of that sensitivity analysis is available in Appendix B.

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APPENDIX B

ADDITIONAL RESULTS FOR THE IMPACT ANALYSIS (DELTA)

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In this appendix, we provide detailed results on subgroup findings for the Delta impact analysis and impact estimates for Delta using a matched-comparison group without imputing any baseline data.

A. Subgroup results for agriculture production (Delta)

In Section V.C we presented summary subgroup results for agriculture production and rice production by gender of households head and the poverty status of the household. Tables B.1 through B.4 present complete subgroup results for the impact estimates shown in Section V.C.

Table B.1. Agriculture production impacts by gender of household head, among all households (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimate	*p-value*	Sample (T)	Sample (C)
Cold season						
Male-headed households						
Household farmed land	41%	58%	-17%**	0.00	921	906
Household harvested crops	26%	33%	-7%**	0.00	921	906
Land under production (ha)	1.10	0.91	0.19	0.06	915	898
Female-headed households						
Household farmed land	29%	43%	-14%**	0.00	215	230
Household harvested crops	13%	33%	-20%**	0.00	215	230
Land under production (ha)	0.47	0.43	0.04	0.75	214	230
Hot season						
Male-headed households						
Household farmed land	59%	57%	2%	0.37	911	892
Household harvested crops	57%	54%	3%	0.11	911	892
Land under production (ha)	1.42	0.81	0.61**	0.00	900	889
Female-headed households						
Household farmed land	30%	31%	-2%	0.68	211	216
Household harvested crops	28%	21%	7%	0.08	211	216
Land under production (ha)	0.64	0.27	0.36**	0.00	209	216
Rainy season						
Male-headed households						
Household farmed land	25%	27%	-2%	0.38	890	864
Household harvested crops	23%	25%	-1%	0.56	890	864
Land under production (ha)	0.47	0.22	0.25**	0.00	881	858
Female-headed households						
Household farmed land	18%	21%	-3%	0.46	207	203
Household harvested crops	12%	19%	-6%	0.09	207	203
Land under production (ha)	0.18	0.17	0.01	0.81	207	203

Source: IWRM Project baseline and follow-up household surveys

Note: Sample includes all households with non-missing data within each subgroup (male-headed or female-headed household). We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median on the full analytic sample.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table B.2. Agriculture production impacts by poverty level, among all households (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimate	*p-value*	Sample (T)	Sample (C)
Cold season						
Poorest households						
Household farmed land	31%	50%	-19%**	0.00	441	319
Household harvested crops	20%	31%	-10%**	0.00	441	319
Land under production (ha)	0.69	0.65	0.04	0.80	441	319
Less poor households						
Household farmed land	43%	57%	-14%**	0.00	410	487
Household harvested crops	25%	36%	-12%**	0.00	410	487
Land under production (ha)	0.92	0.76	0.16	0.15	407	487
Best-off households						
Household farmed land	40%	57%	-17%**	0.00	285	330
Household harvested crops	24%	31%	-7%	0.05	285	330
Land under production (ha)	1.36	1.05	0.31	0.13	281	322
Hot season						
Poorest households						
Household farmed land	43%	46%	-3%	0.30	438	310
Household harvested crops	41%	41%	0%	0.90	438	310
Land under production (ha)	0.85	0.45	0.40**	0.00	434	310
Less poor households						
Household farmed land	58%	54%	4%	0.19	406	478
Household harvested crops	56%	50%	6%*	0.05	406	478
Land under production (ha)	1.30	0.62	0.68**	0.00	404	477
Best-off households						
Household farmed land	59%	56%	3%	0.34	278	320
Household harvested crops	57%	50%	7%	0.07	278	320
Land under production (ha)	1.76	1.08	0.69**	0.00	271	318
Rainy season						
Poorest households						
Household farmed land	17%	15%	3%	0.37	434	295
Household harvested crops	17%	11%	5%*	0.03	434	295
Land under production (ha)	0.27	0.13	0.14**	0.00	432	295
Less poor households						
Household farmed land	25%	32%	-7%*	0.01	395	459
Household harvested crops	23%	30%	-7%*	0.01	395	459
Land under production (ha)	0.39	0.21	0.18**	0.00	394	454
Best-off households						
Household farmed land	29%	26%	3%	0.46	268	313
Household harvested crops	25%	25%	0%	0.98	268	313
Land under production (ha)	0.63	0.28	0.35**	0.00	262	312

Source: IWRM Project baseline and follow-up household surveys

Note: Sample includes all households with non-missing data within each poverty subgroup using the Poverty Probability Index for Senegal (Schreiner 2016). We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median on the full analytic sample.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table B.3. Rice production impacts by gender of household head (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimate	*p*-value	Sample (T)	Sample (C)
Hot season						
Male-headed households						
Household cultivated rice	47%	42%	5%*	0.03	921	906
Area of rice cultivated (ha)	1.37	0.74	0.63**	0.00	903	889
Rice yield (kg/ha)	5,531	4,772	759**	0.00	545	511
Female-headed households						
Household cultivated rice	17%	13%	4%	0.24	215	230
Area of rice cultivated (ha)	0.60	0.21	0.39**	0.00	209	216
Rice yield (kg/ha)	4,367	1,932	2,436**	0.00	59	68
Rainy season						
Male-headed households						
Household cultivated rice	16%	19%	-4%*	0.03	915	903
Area of rice cultivated (ha)	0.43	0.20	0.23**	0.00	883	858
Rice yield (kg/ha)	3,869	4,725	-856*	0.01	246	230
Female-headed households						
Household cultivated rice	6%	12%	-6%*	0.03	213	230
Area of rice cultivated (ha)	0.12	0.10	0.03	0.58	207	203
Rice yield (kg/ha)	2,247	4,413	-2,167**	0.01	35	43

Source: IWRM Project baseline and follow-up household surveys

Note: For cultivating rice and area of rice cultivated, sample includes all households with non-missing data within each subgroup (male-headed or female-headed household). Sample for rice yield is among farming households for each subgroup. We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables. We do not report results for cold season rice production as the rice variety available is not suitable for cold season production. Our survey results found that some farmers did report cultivating rice in the cold season but call-back interviews revealed that this was mainly harvesting rice that was planted during the rainy season, as detailed in section IV.C.1.c.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table B.4. Rice production impacts by poverty status (Delta)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimate	*p*-value	Sample (T)	Sample (C)
Hot season						
Poorest households						
Household cultivated rice	30%	31%	-1%	0.60	441	319
Area of rice cultivated (ha)	0.80	0.41	0.39**	0.00	435	310
Rice yield (kg/ha)	4,294	3,459	885*	0.02	209	144
Less poor households						
Household cultivated rice	46%	36%	10%**	0.00	410	487
Area of rice cultivated (ha)	1.21	0.52	0.69**	0.00	404	477
Rice yield (kg/ha)	5,463	4,473	989**	0.00	232	257
Best-off households						
Household cultivated rice	47%	42%	4%	0.21	285	330
Area of rice cultivated (ha)	1.81	1.04	0.77**	0.00	273	318
Rice yield (kg/ha)	6,365	5,182	1,183	0.06	163	178
Rainy season						
Poorest households						
Household cultivated rice	8%	7%	1%	0.54	439	319
Area of rice cultivated (ha)	0.23	0.11	0.13*	0.01	433	295
Rice yield (kg/ha)	3,020	3,538	-518	0.54	88	44
Less poor households						
Household cultivated rice	16%	24%	-8%**	0.00	408	486
Area of rice cultivated (ha)	0.33	0.16	0.17**	0.00	394	454
Rice yield (kg/ha)	3,720	4,946	-1,226**	0.00	109	147
Best-off households						
Household cultivated rice	17%	20%	-3%	0.41	281	328
Area of rice cultivated (ha)	0.61	0.26	0.34**	0.00	263	312
Rice yield (kg/ha)	4,127	4,803	-676	0.27	84	82

Source: IWRM Project baseline and follow-up household surveys

Note: For cultivating rice and area of rice cultivated, sample includes all households with non-missing data within each poverty subgroup using the Poverty Probability Index for Senegal (Schreiner 2016). Sample for rice yield is among farming households for each subgroup. We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables. We do not report results for cold season rice production as the rice variety available is not suitable for cold season production. Our survey results found that some farmers reported cultivating rice in the cold season but call-back interviews revealed that this was mainly harvesting rice that was planted during the rainy season, as detailed in section IV.C.1.c.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

B. Impact estimates for Delta with un-imputed baseline data

Due to item non-response at baseline, we imputed a small amount of missing baseline data to maximize our sample size for the matched-comparison group, as described in Appendix A. To ensure that our primary impact estimates are not sensitive to our imputation approach, we conducted propensity score matching without imputing baseline data and then estimated impacts on that sample. This resulted in a smaller analytic sample but served as a check on whether our imputation approach was driving our impact results. We first provide baseline equivalence results for the matched sample with no imputed baseline data and then present impact results for this sample.

1. Baseline equivalence

Table B.5 presents baseline equivalence for our matched sample without imputing baseline data. We examined equivalence on all variables available for inclusion in the matching model in Table IV.3 as well as all 3 waves of variables for measures on irrigation, agriculture investment, crop revenue, and land tenure security, and an annual measure of household consumption. In total, we looked at baseline equivalence on 53 variables related to the outcomes measured. We examined absolute effect size differences between group means at baseline whereby an effect size difference of greater than 0.25 standard deviations does not satisfy baseline equivalence (Ho et al. 2007). We find no baseline differences great than 0.25 standard deviations. We find one difference between 0.20 and 0.25 standard deviations. This provides evidence that we achieved baseline equivalence on our matched sample without imputing baseline data.

Since we also report results among households that farmed land at follow-up, we also checked baseline equivalence among that sub-sample of our matched sample. Among the 53 variables we examined, we find only one difference greater than a quarter standard deviation between the treatment and comparison group (results not shown). We also find one difference between 0.20 and 0.25 standard deviations. Based on this, our sample of farming households also achieves baseline equivalence.

Table B.5. Baseline equivalence results for matched sample without baseline imputation (Delta)

Variable	Treatment mean	Comparison mean	Difference	Effect size difference	Sample (treatment)	Sample (comparison)
Household size	9.94	9.83	0.11	0.02	1069	1069
Age of household head	49.64	49.41	0.23	0.02	1069	1069
Household head is male	0.82	0.80	0.01	0.03	1069	1069
Household head received some formal education	0.32	0.38	-0.06	-0.12	1066	1067
Poverty likelihood (<$2.50/day)	0.69	0.67	0.01	0.09	1069	1069
Household consumption	2,675,148	2,715,915	-40,767	-0.03	1069	1069
Cold season						
Household has farm plots	0.78	0.74	0.04	0.09	1069	1069
Household farmed land	0.63	0.60	0.04	0.08	1069	1069
Total amount of land used (hectares)	1.65	1.80	-0.15	-0.04	1069	1069
Household used a gravity irrigation system	0.59	0.55	0.04	0.08	1069	1069
Agriculture investment costs per hectare of land farmed	250,342	277,171	-26,829	-0.05	1067	1067
Household harvested any crops	0.29	0.27	0.02	0.05	1069	1069
Revenue per hectare of land (inclusive of all crops)	112,483	141,446	-28,963	-0.08	1033	1065
Area of rice cultivated	1.39	1.54	-0.15	-0.04	1069	1069
Rice yield (kg per hectare)	584	688	-105	-0.05	1069	1069
At least 1 plot that has access to a river/lake	0.62	0.58	0.04	0.08	1069	1069
Total amount of land irrigated	2.60	3.02	-0.43	-0.09	677	637
Household expressed concern about losing land	0.36	0.37	-0.01	-0.01	1069	1069
Percentage of plots with any title	0.26	0.27	-0.01	-0.02	1069	1069
Household knows the deliberation process to receive a land title	0.41	0.38	0.02	0.05	1069	1069
Hot season						
Household has access to farm plots	0.82	0.79	0.02	0.06	1069	1069
Household farmed land	0.62	0.59	0.03	0.05	1069	1069
Total amount of land used (hectares)	1.37	1.35	0.02	0.01	1069	1069
Household used a gravity irrigation system	0.57	0.55	0.02	0.05	1069	1069
Agriculture investment costs per hectare of land farmed	186,574	190,317	-3,743	-0.02	1069	1069
Household harvested any crops	0.57	0.54	0.02	0.05	1069	1069
Revenue per hectare of land (inclusive of all crops)	313,114	277,483	35,630	0.07	1038	1025
Area of rice cultivated	1.22	1.26	-0.04	-0.01	1069	1069
Rice yield (kg per hectare)	3,045	3,158	-113	-0.02	1069	1069
At least 1 plot that has access to a river/lake	0.59	0.58	0.02	0.03	1069	1069
Total amount of land irrigated	2.21	2.22	-0.01	0.00	658	631

Variable	Treatment mean	Comparison mean	Difference	Effect size difference	Sample (treatment)	Sample (comparison)
Household expressed concern about losing land	0.32	0.40	-0.08	-0.16	1069	1069
Percentage of plots with any title	0.20	0.21	0.00	0.00	1069	1069
Household knows the deliberation process to receive a land title	0.41	0.33	0.08	0.17	1069	1069
Rainy season						
Household has access to farm plots	0.80	0.77	0.03	0.08	1060	1066
Household farmed land	0.42	0.34	0.08	0.17	1060	1066
Total amount of land used (hectares)	0.77	0.71	0.06	0.02	1060	1066
Household used a gravity irrigation system	0.35	0.31	0.04	0.08	1060	1066
Agriculture investment costs per hectare of land farmed	103,104	113,805	-10,701	-0.05	1059	1066
Household harvested any crops	0.22	0.19	0.04	0.09	1025	1066
Revenue per hectare of land (inclusive of all crops)	68,652	86,175	-17,523	-0.07	999	1053
Area of rice cultivated	0.61	0.63	-0.02	-0.01	1060	1066
Rice yield (kg per hectare)	506	606	-100	-0.06	1060	1066
At least 1 plot that has access to a river/lake	0.36	0.31	0.05	0.10	1060	1066
Total amount of land irrigated	1.60	2.08	-0.48	-0.13	445	358
Household expressed concern about losing land	0.34	0.32	0.01	0.03	1060	1066
Percentage of plots with any title	0.22	0.27	-0.05	-0.12	1060	1066
Household knows the deliberation process to receive a land title	0.47	0.36	0.12	0.24	1060	1066

Source: IWRM Project baseline household survey data

Note: Effect size differences greater than 0.25 standard deviation units are in bold. Comparison sample sizes are weighted to the number of times a household is matched to treatment household.

2. Impact results

Tables B.6 through B.11 show impact estimates for the matched-sample with no imputed baseline data. Overall, our findings for the matched sample without imputed baseline data were comparable to our primary estimation model both in statistical significance and magnitude of impacts. This provides evidence that our primary findings were not sensitive to our imputation approach.

Table B.6. Impact estimates for water and irrigation, among households that farmed (Delta, no baseline imputation)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimates	*p*-value	Sample (T)	Sample (C)
Cold season						
Satisfied with the availability of irrigation water	85%	79%	6%**	0.01	406	561
Used a simple gravity irrigation system	7%	28%	-22%**	0.00	411	580
Used a sophisticated irrigation system	90%	65%	24%**	0.00	411	580
Percentage of farm plots that were irrigated	97%	92%	5%**	0.00	418	585
Total area of land irrigated (ha)	2.16	1.53	0.63**	0.00	347	437
Hot season						
Satisfied with the availability of irrigation water	95%	82%	13%**	0.00	580	538
Used a simple gravity irrigation system	8%	12%	-4%*	0.01	582	538
Used a sophisticated irrigation system	90%	91%	0%	0.88	582	538
Percentage of farm plots that were irrigated	96%	99%	-2%**	0.00	584	538
Total area of land irrigated (ha)	2.40	1.50	0.90**	0.00	466	418
Rainy season						
Satisfied with the availability of irrigation water	92%	81%	11%**	0.00	222	260
Used a simple gravity irrigation system	12%	2%	10%**	0.00	224	261
Used a sophisticated irrigation system	85%	93%	-8%**	0.00	224	261
Percentage of farm plots that were irrigated	88%	99%	-11%**	0.00	255	263
Total area of land irrigated (ha)	1.84	1.03	0.80**	0.00	147	165

Source: IWRM Project baseline and follow-up household surveys

Note: Result are among households that report farming in each wave. We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Sample sizes vary based on survey response and farming rates. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median. A household is marked as satisfied with the availability of irrigation water if they reported they were either satisfied or very satisfied. They are marked as unsatisfied if they reported they were neutral, unsatisfied, or very unsatisfied with the availability of irrigation water. A household used a type of irrigation system if it reported its use on at least one of its farm plots. Beyond simple gravity irrigation and sophisticated irrigation, farmers could report using a watering can for irrigation, no irrigation, or some other form of irrigation identified by the respondent.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table B.7. Impact estimates for land under production, among all households (Delta, no baseline imputation)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimate	*p*-value	Sample (T)	Sample (C)
Cold season						
Land under production (ha)	0.77	0.74	0.03	0.67	1054	1065
Household has farm plots	76%	79%	-3%	0.11	1066	1067
Household farmed land	37%	55%	-17%**	0.00	1066	1067
Household harvested crops	23%	34%	-11%**	0.00	1066	1067
Hot season						
Land under production (ha)	1.16	0.70	0.46**	0.00	1038	1041
Household has farm plots	77%	77%	0%	0.96	1053	1044
Household farmed land	54%	52%	3%	0.18	1053	1044
Household harvested crops	52%	47%	5%*	0.01	1053	1044
Rainy season						
Land under production (ha)	0.40	0.25	0.15**	0.00	1016	1006
Household has farm plots	78%	80%	-2%	0.12	1026	1006
Household farmed land	23%	26%	-3%	0.08	1026	1006
Household harvested crops	21%	24%	-3%	0.10	991	1006

Source: IWRM Project baseline and follow-up household surveys

Note: Sample includes all households with non-missing data. We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median. A household has farm plots if it reported that it possessed, borrowed, used, rented, or managed any farm land. A household farmed land if it reported that it cultivated any crops on farm land.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table B.8. Impact estimates for rice production (Delta, no baseline imputation)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimates	*p*-value	Sample (T)	Sample (C)
Hot season						
Among all households						
Household cultivated rice	42%	39%	4%*	0.05	1066	1067
Area of rice cultivated (ha)	1.07	0.63	0.44**	0.00	1039	1041
Among farming households						
Rice investment costs per hectare (‘000 FCFA)	364	325	39	0.06	580	538
Rice yield (kg/ha)	5,484	4,643	842**	0.00	581	538
Rice revenue (‘000 FCFA)	512	281	231**	0.00	425	364
Rice revenue per hectare (‘000 FCFA)	243	214	28	0.24	582	538
Rainy season						
Among all households						
Household cultivated rice	13%	19%	-6%**	0.00	1058	1064
Area of rice cultivated (ha)	0.36	0.22	0.14**	0.00	1019	1006
Among farming households						
Rice investment costs per hectare (‘000 FCFA)	175	215	-41*	0.01	263	263
Rice yield (kg/ha)	3,904	4,898	-995**	0.00	264	263
Rice revenue (‘000 FCFA)	656	523	133	0.30	138	77
Rice revenue per hectare (‘000 FCFA)	270	496	-226**	0.01	264	263
Seasons combined						
Among farming households						
Total rice revenue (‘000 FCFA)	771	380	391**	0.00	537	543

Source: IWRM Project baseline and follow-up household surveys

Note: We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Sample sizes vary based on survey response and whether the measure contains all households or just farming households. For measures with the seasons combined, households are included if they farmed in any season. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables. We do not report results for cold season rice production as the rice variety available is not suitable for cold season production. Our survey results found that some farmers did report cultivating rice in the cold season but call-back interviews revealed that this was mainly harvesting rice that was planted during the rainy season, as detailed in section IV.C.1.c.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table B.9. Impact estimates for agriculture investment and revenue, among farming households (Delta, no baseline imputation)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimate	*p*-value	Sample (T)	Sample (C)
Cold season						
Agriculture investment costs (‘000 FCFA)	512	363	149**	0.00	397	569
Agriculture investment costs per hectare (‘000 FCFA)	1,151	375	777*	0.02	403	560
Revenue all crops (‘000 FCFA)	783	675	108	0.27	209	333
Revenue per hectare all crops (‘000 FCFA)	596	812	-216**	0.00	206	318
Hot season						
Agriculture investment costs (‘000 FCFA)	535	385	150**	0.00	567	530
Agriculture investment costs per hectare (‘000 FCFA)	326	369	-42	0.06	573	529
Revenue all crops (‘000 FCFA)	967	525	442**	0.00	486	431
Revenue per hectare all crops (‘000 FCFA)	673	688	-15	0.89	494	427
Rainy season						
Agriculture investment costs (‘000 FCFA)	385	213	173**	0.00	262	263
Agriculture investment costs per hectare (‘000 FCFA)	228	244	-16	0.38	258	255
Revenue all crops (‘000 FCFA)	914	443	471**	0.00	185	219
Revenue per hectare all crops (‘000 FCFA)	569	608	-39	0.77	185	214
Seasons combined						
Agriculture investment costs (‘000 FCFA)	884	628	256**	0.00	694	748
Revenue all crops (‘000 FCFA)	1,425	900	525**	0.00	589	653

Source: IWRM Project baseline and follow-up household surveys

Note: We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. The sample contains all households who farmed in each season. For measures with the seasons combined, households are included if they farmed in any season. Sample sizes vary based on survey response. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table B.10. Impact estimates for income and agricultural profits (Delta, no baseline imputation)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimates	*p*-value	Sample (T)	Sample (C)
Cold season						
Among all households						
Off-farm household earnings (‘000 FCFA)	254	395	-141**	0.00	842	894
Among farming households						
Agricultural profit (‘000 FCFA)	68	168	-101*	0.02	398	573
Off-farm household earnings (‘000 FCFA)	252	382	-130**	0.00	324	482
Hot season						
Among all households						
Off-farm household earnings (‘000 FCFA)	225	370	-145**	0.00	868	902
Among farming households						
Agricultural profit (‘000 FCFA)	313	97	215**	0.01	557	496
Off-farm household earnings (‘000 FCFA)	220	303	-83*	0.02	469	474
Rainy season						
Among all households						
Off-farm household earnings (‘000 FCFA)	244	338	-94**	0.00	897	850
Among farming households						
Agricultural profit (‘000 FCFA)	341	181	160**	0.01	241	252
Off-farm household earnings (‘000 FCFA)	327	486	-159*	0.02	240	210
Seasons combined						
Among all households						
Off-farm household earnings (‘000 FCFA)	699	1,006	-307**	0.00	1024	1011
Household consumption (‘000 FCFA)	3,006	2,965	40	0.38	986	955
Among farming households						
Agricultural profit (‘000 FCFA)	421	265	156**	0.00	707	751
Off-farm household earnings (‘000 FCFA)	762	971	-209**	0.00	682	706
Household consumption (‘000 FCFA)	3,210	3,098	112	0.05	663	697

Source: IWRM Project baseline and follow-up household surveys

Note: We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate of around 560 FCFA to 1 USD. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Sample sizes vary based on survey response. Agricultural profit measures include farming households that reported both revenue and investment data. Outcomes were trimmed at +/- 3 standard deviations from the median.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table B.11. Impact estimates on land security and formalization, among households who have farm land (Delta, no baseline imputation)

Outcome measure	Treatment mean (adjusted)	Comparison mean	Impact estimates	*p*-value	Sample (T)	Sample (C)
Household knows deliberation process to receive land title	58%	18%	40%**	0.00	655	728
Percentage of plots with any land title	31%	14%	18%**	0.00	792	765
Household is concerned about losing land	17%	21%	-4%	0.05	802	773
Household reported any land conflicts	5%	3%	2%	0.15	712	667

Source: IWRM Project baseline and follow-up household surveys

Note: Sample sizes vary based on survey response. Sample contains households who reported having access to farm land. We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

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APPENDIX C

ADDITIONAL RESULTS FOR THE PRE-POST ANALYSIS (PODOR)

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In this appendix, we provide results from the rainy season for households in the intervention group. We also provide detailed results on subgroup findings for the Podor pre-post analysis.

A. Pre-post rainy season results (Podor)

As explained in Section VI.B, only about a quarter of farmers cultivated land during the 2017-18 rainy season, mainly due to factors external to the IWRM Project. This included significant delays in receiving agricultural loans for the season and a public notice that the Senegal River level would be lower than usual. As a result, we find decreases on most outcome measures relative to baseline because fewer households farmed in this season. Our analysis focuses on pre-post changes for the cold and hot season, but we present rainy season results here for completeness.

Table C.1. Pre-post changes for water and irrigation, among all households (rainy season, Podor)

Outcome measure	Post mean	Pre mean	Difference	*p*-value	Sample (post)	Sample (pre)
Satisfied with availability of irrigation water	21%	45%	-24%**	0.00	248	249
Used a simple gravity irrigation system	0%	3%	-3%**	0.00	249	249
Used a sophisticated irrigation system	28%	47%	-19%**	0.00	249	249
Percentage of farm plots that were irrigated	27%	45%	-18%**	0.00	249	249
Total area of land irrigated (ha)	0.12	0.31	-0.19**	0.00	245	244

Source: IWRM Project baseline and follow-up household surveys

Note: Data were trimmed at +/- 3 standard deviations from the median. A household used a type of irrigation system if it reported its use on at least one of its farm plots. A household is marked as satisfied with the availability of irrigation water if they reported they were either satisfied or very satisfied. They are marked as unsatisfied if they reported they were neutral, unsatisfied, or very unsatisfied with the availability of irrigation water. If a household decided not to farm, we mark them as unsatisfied with the availability of irrigation water as the lack of available water was a reason a household may not farm. Beyond simple gravity irrigation and sophisticated irrigation, farmers could report using a watering can for irrigation, no irrigation, or some other form of irrigation identified by the respondent. Results are among all households surveyed in the rainy season. Sample sizes vary based on survey responses, item-level missing data, and outlier trimming.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

Table C.2. Pre-post changes for agricultural production, among all households (rainy season, Podor)

Outcome measure	Post mean	Pre mean	Difference	*p*-value	Sample (post)	Sample (pre)
Land under production (ha)	0.12	0.31	-0.19**	0.00	247	245
Household has farm plots	92%	78%	14%**	0.00	249	249
Household farmed land	28%	53%	-24%**	0.00	249	249
Household harvested crops	25%	27%	-2%	0.61	249	249

Source: IWRM Project baseline and follow-up household surveys

Note: Results are among all households surveyed in the rainy season. Data were trimmed at +/- 3 standard deviations from the median. Sample sizes vary based on survey responses, item-level missing data, and outlier trimming. A household has farm plots if it reported that it possessed, borrowed, used, rented, or managed any farm land. A household farmed land if it reported that it cultivated any crops on farm land.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

Table C.3. Pre-post changes for rice production, among all households (rainy season, Podor)

Outcome measure	Post mean	Pre mean	Difference	*p*-value	Sample (post)	Sample (pre)
Household cultivated rice	26%	19%	7%	0.07	249	249
Area of rice cultivated (ha)	0.12	0.09	0.03	0.16	248	248
Rice investment costs per hectare (‘000 FCFA)	84	46	38*	0.01	245	247
Rice yield (kg/ha)	1,084	847	237	0.24	248	247
Rice revenue (‘000 FCFA)	22	26	-4	0.58	248	248
Rice revenue per hectare (‘000 FCFA)	40	53	-13	0.32	246	248

Source: IWRM Project baseline and follow-up household surveys

Note: Results are among all households surveyed in the rainy season. Sample sizes vary based on survey response rates, item-level non-response, and outlier trimming. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Follow-up data is inflation adjusted using change in the consumer price index in Senegal from 2012 to 2017. Data were trimmed at +/- 2 standard deviations from the median for per hectare variables and +/- 3 standard deviations from the median for all other variables.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

Table C.4. Pre-post changes for agriculture investment and revenue, among all households (rainy season, Podor)

Outcome measure	Post mean	Pre mean	Difference	*p*-*value*	Sample (post)	Sample (pre)
Agriculture investment costs (‘000 FCFA)	34	119	-85**	0.00	244	246
Agriculture investment costs per hectare (‘000 FCFA)	74	188	-114**	0.00	243	236
Revenue all crops (‘000 FCFA)	18	34	-16*	0.04	231	232
Revenue all crops per hectare (‘000 FCFA)	35	51	-16	0.15	229	219

Source: IWRM Project baseline and follow-up household surveys

Note: Result are among all intervention households in the rainy season. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Follow-up data is inflation adjusted using change in the consumer price index in Senegal from 2012 to 2017. Data were trimmed at +/- 3 standard deviations from the median.

*Significantly different from baseline value at the .05 level, two-tailed test.

**Significantly different from baseline value at the .01 level, two-tailed test.

Table C.5. Pre-post changes for income and agricultural profits, among all households (rainy season and annual, Podor)

Outcome measure	Post mean	Pre mean	Difference	*p*-value	Sample (post)	Sample (pre)
Rainy season						
Agricultural profit (‘000 FCFA)	-10	-86	76**	0.00	205	230
Off-farm household earnings (‘000 FCFA)	105	141	-36	0.07	246	244
Seasons combined						
Agricultural profit (‘000 FCFA)	99	53	46	0.57	249	249
Off-farm household earnings (‘000 FCFA)	104	53	52	0.51	249	249

Source: IWRM Project baseline and follow-up household surveys

Note: Result are among all intervention households in the rainy season. Currency amounts are shown in West African francs (FCFA) and reported in thousands. The current exchange rate is around 560 FCFA to 1 USD. Follow-up data is inflation adjusted using change in the consumer price index in Senegal from 2012 to 2017. Outcomes were trimmed at +/- 3 standard deviations from the median. Sample sizes vary based on survey responses, item-level missing data, and outlier trimming. Seasons combined include results from the cold, rainy, and hot seasons.

*Significantly different from the baseline value at the .05 level, two-tailed test.

**Significantly different from the baseline value at the .01 level, two-tailed test.

B. Subgroup results for agriculture production (Podor)

In Section 7.C we presented summary subgroup results for agriculture production and rice production by gender of households head and the poverty status of the household. Tables C.1 through C.4 present complete subgroup results for the pre-post estimates shown in Section 7.C.

Table C.6. Pre-post changes in agriculture production by gender of household head, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p*-value	Sample (post)	Sample (pre)
Cold season						
Male-headed households						
Household farmed land	55%	73%	-19%**	0.00	221	221
Household harvested crops	50%	67%	-16%**	0.00	221	221
Land under production (ha)	0.29	0.39	-0.10**	0.01	217	217
Female-headed households						
Household farmed land	50%	54%	-4%	0.79	28	28
Household harvested crops	43%	46%	-4%	0.79	28	28
Land under production (ha)	0.21	0.28	-0.07	0.40	28	28
Hot season						
Male-headed households						
Household farmed land	62%	58%	4%	0.44	221	221
Household harvested crops	61%	34%	26%**	0.00	221	221
Land under production (ha)	0.33	0.30	0.03	0.44	217	221
Female-headed households						
Household farmed land	68%	32%	36%**	0.00	28	28
Household harvested crops	57%	29%	29%*	0.03	28	28
Land under production (ha)	0.34	0.11	0.23**	0.00	28	27
Rainy season						
Male-headed households						
Household farmed land	28%	56%	-28%**	0.00	221	221
Household harvested crops	25%	29%	-4%	0.39	221	221
Land under production (ha)	0.12	0.33	-0.21**	0.00	219	217
Female-headed households						
Household farmed land	25%	29%	-4%	0.76	28	28
Household harvested crops	25%	14%	11%	0.31	28	28
Land under production (ha)	0.11	0.16	-0.05	0.49	28	28

Source: IWRM Project baseline and follow-up household surveys

Note: Sample includes all households with non-missing data within each subgroup (male-headed or female-headed household). We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median on the full analytic sample.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table C.7. Pre-post changes in agriculture production by poverty level, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p*-value	Sample (post)	Sample (pre)
Cold season						
Poorest households						
Household farmed land	46%	72%	-26%**	0.00	121	121
Household harvested crops	43%	66%	-23%**	0.00	121	121
Land under production (ha)	0.24	0.35	-0.11*	0.02	121	120
Less poor households						
Household farmed land	67%	74%	-7%	0.30	81	81
Household harvested crops	58%	65%	-7%	0.33	81	81
Land under production (ha)	0.34	0.39	-0.05	0.42	79	80
Best-off households						
Household farmed land	53%	64%	-11%	0.30	47	47
Household harvested crops	51%	57%	-6%	0.54	47	47
Land under production (ha)	0.28	0.42	-0.13	0.13	45	45
Hot season						
Poorest households						
Household farmed land	65%	50%	16%*	0.01	121	121
Household harvested crops	62%	36%	26%**	0.00	121	121
Land under production (ha)	0.32	0.22	0.10*	0.03	120	120
Less poor households						
Household farmed land	60%	62%	-1%	0.87	81	81
Household harvested crops	59%	31%	28%**	0.00	81	81
Land under production (ha)	0.37	0.30	0.07	0.26	80	81
Best-off households						
Household farmed land	60%	60%	0%	1.00	47	47
Household harvested crops	57%	32%	26%*	0.01	47	47
Land under production (ha)	0.28	0.38	-0.11	0.17	45	47
Rainy season						
Poorest households						
Household farmed land	25%	50%	-26%**	0.00	121	121
Household harvested crops	21%	17%	4%	0.41	121	121
Land under production (ha)	0.11	0.29	-0.18**	0.00	121	119
Less poor households						
Household farmed land	30%	54%	-25%**	0.00	81	81
Household harvested crops	30%	36%	-6%	0.40	81	81
Land under production (ha)	0.13	0.29	-0.16**	0.00	80	80
Best-off households						
Household farmed land	30%	55%	-26%*	0.01	47	47
Household harvested crops	30%	40%	-11%	0.28	47	47
Land under production (ha)	0.15	0.42	-0.27**	0.00	46	46

Source: IWRM Project baseline and follow-up household surveys

Note: Sample includes all households with non-missing data within each poverty subgroup using the Poverty Probability Index for Senegal (Schreiner 2016). We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median on the full analytic sample.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table C.8. Pre-post changes in rice production by gender of household head, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p*-value	Sample (post)	Sample (pre)
Hot season						
Male-headed households						
Household cultivated rice	59%	44%	15%**	0.00	221	221
Area of rice cultivated (ha)	0.30	0.22	0.07*	0.03	217	221
Rice yield (kg/ha)	3,677	937	2,740**	0.00	220	220
Female-headed households						
Household cultivatedrice	61%	21%	39%**	0.00	28	28
Area of rice cultivated (ha)	0.32	0.07	0.25**	0.00	28	27
Rice yield (kg/ha)	3,863	477	3,387*	0.02	28	28
Rainy season						
Male-headed households						
Household cultivated rice	25%	19%	6%	0.14	221	221
Area of rice cultivated (ha)	0.12	0.09	0.03	0.22	220	220
Rice yield (kg/ha)	1,084	900	184	0.40	220	219
Female-headed households						
Household cultivated rice	21%	14%	7%	0.49	28	28
Area of rice cultivated (ha)	0.09	0.05	0.04	0.34	28	28
Rice yield (kg/ha)	1,086	436	650	0.23	28	28

Source: IWRM Project baseline and follow-up household surveys

Note: Sample includes all households with non-missing data within each subgroup (male-headed or female-headed household). We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median on the full analytic sample. We do not report results for cold season rice production as the rice variety available is not suitable for the Podor cold season climate. Our survey results found that some farmers did report cultivating rice in the cold season but call-back interviews revealed that this was mainly harvesting rice that was planted during the rainy season, as detailed in section IV.C.1.c.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

Table C.9. Pre-post changes in rice production by poverty status, among all households (Podor)

Outcome measure	Post mean	Pre mean	Difference	*p*-value	Sample (post)	Sample (pre)
Hot season						
Poorest households						
Household cultivated rice	64%	34%	30%**	0.00	121	121
Area of rice cultivated (ha)	0.29	0.15	0.13**	0.00	119	120
Rice yield (kg/ha)	3,811	1,128	2,683**	0.00	121	121
Less poor households						
Household cultivated rice	53%	48%	5%	0.53	81	81
Area of rice cultivated (ha)	0.34	0.22	0.12	0.05	81	81
Rice yield (kg/ha)	3,892	569	3,323**	0.00	80	80
Best-off households						
Household cultivated rice	57%	49%	9%	0.41	47	47
Area of rice cultivated (ha)	0.26	0.32	-0.06	0.38	45	47
Rice yield (kg/ha)	3,077	795	2,281**	0.00	47	47
Rainy season						
Poorest households						
Household cultivated rice	21%	9%	12%*	0.01	121	121
Area of rice cultivated (ha)	0.09	0.05	0.05	0.07	121	121
Rice yield (kg/ha)	813	385	427	0.06	121	121
Less poor households						
Household cultivated rice	28%	26%	2%	0.73	81	81
Area of rice cultivated (ha)	0.12	0.10	0.02	0.53	80	81
Rice yield (kg/ha)	1,231	1,061	170	0.64	80	80
Best-off households						
Household cultivated rice	30%	32%	-2%	0.82	47	47
Area of rice cultivated (ha)	0.18	0.18	0.00	0.98	47	46
Rice yield (kg/ha)	1,536	1,691	-156	0.81	47	46

Source: IWRM Project baseline and follow-up household surveys

Note: Sample includes all households with non-missing data within each poverty subgroup using the Poverty Probability Index for Senegal (Schreiner 2016). We present the adjusted treatment mean which equals the comparison mean plus the impact estimate. Comparison sample sizes are weighted to the number of times a household is matched to treatment households. Outcomes were trimmed at +/- 3 standard deviations from the median on the full analytic sample. We do not report results for cold season rice production as the rice variety available is not suitable for the Podor cold season climate. Our survey results found that some farmers did report cultivating rice in the cold season but call-back interviews revealed that this was mainly harvesting rice that was planted during the rainy season, as detailed in section IV.C.1.c.

*Significantly different from zero at the .05 level, two-tailed test.

**Significantly different from zero at the .01 level, two-tailed test.

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APPENDIX D

NVIVO CODEFRAME FOR THE QUALITATIVE ANALYSIS

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Table D.1 NVivo Codeframe for Qualitative Analysis

Code name	Description
AG. production agricole	Agricultural Production
AG0. AUE GIE GPF	Water user Groups (Association des usagers de l'eau); farmer cooperatives (Groupements d'Intérêt Économique); and women's production groups (Groupements de Promotion Féminine)
AG1. Production agricole	Agricultural production
G. administration foncière et gouvernance	Land administration and governance
G1. Services gouvernementaux locaux dans le domaine de la gestion des terres	Local government services in the domain of land management
G2. Soutien des organismes gouvernementaux	Support for government organizations
I. revenu	Revenue
I1. Changement de revenus	Changes to revenues
I1. Changement de vie	Lifestyle changes
I2. Niveau de vie	Quality of life
I3. Bénéfices agricoles	Agricultural profits
L. sécurité foncière et conflits	Land security and conflicts
L1. Régime foncier	Land tenure
L2. Formalisation des terres	Land formalization
L3. Demande et coûts pour les droits fonciers	Demand for and costs of land rights.
L4. Conflits fonciers	Land conflicts
L5. Accès des femmes à la terre	Women's access to land
L6. Investissements dans les terres	Investments in land
L7. Obstacles à L'accès à la terre	Obstacles to land access
Quotes	Memorable quotes
Exemple : « On ne travaille que pour la banque. »	Example : "We only work for the bank"
S durabilité et impacts externes	Sustainability and external impacts
S1. Durabilité	Sustainability
S2. Impacts en dehors des zones du projet	Impacts outside project areas
S3. Activités de GIRE et bénéficiaires	GIRE Activities and beneficiaries
Sentiment	Codes positive and negative expressions & attitudes
Négative	Codes negative attitudes and sentiments as expressed in KIIs, FGDs, etc.
Positive	Codes positive attitudes as expressed in KIIs, FGDs
W utilisation et disponibilité de l'eau	Use and Availability of Water
W0. Rôle de la SAED	Role of SAED
W1. Disponibilité de l'eau	Availability of Water
W2. Disponibilité de terres irriguées	Availability of irrigated land
W3. Rôle des AUE	Role of waters user organizations