Senegal's Irrigation and Water Resources Management Project at Five Years Post-Compact: Findings from a Mixed-Methods Evaluation

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List of Acronyms

AUE	*Association des Usagers de l'Eau* (water-user association)
CBA	Cost-benefit analysis
DGPPE	*Direction Générale de la Planification et des Politiques Economiques*
ERR	Economic Rate of Return
FCFA	West African CFA franc
GIE	*Groupement d'Intérêt économique* (farmer cooperatives)
GPF	*Groupement de Promotion Feminine* (female-only farmer cooperatives)
IWRM	Irrigation and Water Resources Management
KII	Key Informant Interviews
LTSA	Land Tenure Security Activity
MCA	Millennium Challenge Account
MCC	Millennium Challenge Corporation
PDIDAS	*Projet de Développement Inclusif et Durable de l'agribusiness au Sénégal*
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*
SIF	*Système d'Informations Foncières*
SRV	Senegal River Valley
USACS	*Unité de Suivi des Activités du Compact-Sénégal*

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1. Overview of the final evaluation

The Senegal River Valley (SRV) produces 80 percent of Senegal's rice and covers 240,000 hectares of potentially irrigable land that is suitable for rice as well as high-value horticulture (Diouf et al. 2015). The potential for irrigated agriculture increased in the late 1980s following the construction of two large dams along the Senegal River, which regulated and raised the water level to allow gravity-fed irrigation in the large flat delta region near the river's outflow to the Atlantic ocean (UNESCO, 2003). However, irrigation infrastructure throughout the delta had been degrading over several decades and led to insufficient water delivery to agricultural fields, improper drainage, and ultimately, the abandonment of fields in the area by the early 2000s. From 2010 to 2015, the Millennium Challenge Corporation (MCC) and the Government of Senegal made significant investments in the SRV, through the $540 million Senegal Compact, which aimed to "enable improved agricultural productivity and to expand access to markets and services through critical infrastructure investments in the roads and irrigation sectors" (MCC 2009). The $170 million Irrigation and Water Resources Management (IWRM) Project implemented under the compact was designed to "improve the productivity of the agricultural sector by extending and improving the quality of the irrigation system in certain agriculture-dependent areas of northern Senegal" (MCC 2009).

Activities covered by 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 perimeter at Ngalenka, in the department of Podor.

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

This report presents findings from the final evaluation of the IWRM Project five years post-compact, building on the key findings reported in the interim evaluation report (Coen et al. 2019). The interim report, which covers the first two years post-compact, concluded that although the compact met or exceeded all output targets for building and refurbishment of irrigation infrastructure, the IWRM Project did not expand agricultural production in the way that had been envisioned by the program logic. Specifically, although rice production and area under production increased in the main (hot dry) growing season, the project did not achieve the increase in cropping intensity (measured by how often land is cropped within an agricultural year) nor in vegetable production (represented by tomato and onion farming) that the compact had envisioned. In 2017, the last year covered by the interim evaluation, cropping intensity reached 75 percent, falling short of the compact target of 150 percent, and tomato and onion production only reached 5 and13 percent of the respective compact targets. In fact, the intervention had no impact on overall incomes, as farming households substituted labor and investment away from off-farm activities and toward hot dry season rice cultivation. The objective of this report is to revisit some of the main findings of the interim evaluation, to explore why intended outcomes were not achieved and to establish whether some of the envisioned short- or medium-term outcomes have been achieved in the three years since the interim evaluation.

A. Key findings by research area

Maintenance: Five years after the end of the compact, the irrigation infrastructure that the project built and rehabilitated remains in good condition. However, routine weed clearance and dredging is not keeping pace with what is needed in the Delta Activity area. Water flow rates at key water control structures are lower than the compact target, water flow may be dropping (consistent with a lack of routine maintenance), and lack of maintenance may eventually reduce water available for farming in the Delta Activity area.

Land use and farming: Cropping intensity, defined as the total land used for cultivation across all growing seasons as a fraction of the irrigable land, was 78 percent, well below the compact target of 150 percent. The area of land under production has steadily increased since the end of the compact, but structural obstacles, such as a lack of financing, as well as logistical challenges in preparing land for cultivation in consecutive seasons, prevent wider intensification. Farmers' rice yields are higher than pre-project levels and remain in line with levels observed at interim.

Vegetable production: Land under cultivation in the vegetable growing season, as well as the overall production of tomatoes and onions, increased steadily in the project areas since the interim evaluation, which suggests that the adoption of higher-value crops took longer than the compact had anticipated. However, the total production of tomatoes and onions is still below 20 percent of the compact targets.

Land tenure: In the three Delta area communes studied, demand for formalization of land titles continues to be strong, although lower than during the compact. The demand is driven largely by people's interest in regularizing their existing land tenure. Although parts of the land management system introduced under the compact are no longer in use, land managers have been able to meet the demand for titles through support from other donor programs to carry out some formalization tasks.

Economic rate of return (ERR): Based on information on land under production, yields, and costs collected in the 5 years post-compact, we estimate ERRs for the Delta and Podor activities well below those MCC estimated at the end of the compact (1.8 percent for Delta and -7.5 percent for Podor, compared to 15.9 percent and 3.5 percent respectively). The activities generated smaller benefits than MCC had originally anticipated, primarily because the area of land under production, improvements in crop yields, and profitability per hectare were lower than envisioned.

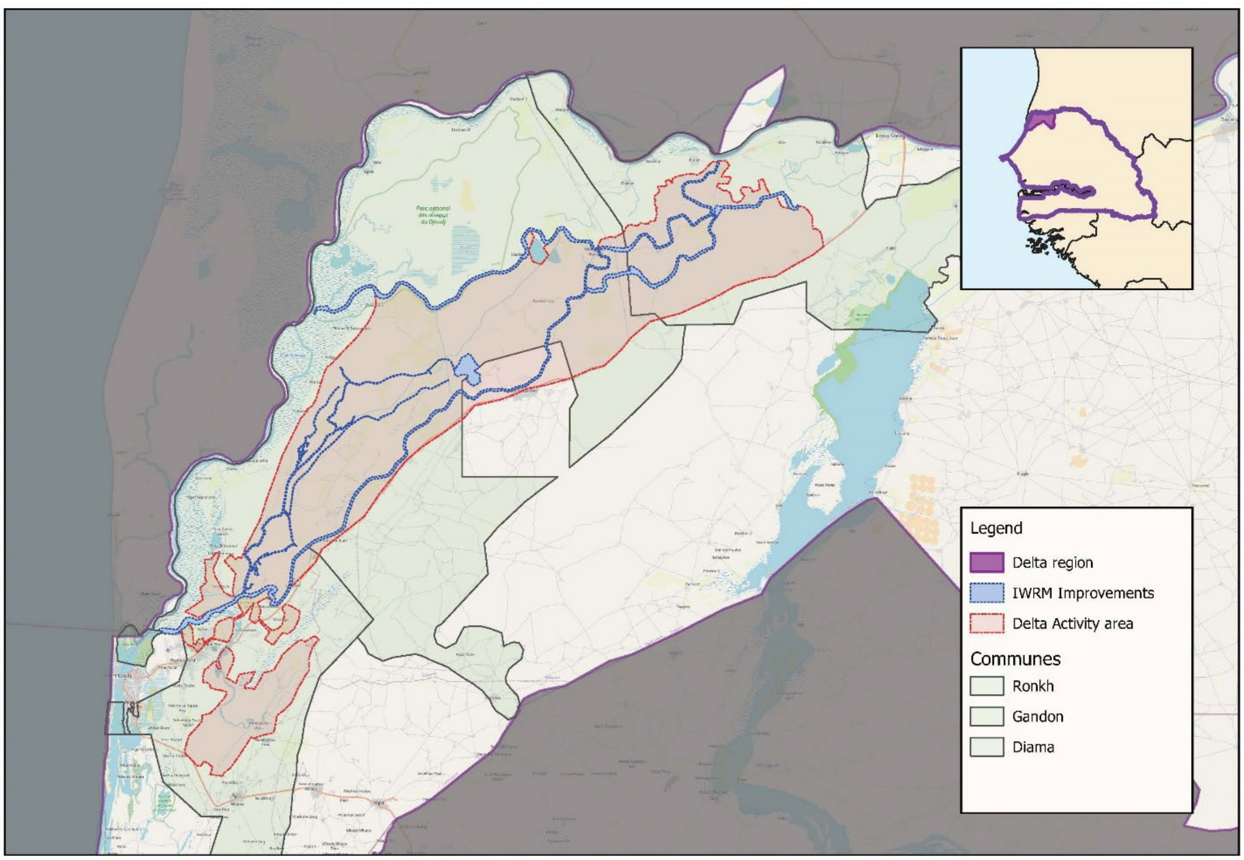
The rest of this report provides additional context on the IWRM Project, summarizes the final evaluation methods, and presents the main findings in more detail. The report itself is structured on addressing five research questions, which focus on the long-term sustainability of the IWRM Project and the extent to which short- or medium-term outcomes have been achieved. The report includes an update to the ERR using values for the interim impact evaluation and final evaluation for the Delta and Podor activities.

B. The IWRM Project

The IWRM Project consisted of three activities: (1) the **Delta Activity**, (2) the **Podor Activity**, (3) and the **Land Tenure Security Activity** (LTSA).[1] The project aimed to increase the volume of irrigation water to develop 8,500 to 10,500 hectares of additional irrigated land, eliminate the risk of abandonment of approximately 26,000 hectares of existing irrigable land, and provide additional supply of water for human and animal use in the Delta, Podor, and adjoining areas. The project also aimed to rehabilitate drainage canals, which would further eliminate the risk of abandonment of irrigated land and increase crop yields. The project also supported the land tenure security activity, to provide for, or maintain, a secure land tenure environment for all of the inhabitants of the region directly affected by the project.

The **Delta Activity** ($159.4 million) rehabilitated existing irrigation and drainage infrastructure and built new irrigation infrastructure in the delta of the SRV (specifically in the communes of Ronkh, Ross Bethio, Gandon, and Diama). On completion, the activity was expected to increase land under irrigated agriculture in the Delta Activity area from 11,800 hectares pre-compact to 39,740 hectares. Figure 1.B.1 shows the location of the improved infrastructure for the Delta Activity.

Figure 1.B.1. Location of improved irrigation infrastructure (Delta)



[1] A fourth activity, the Social Safeguard Activity, was not implemented.

The **Podor Activity** (not shown) constructed a new irrigated perimeter in the commune of Ndiayene Pendao in the Podor Department. The goal of the activity was the creation of 440 hectares of irrigable land.

The **LTS Activity (**not shown) supported the creation and implementation of fair, efficient, and transparent processes for allocating land with a goal to improve the investment climate in the project area and to mitigate the potential for land conflict due to increased demand for irrigated land as a result of the IWRM Project (MCC 2009). The Activity proposed to achieve this through: i) supporting the development and implementation of transparent, fair, and efficient processes for land allocation to ensure equitable and secure access to land in the irrigated perimeters; ii) equipping local authorities with tools, such as manuals of procedures and land registries to improve land management and; iii) reinforcing capacity through communication and training on the newly provided tools and existing land management tools. Its geographic scope encompassed the Delta and Podor Activities and additional areas, covering nine contiguous communes.

The IWRM Project was designed to support the compact program objective of improved agricultural productivity in Senegal and growing access to markets and services through increasing access to irrigable land, expanding land under cultivation, and ensuring that land use rights were formalized. The program logic (Figure 1.B.2) expected improvements in irrigation infrastructure under the Delta and Podor Activities to expand the available area of irrigable land, increase water availability, and improve drainage systems. In the medium term, a greater abundance of water and improved drainage system were expected to increase total agricultural production in the project areas by increasing the total area under cultivation and crop yields. Further, it was expected that farmers would be able to grow rice in both the hot dry and the rainy seasons and expand production of tomatoes and onions, which are valuable income-generating crops in the region. In the long term, these changes were expected to increase agricultural incomes and food security for rural households. The LTSA sought to complement the Delta and Podor Activities by establishing a system of clarified and secure land rights that would reduce land conflicts over newly improved land, increase perceptions of tenure security, and ultimately support agricultural investments on the land. In Podor the LTSA provided titles directly to farmer groups, while in all other areas, including the Delta activity area, titles were available based on demand and are not limited to land in irrigated areas.

Figure 1.B.2. IWRM Project 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 management land tenure security tools Fewer land conflicts Remaining land conflicts are managed and resolved. Land authorities have access to ongoing technical support and tools.		

Note: The program logic is adapted from the program logic in the closeout M&E plan (MCA-S 2015b). Outputs of the project are reported based on the values reported in the compact completion report (MCA-S 2015a).

C. Research questions and methods

The final evaluation of the IWRM Project builds on the findings of the interim evaluation, with a focus on exploring why some of the project's intended outcomes were not achieved and whether this has changed in the subsequent years. The research questions that the final evaluation addresses are summarized in Table 1.C.1 Specifically, we address research questions on the maintenance and sustainability of the infrastructure (research question 1), the change in cropping intensity and adoption of vegetable cultivation (research questions 2 and 3), and the nature and persistence of the demand for titles (research questions 4 and 5)—all elements of the program logic that are crucial to achieving the compact goal of increased income and food security. Finally, we re-estimate the ERR for the IWRM Project. The final evaluation focuses primarily on the Delta Activity area, which accounted for a much larger portion of the overall compact investment, land area, and number of beneficiaries than the Podor Activity area. We restrict our analysis of the Podor Activity to the status of maintenance (research question 1) and the evaluation Cost-benefit analysis (CBA).

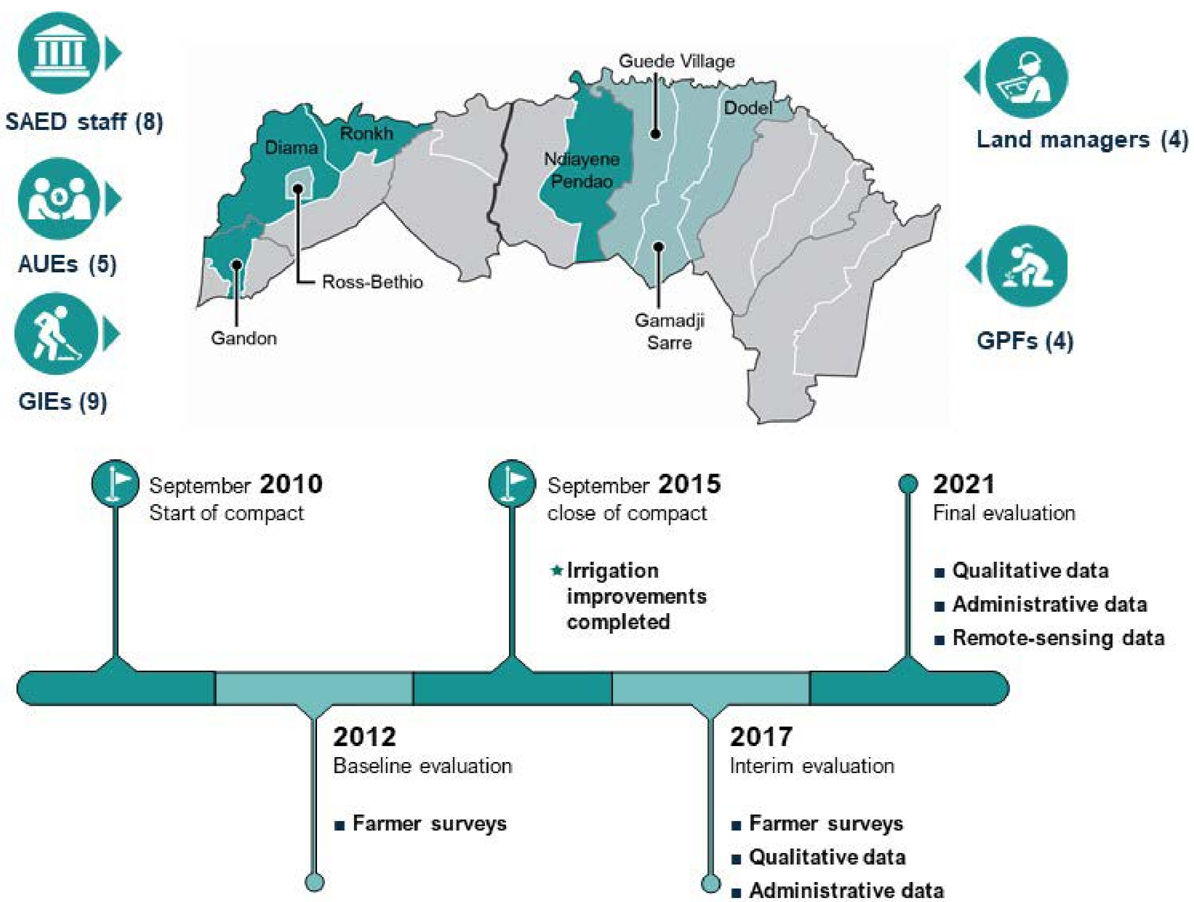
To answer these questions, the final evaluation used a mixed-methods approach that drew on qualitative data from interviews with key informants, quantitative data from administrative sources, and additional analysis of baseline and interim survey data. We complemented this with remote-sensing analysis using a supervised machine-learning approach to classify land under cultivation across seasons.

Our primary method was **in-depth analysis of qualitative data** from key informant interviews (KIIs). To understand how the irrigation infrastructure was being maintained or why it was degrading, and to investigate why farmers were or were not using their plots in multiple seasons and cultivating onions and tomatoes, we interviewed leaders of farmer cooperatives (GIEs), including female-only cooperatives (GPFs), heads of water user associations (AUEs), SAED[2] engineers, and agriculture extension agents. We also conducted interviews with commune land managers and leaders to gather information on who was demanding land titles and how the land management systems were functioning. Most interview respondents were from the Delta Activity area, specifically the communes of Ronkh, Diama, and Gandon. Interviewees in the Podor Activity area were from the commune of Ndiayene Pendao, where the Ngalenka perimeter is located. We show the location of these communes in dark blue in Figure 1.C.1.

Figure 1.C.1 summarizes the final evaluation data sources and the timeline of data collection relative to compact activities and previous evaluation rounds. Mathematica carried out these interviews in February and March 2021, more than five years after compact close and three years after the interim evaluation. The interviews were led by Mathematica's data collection partner in Senegal using phone or video calls to comply with COVID safety protocols, and most interviews included one or more members of the Mathematica evaluation team. The interviews were semi-structured and scripted, designed to uncover mechanisms and assess the change in key program outcomes over time. We used Nvivo software to thematically code the clean interview transcripts, based on the thematic codes that map to the research questions and program logic. See Table A1.1 in annex 1 for details on exact number and type of respondents and the list of administrative data used in the evaluation.

[2] Société d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal et des vallées du fleuve Sénégal et de la Falémé (SAED) is the state entity responsible for promoting irrigated agriculture in the Senegal River Valley through infrastructure development and maintenance.

Figure 1.C.1. Data sources and timeline of IWRM Project evaluation



■ = Data collection activity

GIE = farmer cooperatives; GPF = female-only farmer cooperatives; SAED = National Company for the Development and Exploitation of Land in the Delta of the Senegal river and the valleys of the Senegal river and the Falémé; AUE = water-user association.

We complemented our qualitative analysis with **quantitative analysis of administrative data.** The analysis was based primarily on analyzing trends in administrative data: we relied on official reports of overall crop production and area under cultivation by agricultural season and by year, and water flow rates for the Delta Activity area. Specifically, we relied on official annual reports of overall crop production and area under cultivation by agricultural season and by year, and water flow rates for the Delta Activity area. The post-compact entity assigned by the Senegalese government to track the key performance indicators for the Senegal Compact had provided these data to MCC periodically since the close of compact in 2015.[3] In addition, we used administrative data on land transactions from the World

[3] The post-compact entity responsible for tracking and reporting key performance indicators is the *Direction Générale de la Planification et des Politiques Economiques* (DGPPE). Previously, the *Unité de Suivi des Activités du Compact-Sénégal* (USACS) had this responsibility.

Bank-funded PDIDAS[4] project and household and plot-level data for a representative sample of beneficiaries in the Delta Activity area collected **from the baseline and interim surveys.**[5] We use the quantitative analysis to triangulate the findings in the qualitative analysis and with other data sources, to confirm, compare, and quantify patterns reported in our qualitative data.

Finally, we conducted some primary analysis using a **supervised machine-learning[6] approach** to classify land use types (cultivated land, uncultivated farmland, and other types of land) and estimate area under cultivation across seasons and within project areas. Although this analysis does not identify crop types, estimating the area of cultivated land during the two main rice-growing seasons enabled us to verify information on land under production reported by key informants and gathered from official data sources.

Table 1.C.1. Research questions and approach for the final evaluation

Research question	Analytical methods	Data sources
1. Has the primary irrigation infrastructure in the Delta Activity area and the Podor Activity area been maintained? Why or why not?	In-depth qualitative analysis	KIIs with GIEs, GPFs, AUEs, SAED extension agents; document review of maintenance plans
2. Have farmers increased their cropping intensity as expected by the project logic in the Delta Activity area? Why or why not?	Descriptive analysis of agriculture production data; In-depth qualitative analysis; Supervised machine learning for land-use classification	KIIs with GIEs, GPFs, AUEs, and SAED extension agents; SAED administrative data; Sentinel-2 satellite data
3. Are farmers growing tomatoes and onions as expected by the project logic in the Delta Activity area? Why or why not?	Descriptive analysis of agriculture production data; In-depth qualitative analysis	KIIs with GIEs, GPFs, AUEs, and SAED extension agents; SAED administrative data
4. Which stakeholders were more likely to demand a land title and change land use behaviors?	Descriptive analysis of quantitative data	Household survey data collected for the baseline and interim evaluations
5. Is there continued demand for land titles in the Delta Activity area, and are they being processed? Why or why not?	In-depth qualitative analysis	KIIs with commune land managers, a commune leader, GIEs, GPFs; administrative data from national land database

GIE = farmer cooperatives; GPF = female-only farmer cooperatives; SAED = National Company for the Development and Exploitation of Land in the Delta of the Senegal river and the valleys of the Senegal river and the Falémé; AUE = water-user association.

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[4] The *Projet de Développement Inclusif et Durable de l'agribusiness au Sénégal* (Sustainable and Inclusive Agribusiness Project for Senegal) includes support for land administration funded by the World Bank until June 2021 (World Bank 2020). The program extended support for the land management and administration activities started under the MCC compact in the Gandon, Diama and Ronkh communes (in addition to 6 other communes that do not overlap with the IWRM Project). This data is comparable to the land administration data collected as part of the interim evaluation, even though the interim data comes from land registries created under the LTSA. Both systems track information on the number of applications received and processed, and the type of land transaction.

[5] The interim evaluation report (Coen et al. 2019) includes an in-depth discussion of both the baseline and the interim data.

[6] We conducted the remote-sensing analysis using the Google Earth Engine platform. We used the time series of imagery from the ESA Sentinal-2 program spanning the period 2017 to 2020. We processed and analyzed data using a random forest estimator to classify land into 6 classes by season: cultivated, uncultivated farmland, water, bare land, forest, and wetland. Annex 2 provides further details on the imagery we used, the way the imagery was processed, and the approach to calibrating and training the classification model.

2. Findings

The interim evaluation reported on key outcomes of the program logic two years after the compact closed in September 2015. It showed that although some outcomes of the program logic were achieved, some key outcomes that MCC and the Senegalese government anticipated were not achieved.

The interim evaluation used a mixed-methods approach. This included 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, the interim evaluation used a pre-post design to assess changes in the same outcomes. We used 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. To understand implementation of the LTSA and whether its effects were 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.

Interim evaluation findings from 2017 revisited in the final evaluation in 2021

- The IWRM Project increased access to water through the renovated and the new irrigation infrastructure
- Area under cultivation increased, with an average increase of 0.56 hectares for the treated group in Delta under cultivation during the hot season
- Rice yields increased in Delta, with an estimated impact of 0.94 tons per hectare for the treatment group
- Cultivation shifted from the rainy season to the more productive hot dry season
- Demand for land formalization (titling) increased, and land offices met the demand during compact implementation[1]
- Irrigation infrastructure was well maintained

But:

- Land offices struggled to process demand for titles after the compact and no longer used the computerized land database
- Cropping intensification in Delta reached 75 percent in 2017, falling short of the 150 percent target
- Rice, tomato, and onion production did not meet project targets, reaching 162,460 tons, 5,641 tons and 17,372 tons respectively in Delta for the 2017 season (relative to targets of 277,000, 115,000 and 130,000)

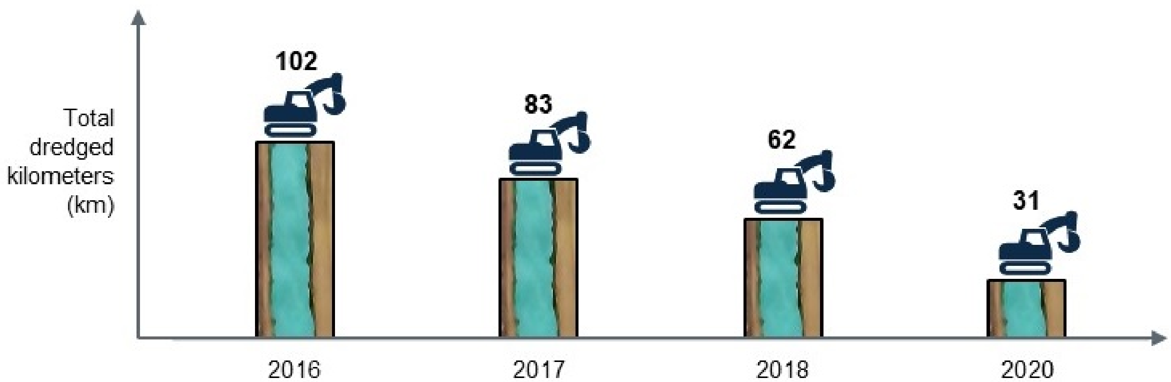
This final evaluation revisits some of the key findings from the interim evaluation to explore how infrastructure maintenance, intensification of land under production, tomato and onion production, and demand for land formalization has changed by early 2021, about five years post-compact. The next sections report on our findings from the final evaluation as they relate to the key research questions and update the project ERRs.

A. Has the primary irrigation infrastructure in the Delta Activity area and Podor Activity area been maintained?

Overall, the primary irrigation infrastructure in the Delta Activity and the Podor Activity areas remains in good condition as of spring 2021. However, both areas are facing problems that may undermine the long-term sustainability of the investments. In the Podor Activity area, maintenance of the canals and pumps is generally good, according to cooperative leaders and SAED, but a structural problem limits the use of the perimeter to the rainy season only: either the pumps are not set low enough in the channel that brings water from the Ngalenka river to the perimeter, or the Ngalenka river that feeds the irrigation system does not have sufficient water in the dry seasons to irrigate the perimeter.[7] The perimeter is therefore used only in the rainy season. In the Delta Activity area, SAED engineers stated that the water control works (dams, sluice gates, and the like) are well maintained and functional. Canals are largely in good structural condition. However, some water user association members noted that the amount of water available for irrigation is impeded by invasive plants, which quickly clog canals. Further, budget shortfalls at SAED are limiting the extent to which canals are being dredged, a necessary routine maintenance practice to ensure sufficient water flow. Total funds available for maintenance have declined each year since the close of the compact, which poses risks to the full functioning of the irrigation systems if SAED is not able to perform necessary maintenance.

Figure 2.A.1 shows a steady annual decline in the amount of dredging carried out in the Delta Activity area since the end of the compact, which suggests a decrease in routine maintenance.

Figure 2.A.1. Dredging of irrigation canals, Delta Activity area (2016 – 2020)



Source: 2016 and 2017 data (SAED 2019); 2018 data (USACS 2019); 2020 data (SAED 2020)

This decline in routine maintenance was also observed by the farmer representatives and water user association presidents we interviewed in spring 2021. Although these respondents confirmed that water was still mostly easily available for irrigation, they expressed dissatisfaction with the management of invasive weeds throughout the Delta Activity area. Farmers complained that these weeds cause problems with their irrigation pumps, and one farmer noted that rice cultivation in the commune of Gandon was not possible over the past year because the main canal had not been cleared.

[7] Respondents provided different explanations for the lack of water in the dry seasons, and we were unable to verify independently whether a design flaw in the pumping station or a change in the Ngalenka water level or some other reason is the cause. We note that respondents agreed that only 300–380 hectares of the 450 hectares perimeter are planted in any year.

SAED, which typically contracts out routine maintenance for a period of two to three years to private companies, acknowledges the scale of the invasive-plant problem and suggested that this is the main focus of much of the routine maintenance. Budget shortfalls have forced SAED to reduce the frequency and scope of their routine maintenance. SAED faces challenges recovering costs through water fees charged to farmers, which are expected to supply much of the maintenance fund. Water fee recovery rates, although improving steadily, continue to be below the compact target of 80 percent. In interviews SAED reported recovering 68 percent of water fees in 2019, an improvement from 41 percent in 2012 and from 62 percent at close of compact in 2015. In addition, maintenance fund shortfalls are affected by the limited budgetary allocation that SAED receives from the Senegalese government. In 2020, SAED received a budget of 800 million FCFA (CFA Franc) (against 2,904 million FCFA initially requested), of which 500 million FCFA were available for maintenance (SAED 2020). Without sufficient budget, SAED may struggle to adequately maintain the irrigation infrastructure.

"Weeds like 'Typha' are really starting to invade the compensating canal (freshwater canals), and I think that in a few years, things will be more difficult because the canal will be narrower. However, so far, no solution has been found (…) I think that for the 'Typha,' there must be a periodic maintenance, for example, every three months or six months, before the situation gets worse."

—GIE president

The quality and timeliness of maintenance affects water flow rates and the availability of water. The flow rates over time at the Ronkh intake, where large sluice gates control the flow of water from the Senegal River into the main MCC-renovated irrigation canal in the Delta Activity area are much lower than anticipated by the IWRM Project over the 2016 – 2019 period. The IWRM Project anticipated a flow rate of 65m^3/s at the Ronkh and "ouvrage G" intake[8], a flow that was never achieved during or after the compact. The maximum flow rate, recorded in compact closeout documents, was 25m^3/s, although this rate was not documented in formal reports from SAED or other entities working in the area (MCA-S 2015b). More recent flow rates provided[9] by the post-compact entity USACS and the pre-second-compact entity DGGPE range from 11.5 m^3/s to 13.2 m^3/s, with a substantial dip in 2017 to 5.8 m^3/s, [10] which was a year of unusually low water in the Senegal river system (Sall et al. 2020). These flow rates are substantially lower than the 25m^3/s flow rate recorded in the compact closeout documents but may reflect a lower need for water in the irrigation system since, as noted above, not all potentially irrigable land is under production in the Delta Activity area. However, flow rates at "ouvrage G," a water control structure located more centrally in the irrigation system, show a decrease from 2.11 m^3/s in 2016 to 1.7 m^3/s in 2019 and 2020 (USACS 2018; DGPPE 2021). This decrease might signal insufficient maintenance or clearing of invasive weeds that slow water flow and reduce the amount of water in the system.

[8] Based on communication with SAED, we understand that the 65m^3/s is a cumulative flow rate for Ronkh (40m^3/s) and "ouvrage G" (25m^3/s).

[9] Data come from USACS 2018b, USACS 2019 and DGPPE. "Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour." July 15, 2020.

[10] Annual flow rates at the Ronkh and "G" water control structures are MCC M&E outcome indicators (MCA-S 2015a). However, the outcomes appeared incomplete and were not routinely included in reports provided by the post-compact entities. Therefore, we are not confident that the data presented above are reliable. We hope that review of this draft report encourages GoS sources to provide more complete and official data on water flow rates to MCC and/or the evaluation team.

B. Have farmers increased their cropping intensity as expected by the project logic in the Delta Activity area?

Farmers in the Delta Activity area have increased their cropping intensity since the close of compact but continue to fall short of the 150 percent target set in the project logic (MCA-S 2015b).

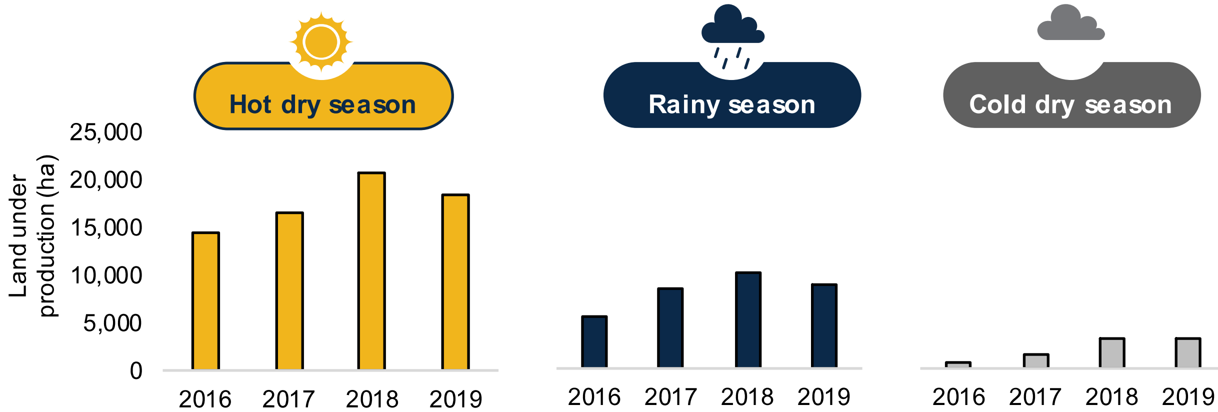
The compact M&E plan defines cropping intensity as the sum of the area under production in each of the three main seasons divided by the total cultivable area. We find that during the 2019 agricultural year,[11] the most recent year with complete data from the DGPPE, 31,052 hectares of land in the Delta Activity area were under production across all three growing seasons (Figure 2.B.1). This is an increase from the pre-compact baseline level of 21,400 hectares under production in 2010 and from the immediate post-compact level of 20,891 under production in 2016. The total cultivable area is determined by the arable land that was made available for irrigated agriculture because of the infrastructure improvements; this total area is assumed not to change over time and is set at 39,290 hectares.[12] Using the compact indicator calculation, this equals a cropping intensity of 78 percent, far short of the 150 percent project goal.

Although compact targets have not yet been met, Figure 2.B.1 shows that land under production during the hot dry season increased from 14,512 hectares in 2016 to 20,766 hectares in 2019, indicating a steady expansion into new farming land. Land under production in the rainy season also increased, rising from 5,619 hectares in 2016 to 9,225 hectares in 2019. And land under production in the cold dry season increased from 760 hectares in 2016 to 3,302 hectares in 2019. Summing the land under cultivation across all seasons and using the compact indicator calculation, cropping intensity was 53 percent in 2016, increased to 88 percent in 2018, and dropped back slightly to 78 percent in 2019.

[11] The agricultural year is divided into the hot season (March to June), the rainy season (June to October), and the cold dry season (November to February). Production data for a specific year cover the period starting with the hot season (approximately March) and ending with the cold dry season (extending into approximately February of the following calendar year).

[12] The cultivable area is defined in the closeout M&E plan as the "the entire surface area that can be cultivated (reported by SAED as « *superficie exploitable* »)." (MCA-S 2015a) There is significant disagreement across different compact documents and post-compact reporting about what the actual area is. The numbers range from around 27,000 hectares (reported recently in DGPPE. "Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour." July 15, 2020) to 39,290 hectares (reported in the Senegal Compact [MCC 2009]). We use 39,290 hectares because this is the number used in the MCC CBA model.

Figure 2.B.1. Land under cultivation across seasons, (2016 – 2019)



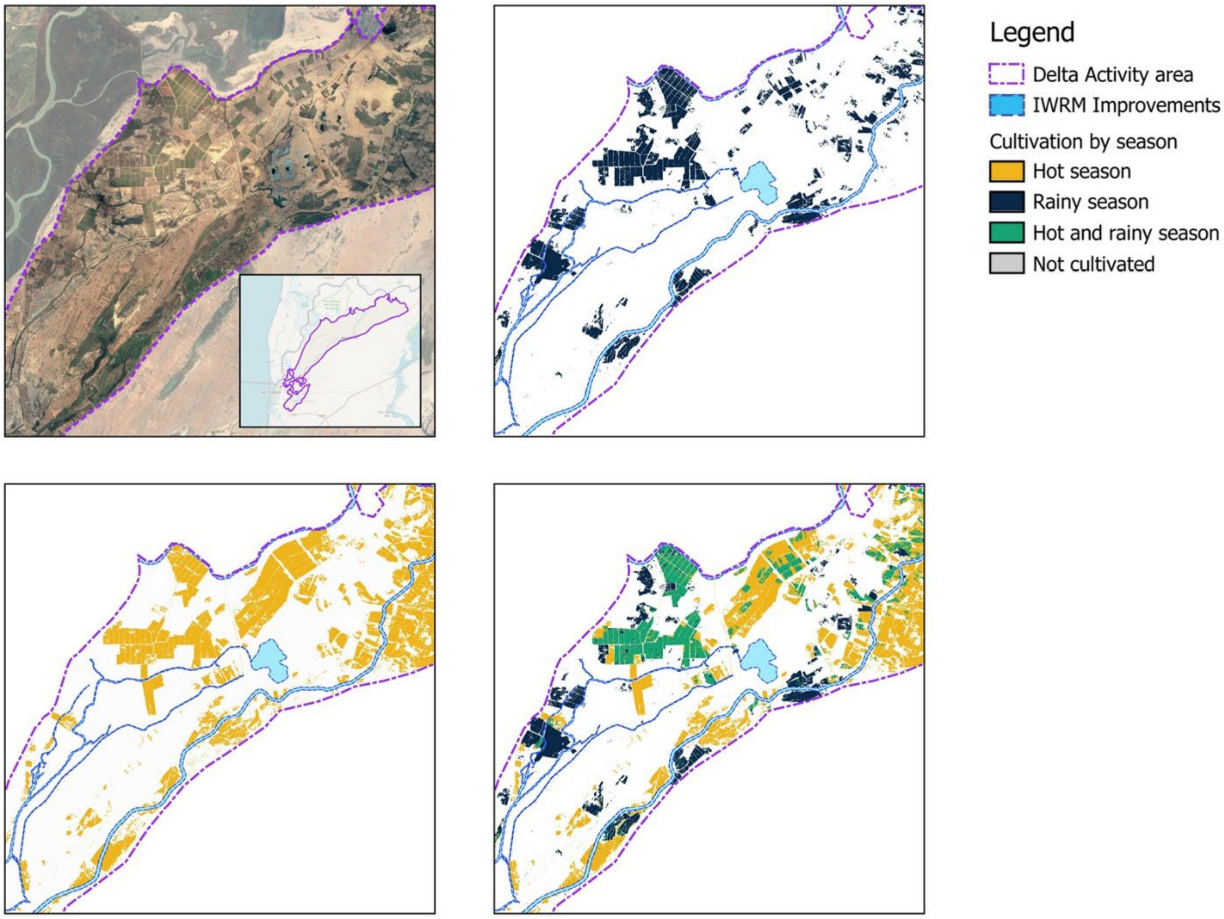
Source: 2016 data (USACS 2018a); 2017 data (USACS 2019); 2018 data: (DGPPE. “Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour.” July 15, 2020); 2019 – 2020 data: (DGPPE . “Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour.” March 4, 2021)

Cropping intensity can increase either by an expansion of the overall extent of land under production or through cultivating the same plot across multiple seasons (or both). The data underlying Figure 2.B.1 cannot be used to distinguish between these two explanations. To understand better how farming in the Delta Activity area has changed, we triangulate these results with detailed findings from our qualitative data and with satelite data to visualize how land use is shifting across time.

Figure 2.B.2 shows land cover maps for the 2019 agricultural season generated using a supervised machine-learning approach to classify parcels as cultivated based on the profile of the vegetation index over time. We conducted the analysis using the Google Earth Engine platform (Gorelick, N. et al 2017). The maps show land in the Delta Activity area that was cultivated during the specified season.[13] The top left panel shows a satellite photo of the area for reference. Panels in the top right and bottom left show the area under cultivation for the hot and rainy seasons. The bottom right panel combines the land classification maps for the hot dry and rainy seasons, showing land cultivated in the hot dry season only in yellow, in the rainy season in blue, and in both seasons in green. Many of these areas are likely used for rice cultivation, which is the most common crop in the hot dry season and the rainy season in this area. In these maps, we illustrate that a significant portion of land is cultivated in both rainy and hot dry seasons, an indicator of intensification.

[13] See annex 3 for a detailed discussion of the remote-sensing methodology.

Figure 2.B.2. Map of land under cultivation for a portion of the Delta Activity area (2019)



Source: Sentinel-2 imagery from European Space Agency courtesy of Google Earth Engine.
Note: The boundaries of the Delta Activity area are estimated based on maps included in compact documentation. Data preparation and processing were done in the Google Earth Engine application. Background image in top left panel from Google Earth Engine application.

Table 2.B.1 aggregates the total area cultivated by season for 2018, 2019, and 2020 using the satellite and machine learning data. We find the area cultivated in each of the seasons, as measured with the remote data, roughly equivalent to the data provided by DGPPE/SAED for the total hectares under production per season in the Delta Activity area.

Table 2.B.1. Land under cultivation by season (remote-sensing land classification)

Cultivation measure (ha)	2018	2019	2020
Hot dry season	19,342	18,473	21,473
Rainy season	9,408	11,551	14,460
Cold dry season[a]	4,113	3,294	2,197
Total across seasons	32,863	33,319	38,130
Total extent[b]	27,211	25,435	28,294
Hot dry and rainy season	5,652	7,884	9,835
Intensity[c]	84%	85%	97%

Note: Processing of imagery and area calculations done in the Google Earth Engine application.

[a] We are more cautious about the cold dry season area estimates because cropping patterns in this season vary a great deal—farmers often stagger planting throughout the season and sometimes plant twice, making it challenging to distinguish land under cultivation.

[b] Total extent of land under cultivation is calculated by summing land under cultivation in one or both of the hot dry season and rainy season, and land under cultivation under cold season. We make the simplifying assumption that land under cultivation in the cold season is not used in other seasons.

[c] Intensity is calculated as the total land under cultivation across seasons divided by the cultivable area. In order to be consistent with other sections of the report and to facilitate comparisons, we maintain the assumption that the cultivable area is 39,290.

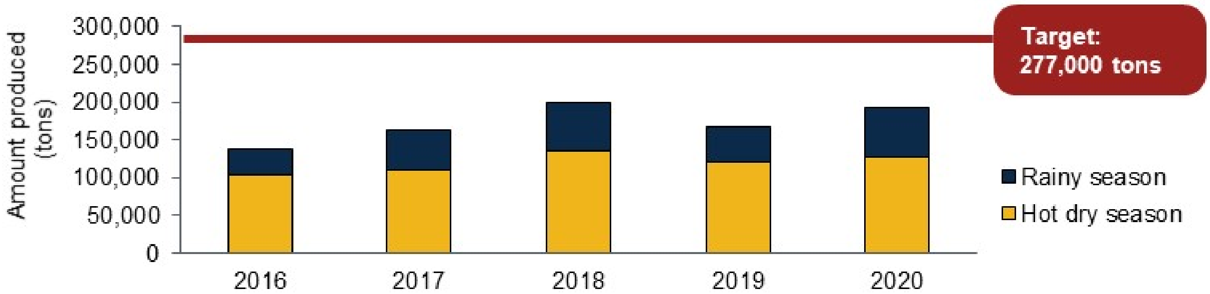
The findings from our analysis of the remote data are also corroborated by farmers and cooperative leaders we interviewed in 2021 in the Delta Activity area, who described an increase in intensification over the period 2018–2020. Of particular note is the increase in double cultivation across the hot dry and rainy season increasing from 5,500 hectares in 2018 to 9,835 hectares in 2020. Over the same period, the overall extent of cultivation has not changed much, suggesting that the increase in cropping intensity is happening because farmers are cultivating the same parcels multiple times per year. Interviewees reported multi-season production both on plots that are suitable for vegetables, where some farmers plant crops in multiple seasons, and on rice plots,[14] where successive planting of rice in the hot dry and rainy seasons is common. These reports suggest that a significant portion of the land area under production in the hot dry and rainy seasons is double cultivated and that cold dry-season cropping is still covering only a small proportion of the area.

Interview respondents also provided more detail on how intensification is happening and who is doing it. Intensification of production varies by the size of a farmer's operation and by access to finance for farming. As in the interim evaluation, we heard in our interviews that smaller farmers are cultivating year-round, but that they usually cultivate different plots in different seasons, including plots that are not irrigated. Respondents noted additional constraints to cultivating the same plot during multiple seasons, which make it challenging for some farmers to increase intensity. Specifically, to cultivate rice in the adjacent hot dry season and rainy season, farmers must plant early, harvest their hot dry season rice, and then quickly prepare the fields to plant for the rainy season. This pushes some farmers to pick either the rainy or the hot dry season to cultivate rice, but not both. Further, some farmers choose to leave land fallow for parts of the year or to rotate crops to "rest" the soil and improve future production.

[14] Paddy rice grows best in water-retentive clay soils, and vegetable crops often grow best in well-drained sandier or loamy soils.

We also explored rice production in more detail because the SRV is a major source of rice, and the IWRM Project was intended to increase its overall production. Figure 2.B.3 shows that overall rice production has increased since 2016, but in 2020 was still 70 percent[15] of the annual production target set out in the compact—277,000 tons of paddy rice for the years 2016–2020.

Figure 2.B.3. Rice production relative to compact target (2016 – 2020)



Source: 2016 data (USACS 2018a); 2017 data (USACS 2019); 2018 data: (DGPPE. "Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour." July 15, 2020); 2019 – 2020 data: (DGPPE . "Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour." March 4, 2021)

Interview respondents confirm that the area under production for rice has grown since the end of the compact. Some noted that that expansion of rice production has occurred mostly in the commune of Diama. But respondents also noted an increase in production and intensification in Ronkh, driven primarily by large producers with the means to cultivate rice in multiple seasons.

"Well, there is an exponential evolution (in quantities cultivated) because there are agricultural seasons which have reached the maximum because now there is a mastery over cultivation methods and access to water, which promote good harvests."

—GIE President

Across the Delta Activity area, rice *yields* also appear to have increased since the compact close. In other words, the quantity of rice produced per hectare of land has increased. Respondents attributed yield increases partly to improved drainage (one of the project's goals) and to the expansion of cropping in the hot dry season, which is producing higher yields than the rainy season. Cooperative leaders in the Delta Activity area stated that rice yields increased in the post-compact years from between 4 and 7 tons of rice per hectares to 5 to 7, with some farmers achieving 8 tons in the hot dry season. The improvements in yields are consistent with our farmer survey findings in the interim evaluation and are reflected in the implicit yields for the hot dry and rainy season reported by DGPPE in their post-compact indicator tables.[16]

Despite the central importance of rice production, interviewees in 2021 continued to underscore the risks inherent in rice cultivation and used these risks to explain, in part, increasing interest in market crop cultivation. Respondents in Gandon, Ronkh, and Diama noted problems with water availability for rice, a

[15] DGPPE reported that rice production for 2020 was 127,222 tons in the hot dry season and 65,823 tons in the rainy season.

[16] We calculate implicit yields for the hot and rainy season by dividing the total rice production in tons in each season by the area cultivated over the years 2016 to 2020. The implied rice yields are 6.3 to 7.1 tons per hectare for the hot season and 5 to 6.4 tons in the rainy season. Note that this calculation assumes that all land under production in the hot and rainy season is used to cultivated rice.

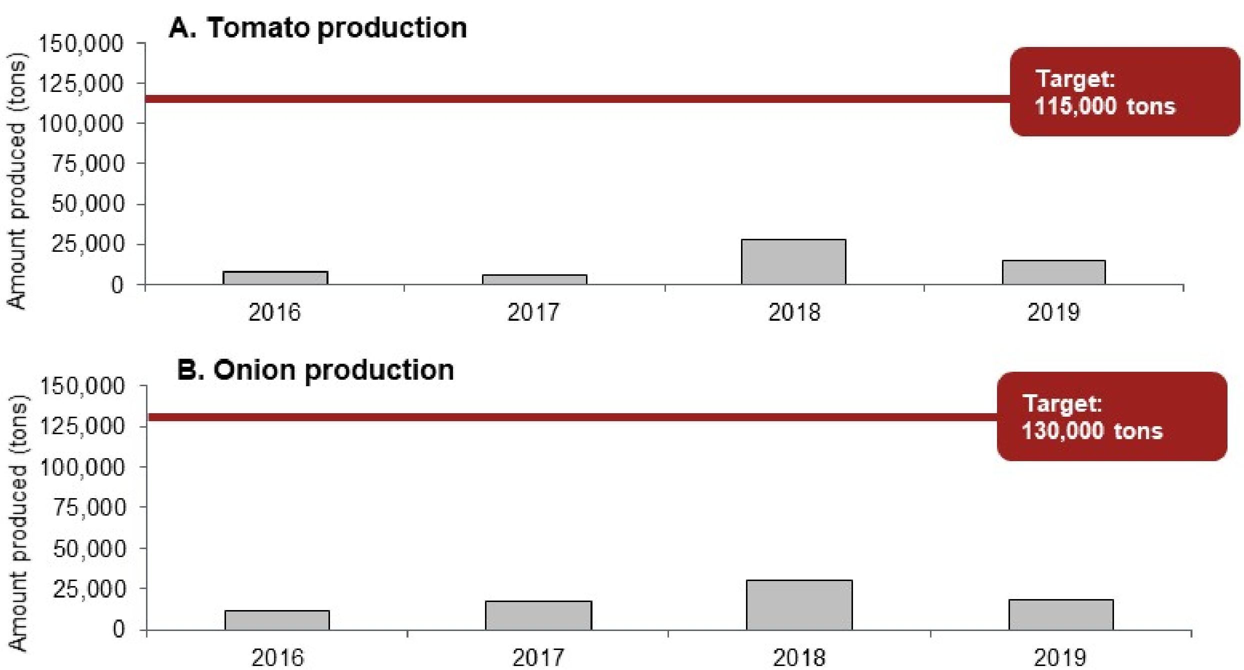
high water-use crop, and decreases in rice production due to clogged canals and occasional drainage problems, invasive weeds in plots, bad seed quality, and pests. They further noted that small farmers find rice production less profitable than market crops; to make rice cultivation more profitable, they argue, farmers must cultivate rice on more than one hectare and need more capital to pay for the higher production costs associated with machine rental, hired labor, and transportation. In short, rice yields are improving, but crop choice appears to be evolving as farmers respond to changing conditions.

C. Are farmers growing tomatoes and onions as expected by the project logic in the Delta Activity area?

Farmers have increased their tomato and onion production since the 2016–2017 cold dry season, the last season reported in the interim evaluation. However, overall production still falls far short of the volume envisioned by the compact project logic.

Specifically, the compact anticipated production of 115,000 tons of tomatoes and 130,000 tons of onions by 2020 in the Delta and Podor project areas (MCA-S 2015b). Instead, tomato production increased from 7,700 tons in 2016 to 14,800 tons in 2019, and onion production has increased from 11,600 tons in 2016 to 18,500 tons in 2019. Although these production numbers are clearly increasing over time, they are still less than 20 percent of the compact targets (Figure 2.C.1).

Figure 2.C.1. Tomato and onion production relative to compact targets (2016 – 2019)

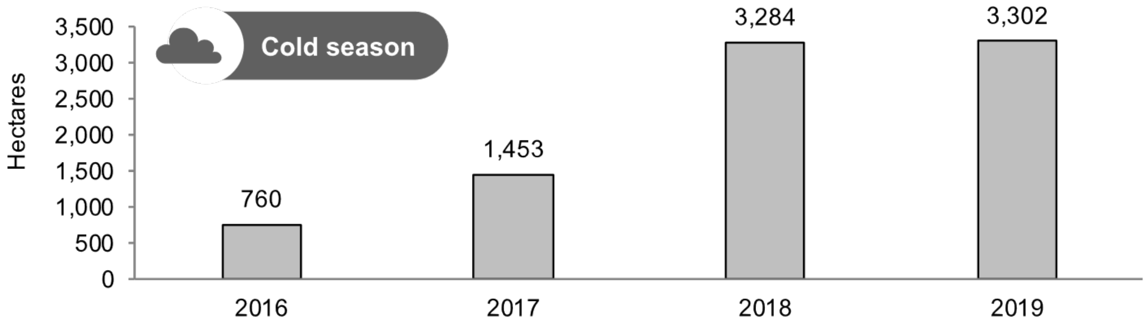


Source: 2016 data (USACS 2018a); 2017 data (USACS 2019); 2018 data: (DGPPE. “Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour.” July 15, 2020); 2019 – 2020 data: (DGPPE . “Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour.” March 4, 2021)

Note: Data for 2020 from cold dry season is not included because the agricultural season was not yet complete.

The shortfall in production of tomatoes and onions shown above can be explained partly by the relatively small area of land dedicated to market crops in the Delta Activity area. As of 2020, land under production in the cold dry season, the preferred season for vegetable crops such as tomatoes and onions, increased from 760 hectares reported in 2016, immediately post-compact, to 3,302 hectares in 2019 (Figure 2.C.2).

Figure 2.C.2. Land under cultivation in the cold dry season, (2016 – 2019)



Source: 2016 data (USACS 2018a); 2017 data (USACS 2019); 2018 data: (DGPPE. “Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour.” July 15, 2020); 2019 – data: (DGPPE . “Annexe.3: Données des indicateurs Post Compact du PIGRE mis à jour.” March 4, 2021)

Note: Data for 2020 from cold dry season is not included because the agricultural season was not yet complete.

In our 2021 interviews with representatives from farming cooperatives from all three communes in the Delta Activity area, respondents confirmed that more land is being used for vegetable production than in previous years,[17] although it is not clear whether farmers are alternating between rice and vegetable production on the same plot or expanding the area under production to land/soil suitable for market vegetables. Respondents also noted that in the past five years, larger investors and industrial operators are expanding production and processing of tomatoes and onions in the Delta Activity area. Farmers in some communes are entering into contracting arrangements with industrial tomato producers and processors, including SOCAS, a major national producer of tomato paste.[18] Several farmers expressed reluctance to cultivate tomatoes and onions due to a perception that upfront costs are too high, concerns about potential losses if production fails due to poor seeds, lack of water or poor timing of irrigation and reports from other farmers who have incurred losses cultivating these crops.

Although not a focus of the research questions guiding this final evaluation, interview respondents noted that vegetable production on small market garden plots remains an important activity for women and young people who are interested in agriculture but who cannot access large land areas. One respondent estimated that about one fifth of market garden production is by women, while very little of rice cultivation is by women. According to some interviewees, working on rice plots is difficult for women because rice cultivation sometimes requires farmers to spend the night in the field or spend long periods fighting off birds. In addition, women may have better access to small/family plots, which are suitable for

[17] This compact focused on measuring tomato and onion outputs, but vegetable production in the Delta Activity area extends to other crops, including lettuce, okra, cucumber, pepper, mint, sorrel, squash, carrots, eggplant, pumpkin, peanut, potato, cabbage, turnip, hibiscus.

[18] An international tomato association report published in 2018 suggests that these types of arrangements are long-standing modes of contracting in the SRV that pre-date the compact, but that the terms of these contracts are changing, and not to the benefit of producers (http://www.tomatonews.com/en/senegal-the-industry-has-fallen-on-hard-times_2_252.html)

cultivating vegetables, whereas rice is usually produced on larger plots of land farther from villages. Young people engaged in agriculture are also prioritizing vegetable production above rice because of its profitability, according to some interviewees.

D. Which stakeholders were more likely to demand a land title and change land use behaviors?[19]

The LTSA increased land formalization during the compact and through 2017.[20] Analyzing the data we collected for the interim evaluation, we found that the poorest households and households with a small area under cultivation had the largest increases in formalizations of their plots. We also found that most people seeking a land title are private individuals, although a significant share of titles were requested by GIEs or other cooperative groups. Many groups seeking land titles are also historically disadvantaged groups, including women.

Demand for titles, measured using commune land office data on the number of applications received, increased in the last year of the compact and persisted through the first two post-compact years (Coen et al. 2019). The interim evaluation showed that the patterns of demand vary by commune, with a large portion of demand in Gandon for residential plots, and most demand for titles in Ronkh and Diama were for agricultural plots. To better understand how land titling and land use behavior changed during and after the compact, we conducted additional analysis of the baseline and interim household survey data from the Delta Activity area. First, we examined the likelihood of owning a titled plot by the characteristics of the plot owner, and how this has changed between baseline and interim survey rounds. Second, we investigated how acquiring a title relates to changes in intensification and agricultural investment.

A pre-post analysis comparing the plots in the baseline survey and the interim survey[21] show the share of plots with any kind of title increased from 24 percent to 32 percent in the Delta Activity area. This increase in titling is associated with different characteristics of the household that own a titled parcel, which suggests that some stakeholders were more likely than others to acquire titles over this period. At baseline, a greater share of titled plots were owned by wealthy households, households with large areas under cultivation, and households cultivating rice. In contrast, at interim, we find that the biggest increase in the share of plots with a title was among the poorest households and households with smaller area

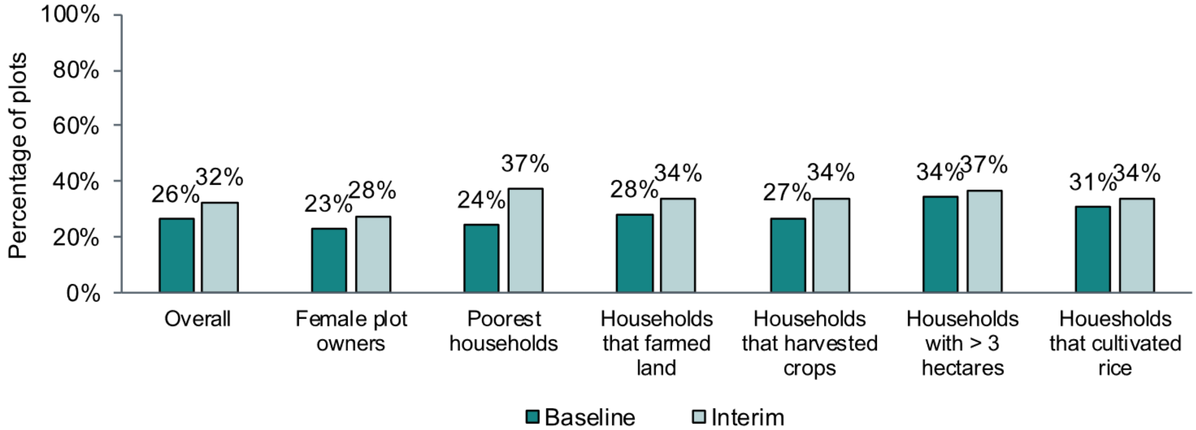
[19] MCC requested that we analyze interim survey data to examine the characteristics of land formalization recipients. Therefore, the data used in this section date from 2017 and 2018.

[20] Requests for land rights fall into two broad categories: (1) applications for the formalization of existing land holdings (*regularisation*), and (2) applications for new land (*affectation*). A successful application ultimately provides the applicant with a land title, referred to as *titre d'affectation,* which grant holders occupancy and use rights on their land. Titles can be issued to both individuals and commercial entities, such as GIEs, GPFs, or businesses. Registered owners can request and pay for documentation demonstrating their land rights.

[21] Data on plots from the baseline and interim data were collected in different ways and are not perfectly comparable. First, the data does not allow individual plots at baseline to be linked with plots at interim, so it is likely that some of the changes in average values we observe over time are driven by changes in the composition of plots in the sample. Second, data on plot ownership and titling was collected differently across both surveys; the baseline survey collected data from one respondent on all parcels, regardless of whether the plot was used by or owned by another household, whereas the interim survey collected data from the person responsible for each plot and did not ask about plots that are not owned by the household. Finally, we expect that exogenous changes will have influenced the sample of plots in a way that may affect the share of titled parcels. For example, we understand that between the baseline and interim data collection, some portion of the land owned by respondents from Ronkh were allocated to a large investor, thus potentially removing a portion of the baseline sample from our interim data collection.

under cultivation (Figure 2.D.1). The increase in titled plots was greatest for households located in the Gandon commune compared to Diama and Ronkh (Figure 2.D.2). The apparent decline in titled plots in Ross Bethio may be a result of sample attrition between baseline and interim and having a very small sample for the area (only 142 households in our sample are from this commune).

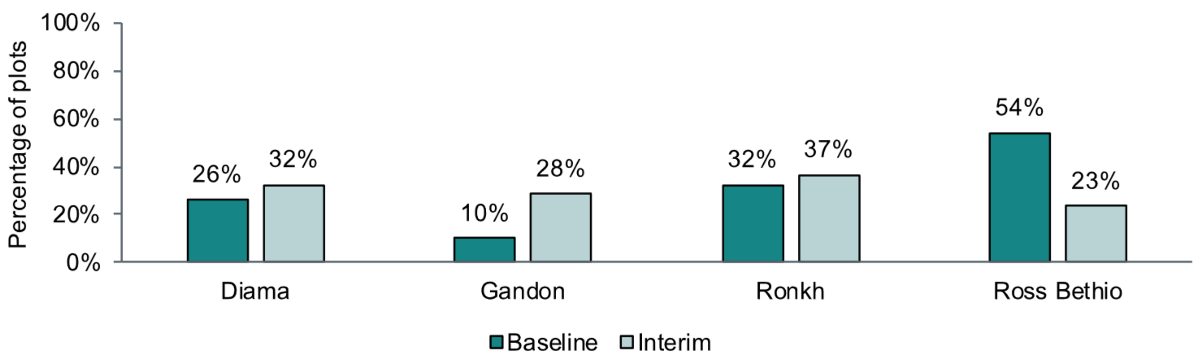
Figure 2.D.1. Share of plots with title, pre-post by characteristics of household



Source: IWRM Project interim and baseline evaluation household survey

Note: The analysis sample consists of all plots used in the main growing season with non-missing information on land titles. We restrict the sample to plots held by households in the Delta Activity treatment group. The sample size varies for each subgroup analysis but includes at most 2,796 plots for the baseline sample and 2,027 plots for the interim sample. Household poverty is defined using the Poverty Probability Index for Senegal (Schreiner 2016), which is a 10-question index that maps a likelihood (ranging from 0 to 100 percent) that a household is living on less than $2.50 a day (Schreiner 2016). We define the poorest households as those with a score above 75 percent at baseline.

Figure 2.D.2. Share of plots with title, pre-post by commune of household



Source: IWRM Project interim and baseline evaluation household survey

Note: The analysis sample consists of all plots used in the main growing season with non-missing information on land titles. We restrict the sample to plots held by households in the Delta Activity treatment group. The sample size varies for each subgroup analysis but includes at most 2,796 plots for the baseline sample and 2,027 plots for the interim sample.

We also analyze the change in titling and land use behavior by examining household-level data for observations that are in both the baseline and the interim samples. This analysis looks at the relationship between acquiring land titles and changes in land use behaviors between the baseline and interim. In our sample of 1,275 households in the Delta Activity area, 21 percent of households increased the number of plots with a title. However, fewer than half these households (8 percent of the overall sample) also engaged in productivity-enhancing land use behavior, defined as intensification or increased agricultural investment. More households (13 percent of the sample) increased the number of titled plots without increasing intensification or investment, and even more (17 percent of the sample) increased investment or intensification without increasing the number of titled plots, which suggests a limited relationship between land titling and land use change. The demographic and socioeconomic characteristics of the 8 percent of households that both increase their share of titled plots and increase investment or land under production are nearly identical to the full sample and are equally distributed across communes (not shown). This suggests that there are no clear correlates explaining why households might simultaneously increase the intensity of production and acquire land titles.

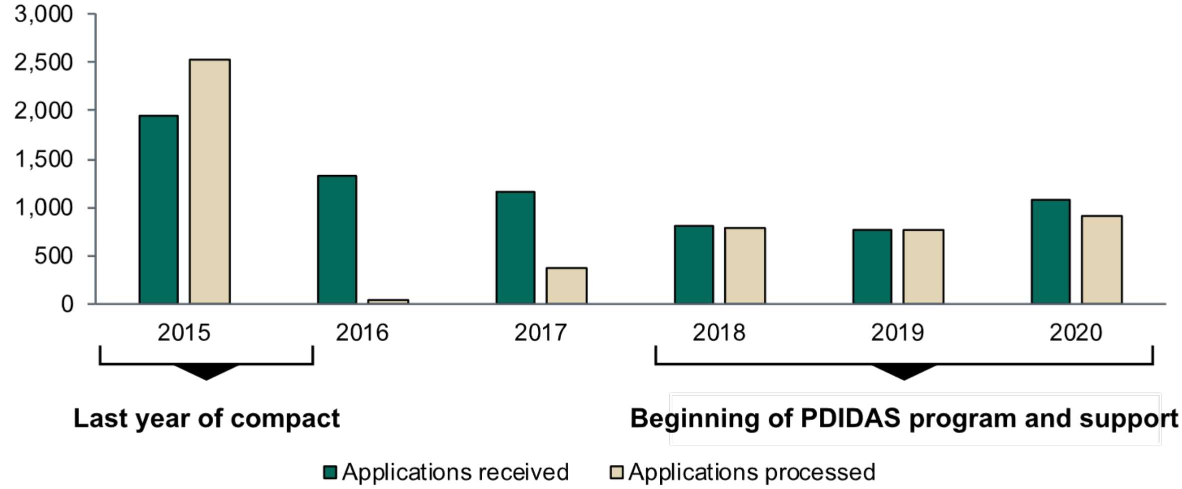
E. Is there continued demand for land titles in the Delta Activity area, and are they being processed?

We find that demand for land titles has been sustained in the Delta Activity area since the end of the compact and, with the support from the World Bank's PDIDAS[22] program, commune land managers are able to process the new applications promptly. Land managers expressed concern that when the PDIDAS program ends in mid-2021, they will struggle again to meet demand.

Land managers in Gandon and Ronkh communes reported that there is a continued awareness of the benefits and a demand for formalized land rights. Demand for land titles has persisted, although the pace of demand has slowed since the interim data collection in 2017. Across communes, demand for titles spiked in 2015, a result of efforts under the LTSA to support applications. Because of a lack of funding following the compact, land managers were unable to process many of the applications submitted in 2015—the interim evaluation found that by 2017 there was a significant backlog of application at commune land offices. This pattern is clear in the data from Gandon commune, which shows the number of applications and title allocations over time (Figure 2.E.1).

[22] Several programs have been designed to improve land tenure security operating throughout the Senegal River Valley. In addition to the recently completed PDIDAS project, the World Bank recently approved the Senegal Cadastre and Land Tenure Improvement Project, which will build upon previous work in the land sector (World Bank 2021). The project will include support for land administration in rural communes, but the target areas are not yet determined. These projects build on the work undertaken through the LTSA.

Figure 2.E.1. Land applications received and processed, Gandon (2015 – 2020)



Source: Data for 2015–2017 come from land bureau records held in the commune of Gandon collected during the interim evaluation (Coen et al. 2019). Data for 2018–2020 come from the national land database created under the PDIDAS program.

Demand for formalization or titles persists in the other communes we studied for the final evaluation. Data in Diama from the national land database[23] suggest a steady interest in formalizing land in recent years, with 741 titles issued in 2018, 563 in 2019 and 1,012 in 2020. Ronkh also seems to have experienced persistent demand for land titles. The national land database reports 1,800 transactions for 2019,[24] which is higher than the demand we found in the interim evaluation (covering 2015–2017) which peaked at 1,121 applications for formalization or titles in 2015.

> **"Regarding the land component, I think the work Millennium Challenge Account (MCA) did is commendable. It communicated and raised awareness, which means that our work was not too difficult. (…) However, there are no records, meaning that (…) we do not have the geographical coordinates with us, because the SIF did not work."**
>
> ***—Land Manager***

Land managers we interviewed in 2021 from Gandon, Diama, and Ronkh communes report that they have been able to process the ongoing demand for titles quickly and credit the support from the PDIDAS program. Figure 2.E.1 shows that from the start of support from the PDIDAS program in 2018, the land bureau in Gandon has been able to process more applications than in the post-compact years of 2016 and 2017. Land managers expressed concern that when the PDIDAS program ends in mid-2021, some aspects of the land systems will no longer be maintained, and applications will not be processed as quickly. They also noted that demands for land titles are becoming more complex, potentially as a result of increased land value and a shortage of new land,

[23] The data reported for 2018–2020 is from the national land database, which was created under the PDIDAS program. The national land database is maintained by the *Direction Générale des Impôts et Domaines*. This database supersedes the land information system created under the LTSA. Although the data created under the PDIDAS program can be used to track the same indicators we analyzed in the interim report (applications received, applications processed and type of application), it is not possible to link the records from 2015-2017 to the 2018-2020 period. This prevents us from determining whether an application received in the 2015-2017 period was processed in the 2018-2020 period.

[24] For Ronkh, no transactions are reported for 2018 or 2020. Based on the numbers reported in our interview with the land manager, we believe that these might represent all transactions for 2018–2020.

with land managers having to deal with claims to ownership that conflict with the *Plan d'Occupation et d'Affectation des Sols.* In some cases, claimants are encroaching on rights of way of pastoralists, other people's land, or forest areas.

> **"This project was really a trigger, raising the rural world's awareness of the usefulness of land titles (…) MCA gave much more value to the land. Land is a value added to development (...) that is to say, it is a resource that must be calculated in the development of a country."**
>
> ***—Land Manager***

Our interviews suggested that most people seeking a land title are private individuals, although a significant share of titles are being provided to GIEs or other cooperative groups. Many groups seeking land titles are also historically disadvantaged, including women. Respondents reported that women are eager to acquire titles but find it difficult to find land. If women already have access to land, they appear eager to get titles to protect their use rights. Land managers reported in interviews that if women are interested in acquiring large plots, they must often gain access to land either through inheritance or through purchasing land, since they have historically not been allocated land by the commune. Some respondents also reported that women operating small market gardens in Diama commune have been quick to submit applications for regularization of their small plots. Across many respondents, including leaders of GIEs and GPFs, we found the general lack of available land in the villages cited as a major reason that female farmers are not able to access land.

Land managers and farmer groups interviewed in 2021 suggested that demand for titles from private individuals (as opposed to companies or cooperatives) is driven by a desire to protect the interests of a person's heirs. Finally, despite the continued demand for and issuance of titles, land managers report that many people continue not to pick up their title documents. They are choosing not to pay the fees required to acquire a copy of the documentation unless they have a particular need to provide proof of ownership, such as when they want to take out a loan or participate in a government program. This suggests that people perceive a benefit to having greater tenure security, but that title documents themselves may not be opening significant opportunities to access credit or participate in land markets.

F. Evaluator's estimate of post-compact ERR

MCC's investment in the IWRM Project was ultimately expected to benefit farmers by improving their incomes. During compact development, MCC created ex-ante CBA models for the Delta and Podor Activities to assess whether the potential benefits of the activities warranted the potential costs. MCC published an updated closeout version of the models using information from 2014 (near the end of the compact) on actual project costs and observed cultivation patterns (MCC 2014a, MCC 2014b). Both models assumed that the project would generate benefits on farmer incomes through increasing yields, expanding production on previously unused land, and increasing land use intensity across the three main growing seasons.

As part of the final evaluation, we recalculate the ERRs for the Delta and Podor Activities using parameter estimates from the interim report (from the impact evaluation for the Delta Activity and the pre-post performance evaluation for the Podor Activity), as well as the findings in this report. Integrating the interim estimates into the models lends credibility to the estimates of the "without project" scenario, or counterfactual, especially for the Delta Activity, where we have a rigorous impact evaluation. In addition, using the findings in this report ensures that the evaluation CBA model reflects up-to-date information about the benefits of the project in the post-compact period. The evaluation CBA model, though not identical to the MCC models, takes a similar approach to estimating the benefits generated by increasing yields, expanding land under cultivation, and increasing land use intensity. Table 2.F.1 summarizes the ERRs calculated by MCC and the ERRs generated as part of the evaluation. For both the Delta and the Podor Activity, we find a negative ERR. The ERRs are both well below the positive ERRs estimated by MCC and below MCC's current hurdle rate of 10 percent[25], the benchmark rate at which MCC will consider a project for investment.

Table 2.F.1. MCC and evaluation ERRs for the IWRM Project

	Original MCC CBA ERR	Closeout MCC CBA ERR	Evaluation CBA ERR
Delta Activity	15.9%	15.9.%	1.8%
Podor Activity	7%	3.5%	-7.5%
Year of model	2009	2014	2021

Source: MCC closeout CBA models, Original MCC CBA model.

Note: ERRs were calculated over a 20-year time horizon, except for the closeout ERR for the Podor Activity, which was calculated over a 25-year time horizon.

The rest of this section summarizes the benefit and cost streams used in the evaluation CBA model, the data sources used, and the ERR results. To explain what drives the difference between the MCC ERRs and the evaluation ERR, we also explore how sensitive the results are to changing key parameters of the model.

Benefit and cost streams, and data sources

The evaluation CBA models calculate the stream of net benefits generated by the Delta and Podor Activities over a 20-year time horizon,[26] beginning with the first year of the compact. Table 2.F.2 summarizes the parameters we use to calculate net benefits, where the data come from, and how they are used to calculate the counterfactual or without-project scenario. For both activities, we measure the benefits generated by the project from (1) agricultural production on newly irrigable land, and (2) better yields and greater land use intensity on existing and newly irrigated land. Specifically, we calculated the average economic value of agricultural production by subtracting the cost of production from the value of total yields, as reported in the interim farmer survey. As with MCC's CBA models, we calculate the value of producing each rice (hot dry season and rainy season), and tomatoes and onions (cold dry season) on a per-hectare basis, with and without the project. The per-hectare benefits are scaled up by the area under production in each season for each year in the with- and without-project scenarios.

Cost streams for the with-project scenario are the overall activity investment, which includes the cost of infrastructure improvements, a portion of the LTSA program, resettlement costs, and an incremental increase in operating costs. We use the cost streams reported in the MCC closeout CBA model; this is the most complete data source we have that includes the contributions both from MCC and from Senegalese

[25] For reference, the Government of Senegal uses a hurdle rate between 8 and 9 percent when conducting cost-benefit analysis.

[26] We based the decision to use a 20-year time horizon on MCC's Guidance for Economic and Beneficiary Analysis. The shorter time frame relative to the MCC closeout CBA model will lead to lower benefits overall. https://www.mcc.gov/resources/story/story-cdg-guidelines-for-economic-and-beneficiary-analysis

government. Costs and benefit streams were adjusted to ensure that the dollar values were reported for the same base year.

Table 2.F.2. Key parameters and data sources for the evaluation CBA models

Model parameter	Role in model	Data source (with project)	Data source (without project)
Benefit streams			
Area under cultivation by season	Aggregate income over project area	• DGPPE indicator tracking data on land use by season	• Based on assumptions in MCC closeout CBA
Rice yield	Output per hectare	• Interim impact evaluation estimates (Delta) • Interim pre-post estimates (Podor)	• Interim impact evaluation estimates (Delta) • Interim pre-post estimates (Podor)
Tomato and onion yields	Output per hectare	• MCC closeout CBA	• MCC closeout CBA
Output prices	Financial value of output	• Interim evaluation survey data • Final evaluation data	• Prices assumed to be the same as with project
Cost of cultivation	Financial cost of cultivation	• Interim impact evaluation estimates (Delta) • Interim pre-post evaluation estimates (Podor)	• Interim impact evaluation estimates (Delta) • Interim pre-post evaluation estimates (Podor)
Cost streams			
Infrastructure investment costs	Economic costs	• MCC closeout CBA	• $0 (no costs without the activity)
Land tenure activity	Economic costs	• MCC closeout CBA	• $0 (no costs without the activity)
Operating costs	Economic costs of maintaining more infrastructure	• MCC closeout CBA	• MCC closeout CBA

Before calculating the ERR, we convert the financial values of benefits into economic values using conversion factors for inputs and outputs.[27] These conversion factors account for policy distortions that drive a wedge between input and output prices and imply that the prices faced by farmers may not reflect the true value (or cost) of outputs (or inputs) to the economy of Senegal. For example, the Senegalese government imposes an import quota on rice. Although this policy increases prices for rice farmers (as is its aim), it does so at a cost to consumers in the country who have limited access to cheaper rice from the world market. The price received by farmers for their rice therefore includes an implicit cost on consumers. Similar issues apply to fertilizer (and other inputs) where large subsidies distort the market.

[27] We use a conversion factor for rice output of 0.95. Since input conversion factors differ by input type, we calculate a weighted average conversion factor. The factor is calculated by weighting each input-specific conversion factor by the share of each input in the overall cost of production reported by farmer. The conversion factor for inputs is 1.38. Our approach to converting financial values to economic values is to use conversion factors for inputs and outputs that were used in a CBA of a JICA irrigation program in the SRV (Miklyaev et al. 2017). This source provides extensive documentation for how conversion factors are calculated. A comparison of world market prices with farmgate prices for a subset of inputs and outputs in rice farming suggests that these are credible conversion factors.

Results of the evaluation CBA

We report the main results of the evaluation CBA models in Table 3.3 and find that the ERR for the Delta Activity is 1.8 percent. This low ERR reflects a number of factors, including the fact that land use across seasons and land use intensity remain low, and that vegetable production remains limited. The ERR for the Podor Activity is -7.5 percent. In the Ngalenka perimeter, it appears that land is used only once per year, in the rainy season, and only for rice cultivation (see annex 2). The low land-use intensity and lack of vegetable production limits the benefits generated by the project.

Table 2.F.3. Results of evaluation CBA models

	Delta Activity	Podor Activity
ERR	1.8%	-7.5%
Present value of increased farm income	$70,327,209.80	$1,031,799.67
Present value of investment cost	$(145,103,413.28)	$(6,155,636.64)
Maximum land under cultivation in any season (ha)	19,807	351
Land use intensity	0.84	0.80

Note: All values in this table are report in constant 2017 US dollars. Local currency is converted using an exchange rate of 581 FCFA/USD, based on the World Development Indicator annual average exchange rate tables. Present value calculations use a discount rate of 10 percent over a 20-year period. Intensification is calculated for Delta assuming 39,399 hectares of cultivable land and assuming 440 hectares for Podor.

Explanation for difference between evaluation CBA ERR and MCC ERR

The ERRs from the evaluation CBA models are considerably lower than what is reported in MCC's closeout CBAs. As noted above, the evaluation ERR for the Delta Activity is 1.8 percent, compared to 15.9 percent reported at closeout. The evaluation ERR uses the same infrastructure investment costs as the closeout ERR, so any differences in the ERR are driven by differences in assumptions on the benefit side. Table A3.3 in annex 3 shows a comparison of the updated values for key parameters used in calculating benefits in the evaluation CBA compared to MCC's closeout ERR for the Delta Activity. (We also provide a similar table for Podor in the Annex but do not provide a discussion in the report. The key drivers of the difference in ERRs are for the Delta Activity are:

- **Rice yields.** The evaluation CBA assumes smaller incremental yields between the with- and without-project scenario and smaller overall levels of yields than the MCC closeout CBA, which would lead to a higher evaluation CBA ERR. The MCC model assumed yields of 7,500 kg/ha with the project and 6,800 kg/ha without it, and our data from the interim impact evaluation found hot dry season yields[28] to be 5,379 kg/ha for the treatment group and 4,439 kg/ha for the control group.
- **Profitability of rice production.** The MCC closeout CBA model assumes that the project increases the incremental profitability of farming rice in both the hot dry and the rainy season between the with- and without-project scenario, which leads to a higher MCC ERR. The higher with-project profits are driven by both higher incremental yields (leading to greater revenues) and a greater difference in

[28] The MCC closeout CBA values are also higher than the yields reported by DGPPE for the IWRM Project tracking indicators. For the period 2018–2020, DGPPE reports implied yields for the hot season ranging from 6,320 to 6,530 kg/ha and for the rainy season from 4,697 to 6,096 kg/ha.

costs between the with- and without-project scenario. The evaluation CBA uses lower incremental profits, based on estimates from the impact evaluation.

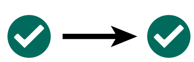
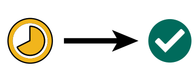
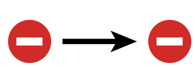
- **Profitability of vegetable production.** The MCC closeout model assumes that production of tomatoes and onions yields profits per hectare that are almost 10 times higher than profits reported in the interim evaluation's survey data (with-project profits are 135,000 FCFA/ha for the treatment group in the evaluation CBA and 5,300,000 FCFA/ha for the MCC model). This leads to a higher MCC ERR. Although the closeout CBA model assumed no difference in profits per hectare between the with- and without-project scenario, the expansion of production on new land implies that the higher level of profits relative to the evaluation model significantly increases project benefits in the with-project scenario.
- **Area under cultivation.** In the closeout and evaluation CBA models, per-hectare profits are aggregated up to the project level by the overall area under production each season. The MCC closeout CBA model anticipates that a higher area of land will be cultivated with rice than what is observed in the DGPPE data (and used in the evaluation CBA model). This leads to a higher MCC ERR. DGPPE reports that for the Delta Activity area, the peak land under cultivation in 2018 was 20,766 hectares in the hot dry season and 10,537 hectares in the rainy season, whereas the MCC closeout CBA model anticipates more than 30,000 hectares in the hot dry season and 27,000 hectares in the rainy season.

3. Conclusion

A. Summary of findings

Revisiting the IWRM Project five years after the close of the MCC Senegal Compact, we find that it looks closer to achieving some of the medium-term objectives identified in the program logic than it did in 2017-2018, but only in the Delta Activity area. Figure 4.A.1 summarizes the key findings and research questions in this final evaluation by activity area (Delta and Podor).

Table 4.A.1. Recap of interim findings and summary of final evaluation findings in the IWRM Project logic

Outcome	2017 vs. 2021	Explanation (section references)
Short-term outcomes (Delta)		
Increase potentially irrigable land to 39,300 hectares		Qualitative and quantitative data suggest that the IWRM Project has increased potentially irrigable land in the Delta Activity area. The total area is not clear but may be as high as anticipated in the project plan.
Increase amount of land under production to 42,030 hectares		Land under production has increased steadily since the compact closed and the total area under production across all three seasons may be close to the goals envisioned by the compact when all three 2020 agricultural seasons are complete (Section 2.B).
Increase water flow (65m^3 per second)		The target flow rate was not achieved at project end or since compact close. Although the closeout report indicates a flow rate of 25 m3/s, no reliable source has reported a flow rate higher than about 13 m3/s at the Ronkh intake. Flow rates at the "G" water control structure show a slight decrease since compact close (Section 2.A).

Outcome	2017 vs. 2021	Explanation (section references)
Establish satisfactory drainage system	→	Although some respondents at interim had problems with adequate drainage, qualitative data in 2021 suggest that the drainage system constructed by the IWRM Project is a great improvement over the previous infrastructure. Rice yields have increased, which interviewees attribute in part to better drainage of used irrigation water.
Short-term outcomes (Podor)		
Construction of a new irrigated perimeter with 450 hectares of cultivable land	→	Farmers widely praised the new perimeter at Ngalenka at interim. In the intervening years, farmers have found that some parcels cannot get access to water in the dry seasons. At most, 380 ha are cultivated, which is an improvement over baseline but lower than the project goal.
Short-term outcomes (LTSA)		
Improved local land governance	→	Increased demand for land formalization at interim was met with increased regularization with the support of tools, training, and financing from the LTSA.
Continued use of improved land security tools	→	Communities continued to use land tenure security procedures to process applications and formalize land requests through early 2021, supported by the World Bank's PDIDAS project. The POAS continued to guide some or many land use decisions. However, the electronic SIF was no longer in use (Section 2.E).
Fewer land conflicts Remaining land conflicts are managed and resolved.	n.a	The final evaluation did not assess changes in land conflicts after interim data collection
Land authorities have access to ongoing technical support and tools.	→	The PDIDAS project has provided support for ongoing technical support to land managers, which had largely fallen away in the years immediately post-compact. However, the PDIDAS project ends in mid-2021, which may slow or halt progress on land formalization and official transactions (Section 2.E).
Medium/long-term outcomes (2016–2020) Delta		
Infrastructure servicing and maintenance	→	The irrigation infrastructure that the project built and rehabilitated remains in good condition several years after the end of the compact. However, routine weed clearance and dredging is not keeping pace, and lack of maintenance may eventually reduce water available for farming in the Delta Activity area (Section 2.A).
Increased cropping intensity in the Delta (150%)	→	Cropping intensity has increased over the years since compact close but is far short of the 150 percent envisioned in the compact target. The maximum achieved by 2020 is about 78 percent. Since intensification is predicated on a total potentially cultivable area of 39,920 hectares, the shortfall may be due to an unrealistic target for total cultivable area (meaning that the area expected to be reached by the new/rehabilitated irrigation may not be arable land), a misunderstanding of the constraints to intensification, or some other miscalculation in the compact planning (Section 2.B).

Outcome	2017 vs. 2021	Explanation (section references)
Increased agricultural production • 277,000 tons of paddy rice		Rice production has increased substantially since the close of compact. However, annual paddy rice production fell short of the compact target, reaching 70 percent of the target in 2020, based on SAED data reports (Section 2.B).
Increased agricultural production • 115,000 tons of tomatoes • 130,000 tons of onions		Tomato and onion production in the Delta Activity area has increased year on year since the close of compact. However, the total production targets are substantially higher than production realized in this region at any time since compact close (Section 2.C).
Medium/long-term outcomes Podor		
• Increased cropping intensity in the Ngalenka basin (80%) • Increased agricultural production of paddy rice, tomatoes, and onions • Increased agricultural incomes • Strengthened job opportunities in farming sector • Improved land access • Infrastructure servicing and maintenance • Contribution to increased investments in agricultural sector	n.a	The final evaluation did not focus on the Podor Activity area. However, qualitative interviews with key stakeholders in 2021 indicated that the Ngalenka perimeter is farmed only in the rainy season and either the pumps are set too high to draw water from the intake stream or the supply stream is too low in the dry seasons to fully supply the irrigation needs of the perimeter. Since the program logic suggests that an increase irrigation is a prerequisite for medium- and long-term outcomes related to agricultural production and income, it is unlikely that those outcomes were achieved. As described in the interim report (Coen et al. 2019), women received some access to land in the Ngalenka perimeter but were unable to make the land productive due to restrictions on irrigation and type of land allocated in the perimeter (land appropriate for horticulture but irrigation not provided during the horticulture season).
Medium- to long-term outcomes (LTSA)		
Improved local land access		Increased demand for land formalization at interim was met with increased regularization with the support of tools, training, and financing from the LTSA. Support was continued through subsequent programs.
Security for investments	n.a	The final evaluation did not focus on security for investments in land.
Contribution to increased investments in agricultural sector		The interim evaluation found that the IWRM Project helped poorer households and households with small landholding increase their proportion of land under title/formalization. We found a little evidence that obtaining title correlated with some increased investment in productive use of land, but the findings are small enough that they could be spurious (Section 2.D).

represents evidence of achievement — represents mixed evidence of achievement — represents evidence of lack of achievement

Note: For details on the 2017 summary of findings, see Figures V.11, VI.9, and VII.1 in the interim report (Coen et al. 2019).

n.a. = not applicable.

In the Delta Activity area, we observe an overall increase in land under production and more interest in growing high-value vegetable crops, such as tomatoes and onions. Several years after the compact, farmers in the area may have experienced long-term changes in their production patterns because of the greater availability of water. Despite improvements, however, the intensity of land use remains well below the 150 percent that was anticipated by the program logic, a result largely of structural obstacles that limit farmers' ability to crop rice multiple times per year. Taken together, these factors lead to an ERR of 1.8 percent for the Delta Activity, well below the closeout (end-of-compact) ERR of 15.9 percent.

In contrast, the Podor Activity appears further from achieving its objectives than at interim. In the interim report, we found that the Ngalenka perimeter was being used to produce rice in the hot dry season, and for one agricultural year was used for production across multiple seasons. Since then, production has ceased in the hot dry season and shifted to rainy season rice production only. This may be due to (1) a structural problem with the height of the irrigation pump intake, or (2) a lack of water in the creek that is used to feed the irrigation perimeter. As a result, there is simply not enough water available to fill the irrigation perimeter in the hot dry season. Further, the land is not being used for producing vegetable crops, because too few parcels are appropriate for such crops to merit using the expensive grid-electricity pumps, and farmers are choosing to focus their efforts on a single agricultural season best suited to rice. These findings contribute to a very low ERR of -7.5 percent for the Podor Activity, compared to the closeout ERR of 3.5 percent.

Risks remain regarding the long-term sustainability of the irrigation infrastructure. Maintenance activities are underfunded relative to what is planned in SAED's budgets, and there are persistent problems with water fee recovery, which results in insufficient routine maintenance. The effects of the LTSA are persistent, especially regarding land administration procedures, training of land managers, and the raising of awareness with the public, even though the land information systems are no longer being used. There is persistent demand for land titling, even several years after the compact. However, the continued ability of land administrators to meet demand for land titles depends on support from other donor programs and from the Senegalese government.

B. Recommendations for MCC project design

The following recommendations are based on the findings in this report as well as relevant findings from the interim evaluation.

Farmers adopt new practices slowly; MCC could consider a longer timeline for behavior change, such as adopting new cultivation techniques, new crops, or expansion and intensification of farming. The interim evaluation compared households in the treatment area to households in the comparison area at 2 to 3 years after the completion of the irrigation infrastructure. At that time, we found that the IWRM Project was beginning to change the behavior of farmers, who were shifting toward more rice cultivation in the hot dry season. By the final evaluation, at 5 years post-compact, we learned that farmers (including larger-scale farm businesses) were expanding the area under cultivation and increasingly cropping in two seasons. These slower-than-expected changes may be the result of farmers' risk aversion, or an indication that they lack access to complementary inputs, such as credit, labor, or farm machinery. Because the CBA and the logic model anticipated larger changes at an earlier date, delays in these changes contributed to low post-compact ERRs. For a better understanding of the trajectory of changes, we recommend that MCC revise down their assumptions about the speed of behavior change in future CBA models and consider continued monitoring of the area under cultivation over the next 3 to 5 years.

A condition precedent for ensuring sufficient maintenance post-compact is necessary but may not be sufficient to ensure sustainability of maintenance plans. MCC anticipated the importance of maintenance for the sustainability of the project outcomes and included a condition precedent to improve the collection and management of maintenance funds. At 5 years post-compact, SAED reported that it has improved the rate of water fee collection to 68 percent relative to a target of 80 percent. However, the Senegalese government's contribution to the maintenance fund appears lower than necessary, and our final evaluation found that maintenance is not keeping up with the needs of farmers in the area. We recommend that irrigation projects include water tariff reform to create a self-sustaining maintenance fund.

Model various constraints when planning a contiguous perimeter such as Ngalenka. Only a portion of the Ngalenka perimeter is in use, and it is used only in one season. The interim evaluation found that the cost of using the grid-electricity pumps was so high that a minimum of 300 of the 450 hectares must be under production to offset the cost of running and maintaining the pumps and to make production viable. During construction, implementers recognized that 80–130 hectares of the perimeter has soil that is well suited for some crops, but not for rice, or is at too high an elevation to be irrigated. Therefore, farmers with land in those 80–130 hectares may never have enough water to grow irrigated crops. In the intervening years, it has also become evident that the creek feeding the perimeter supplies insufficient water in the hot dry season, which renders the perimeter unusable. MCC should consider reviewing the original engineering plans and the local hydrogeological constraints to see whether these risks could have been anticipated.

Include a gender expert in the design of projects intended to benefit women. MCC and MCA Senegal implemented, for the Ngalenka perimeter, land allocation practices that resulted in women's cooperatives obtaining access to land within the perimeter. Unfortunately, a substantial portion of the land not well suited to rice was allocated to women's cooperatives for horticulture. The constraint to irrigating these parcels described above (and in the interim evaluation report) during the appropriate season for horticulture has prevented the women's cooperatives from fully benefiting from the land allocated to them. More generally, the project may have benefited from a gender mainstreaming approach that includes the gender perspective through each stage of a project, from planning through design, construction, and management (see for example Morgan et al. 2020).

Sustaining improvements to land administration may require long-term donor support, but MCC compacts can catalyze investment. The LTSA led to large and sustained increases in demand for land formalization. The interim evaluation showed that in the period between the close of compact and the start of the World Bank's PDIDAS program, land offices struggled to process applications. As the PDIDAS program comes to a close, demand may not decline, but the capacity of communes to carry out each step in the application process may not be sustainable. A five-year compact may not offer enough time to establish a self-sustaining land-titling system, especially if there is need first to change policy and then to follow a process requiring town/rural planning, surveying and mapping, and adjudication and dispute resolution. In the case of Senegal, the bulk of titling happened in the last year of the compact. Despite these potential risks to sustainability, the LTSA appears to be an example of how donor funding can be catalyzed to support and extend MCC's land activities to build on the enthusiasm and interest generated through the project. MCC should continue to consider specifically who will take up the funding, maintenance, and continued operation of land systems that get created, whether this is other donors who have a different funding model or, more pertinently, partner governments.

C. Recommendations for MCC evaluations

Expand the types of potential beneficiaries considered in evaluations of large irrigation projects and explore different ways of getting data from these actors. Large- and medium-scale farmers are an important group that operates in a way very different from that of small holders in the Delta Activity area. They face different constraints, operate at different scale, and potentially have a greater appetite for risk than small farmers. These actors may also have much more formalized information systems and farm management practices that should be considered in designing data collection instruments. For example, it might be useful to design shorter surveys that look more like the World Bank's enterprise survey—that include a greater focus on employment—rather than a household survey. These types of farmers are also crucial for understanding how and whether the project logic for the IWRM Project is being realized. The role that commercial farmers play is also important for having a CBA model that links up clearly with the evaluation.

Using satellite data and establishing data use agreements for local country data systems could provide low-cost alternatives to primary data collection, but there are some limits. During both the interim and the final evaluation periods, we encountered difficulty obtaining official, credible data from Senegalese government entities charged with collecting indicator data for IWRM. As an alternative, and to triangulate data we received from official and unofficial sources, we used satellite data to estimate area under production in the Delta Activity areas and to review and demonstrate changes in farming practices over time. As use of satellite data becomes more precise (with higher resolution and development of accurate methods to identify crops), some changes can be measured without relying on local data systems. However, understanding how farmers make decisions, why subgroups such as women do or do not benefit from an intervention, and changes in the well-being of poor households will continue to require collecting data from individuals into the foreseeable future.

D. Dissemination plan

Mathematica delivered a draft final report in English and in French for review and comment by stakeholders at MCC and MCA in Senegal. Mathematica also presented the results to both groups of stakeholders. We revised the report based on the comments and questions and submitted a final version in English and in French in July. We have delivered public-use and restricted use data files to MCC, following TREDD guidelines. Mathematica will collaborate with MCC and stakeholders in an ongoing manner to look for opportunities—including conferences, workshops, and publications—to share results and encourage donors, implementers, and policymakers to integrate the findings into future programming.

4. Evaluation administration

A. Summary of IRB requirements and clearances

Mathematica submitted the instruments and sampling plan for the qualitative data collection to our U.S.-based IRB, which provided its approval in February 2021.

B. Preparing data files for access, privacy and documentation

Data delivery will include the survey data collected for the interim evaluation report. Mathematica will prepare the data according to the TREDD guidelines (MCC 2020) to ensure that it protects the privacy of respondents and does not allow reidentification. The preparation process includes reviewing raw data to ensure that outliers, geographic identifiers, and small cell sizes cannot be used to reidentify respondents.

Mathematica will also prepare documentation of the quantitative and qualitative data collection activities, including data collection instruments and sampling protocols. We will also provide documentation of scripts used in the analysis.

C. Evaluation team: Roles and responsibilities for the final evaluation

Dr. Sarah Hughes led the team as project director, overseeing design and implementation of all evaluation activities. **Dr. Anthony Harris,** an agricultural and land-focused economist at Mathematica, conducted the quantitative data analysis, the economic rate of return analysis and the remote-sensing analysis. **Mr. Ahmadou Kandji**, a Dakar-based research coordinator and consultant, worked closely with Mathematica and local stakeholders to facilitate logistics for data collection and worked with Dr. Hughes to conduct qualitative data collection. In addition to Dr. Hughes and Mr. Kandji, **Ms. Sarah Leser** supported the qualitative analysis and managed the project internally for Mathematica. **Dr. Evan Borkum** provided quality assurance review of all deliverables. **Mr. Jeremy Page** led the data preparation team under Dr. Harris' guidance.

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Annex 1: Data collection and evaluation administration

A. Evaluation administration

The interviewees in the Delta are from the communes of Ronkh, Diama, and Gandon, and those in Podor are from the commune of Ndiayene Pendao. In those communes, Mathematica's local team spoke with land managers, representatives of water user associations, leaders of farmer cooperatives (GIEs and GPFs), and a commune leader. The team also interviewed SAED representatives.

Table A1.1. Final evaluation data sources

Data source	Data collection method	Number	Sample
Farmer cooperative leaders	KIIs	13	Male and female leaders of farmer cooperatives (GIEs and GPFs) in Diama, Ronkh, Gandon, and Ndiayene Pendao (2 to 4 per commune)
Heads of AUEs	KIIs	5	Heads and members of AUEs in 3 of the 4 targeted communes (3 in Gandon, 1 in Ronkh, and 1 in Ndiayene Pendoa)
SAED staff	KIIs	3	Key SAED staff from the Dagana and Podor delegations and from the St. Louis headquarters who collect data on agriculture production, irrigation infrastructure and land titling. (1 group meeting and 2 individual meetings)
Land managers and commune leader	KIIs	4	Land managers and one commune leader in three communes in the Delta Activity area: Diama, Ronkh, and Gandon
Infrastructure maintenance plans	Document review	n.a.	Review of maintenance plans and reports for irrigation infrastructure in Delta and Podor
Administrative data	Data transfer	n.a.	Data on land under production and main crops cultivated by agriculture season from official sources; data on land management from national land database

GIE = farmer cooperatives; GPF = female-only farmer cooperatives; SAED = National Company for the Development and Exploitation of Land in the Delta of the Senegal river and the valleys of the Senegal river and the Falémé; AUE = water-user association.

B. Changes to research questions and methodology due to COVID-19 restrictions

The design of the final evaluation was revised with the onset of the COVID-19 pandemic, which restricted the team's travel and led to revisions in the mode of data collection. Data collection was originally planned for March-April 2020 but was pushed back to February-March 2021. Together with MCC, Mathematica revised the research questions, methods, and data sources. The US-based and local teams switched to remote data collection methods and were not permitted to travel within Senegal. As a result, Mathematica dropped focus group discussions, switching entirely to individual KIIs for the qualitative interviews, except for one group interview with SAED staff. The team also abandoned the engineer's trips to assess the current state of infrastructure, focusing instead on a document review of infrastructure maintenance plans. The team also abandoned the review of land application records in Delta Activity area communes since this required in-person travel within Senegal to the land manager's offices.

Table A1.2. Research questions for the final evaluation

Research question	Analytical methods	Data sources
1. Has the primary irrigation infrastructure in the Delta Activity area and the Podor Activity area been maintained? Why or why not?	In-depth qualitative analysis	KIIs GIEs, GPFs, AUEs, SAED extension agents; document review of maintenance plans
2. Have farmers increased their cropping intensity as expected by the project logic in the Delta Activity area? Why or why not?	• Descriptive analysis of agriculture production data; • In-depth qualitative analysis; • Supervised machine learning for land-use classification	KIIs with GIEs, GPFs, AUEs, and SAED extension agents; SAED administrative data; Sentinel-2 satellite data
3. Are farmers growing tomatoes and onions as expected by the project logic in the Delta Activity area? Why or why not?	Descriptive analysis of agriculture production data; In-depth qualitative analysis	KIIs with GIEs, GPFs, AUEs, and SAED extension agents; SAED administrative data
4. Which stakeholders were more likely to demand a land title and change land use behaviors?	Descriptive analysis of quantitative data	Household survey data collected for the baseline and interim evaluations
5. Is there continued demand for land titles in the Delta Activity area, and are they being processed? Why or why not?	In-depth qualitative analysis	KIIs with commune land managers, a commune leader, GIEs, GPFs; administrative data from national land database

GIE = farmer cooperatives; GPF = female-only farmer cooperatives; SAED = National Company for the Development and Exploitation of Land in the Delta of the Senegal river and the valleys of the Senegal river and the Falémé; AUE = water-user association.

Annex 2: Technical notes on remote sensing analysis

This annex provides an overview of the remote sensing methods used to estimate the extent of cultivation within and across growing seasons in the Delta Activity area.

A. Overview

We use Sentinel-2 imagery to produce maps showing the area under cultivation – referred to in the remote sensing literature as a “cropland mask” - for the three growing seasons in the Delta Activity area for the period 2018–2020. This period covers three full agricultural years in the area spanning from March 2018 (beginning of hot dry season) to end of March 2021 (end of cold dry season). We generate the cropland mask using a supervised machine learning approach that classifies pixels as cultivated/not cultivated based on the time series progression of vegetation over the course of the growing season as well as data from other bands (see Valero et al. 2016 for a discussion of machine learning approaches to classification). The model is trained using data on points and polygons within the area that we provided based, on a visual inspection of the Delta Activity area in each of the nine growing seasons we study.

B. Data sources

We use imagery for the period 2018–2020 from the ESA Sentinel-2 program. Sentinel-2 is a wide-swath, high-resolution, multi-spectral imaging mission supporting Copernicus Land Monitoring studies, including the monitoring of vegetation, soil and water cover, as well as observation of inland waterways and coastal areas. The imagery was accessed and processed using Google Earth Engine. The imagery has different resolutions, but the RGB and near infra-red bands are 10 m resolution. Images are collected every five days.

C. Data preparation

First, we compiled a collection of one image per day from the Sentinel-2 satellite program for each growing season[29] defined over an area of interest that encompassed the Western delta of the SRV. We mask cloud pixels and filter out select images with sandstorms that were not removed through automatic cloud masking procedures. Our area of interest draws from multiple scenes, so we created a mosaic by selecting pixels from the earlier image wherever there was overlap between two scenes taken on the same day.

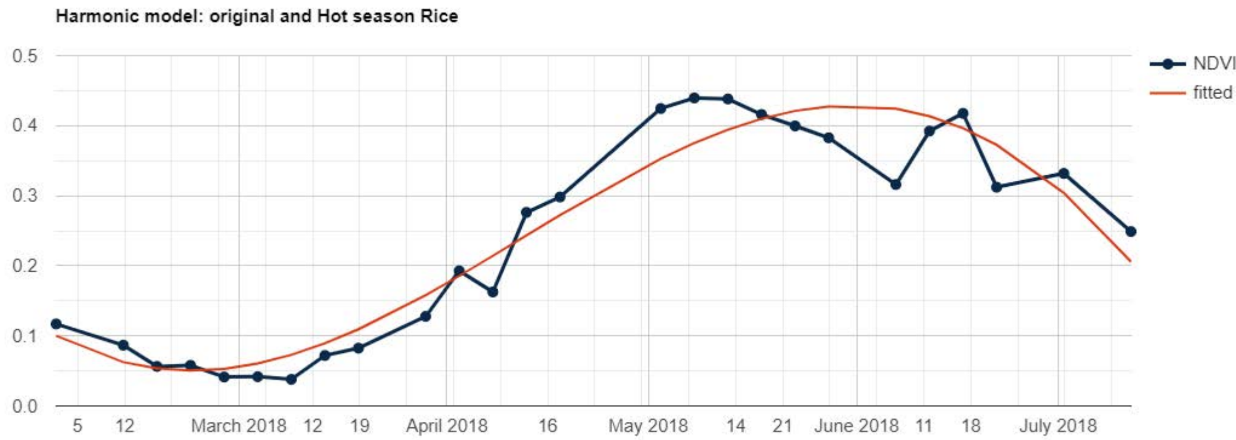
Second, we calculated a series of vegetation metrics, including the normalized difference vegetation index (NDVI) for each pixel and for each image[30]. For each pixel we estimated a harmonic regression to model the evolution of the NDVI over the calendar year. Harmonic regression is a time series approach frequently used to estimates biological phenomena that have a cyclical pattern over time. We allow for one cycle per season but allow for two cycles in the cold dry season to account for the possibility that some pixels may be in plots that are cropped twice in the growing season. Below is an example of what the time series and fitted regression looks for the set of pixels cropped with rice in the hot season. In

[29] The windows for each growing season were defined as February 1 to July 15 for the hot season, July 1 to November 30 for the rainy season, and November 30 to April 1 of the subsequent year for the cold dry season. We also defined windows of time where we expected growth to peak, towards the end of each season and windows where we expected fields to be in the preparation/flooding phase early in the season.

[30] We also calculate green chlorophyll vegetation index (GCVI), Merris Terrestrial Chlorophyll Index (MTCI), Red edge NDVI740 and Red-Edge Normalized Difference Vegetation Index (NDVI705)

contrast to cultivated land, bare land or rivers will have flatter profiles while natural vegetation such as weeds in irrigation drainage basins or forests may have more gradual evolutions over time. We also calculate a number of simpler metrics, including the median value during peak growth (for all bands and vegetation indices).

Figure A2.1. NDVI profile and fitted harmonic regression – Hot dry Season 2018 cultivated parcels



Note: The NDVI series is the average value across all pixels that are identified in the training dataset as cultivated during the hot dry season. The fitted curve is a harmonic regression with one phase fitted to the average values of the NDVI across the training dataset the predicted values of a harmonic.

D. Classification of crop mask

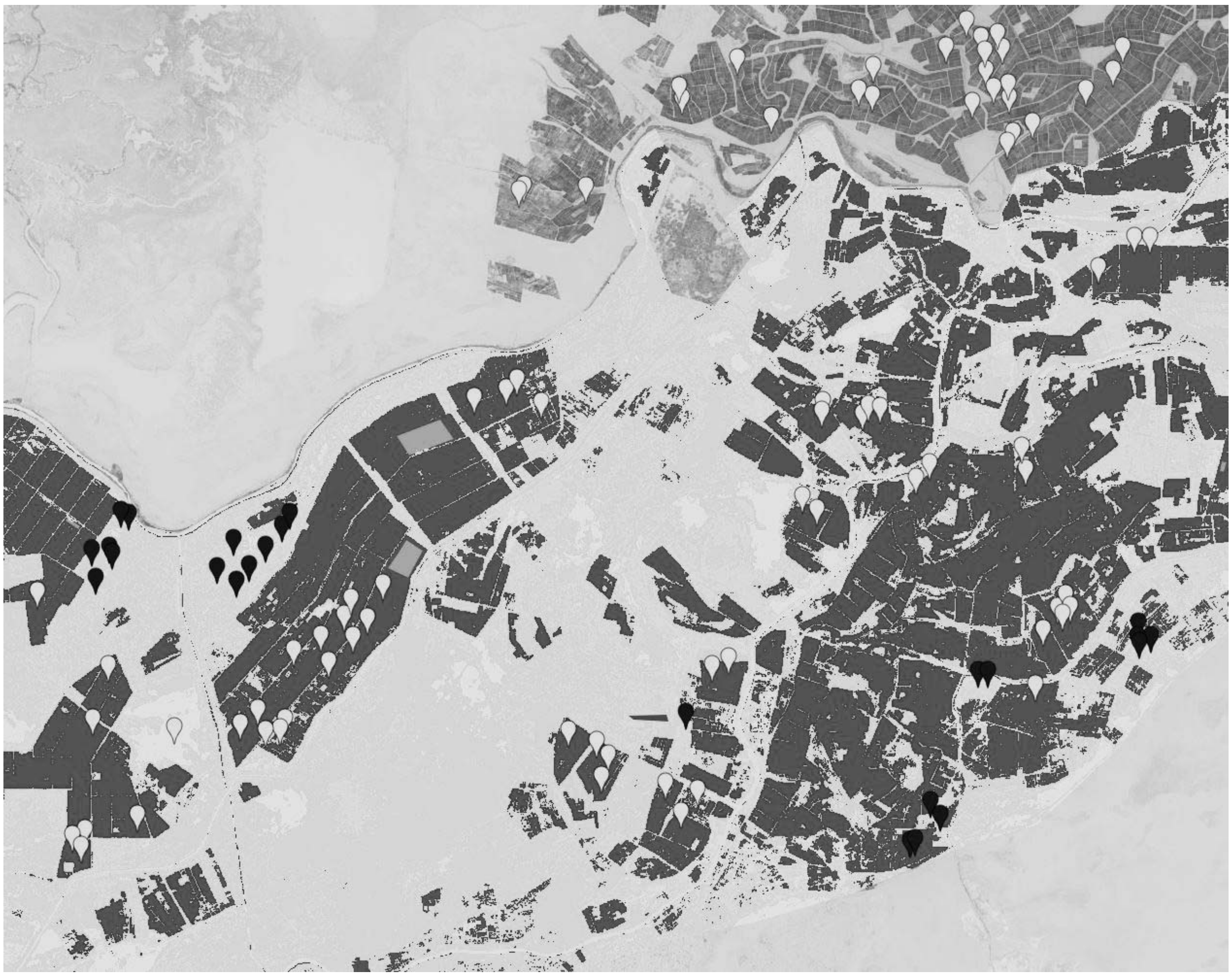
Third, we use a supervised machine learning approach to classify land based on the spectral signature of the images and the results of the harmonic regression that are stored in each pixel. We use a random forest classifier with 150 trees. This approach classifies land use type for each pixel based on the image bands that we select – these bands include the harmonic regression coefficients and some summary statistics of the vegetation indices for each season. The additional bands we include are: median values during the peak growth window and difference between the maximum value of each index and band over the peak growth window and the minimum value for each index and band over the land preparation window. The random forest classifier uses manually tagged pixels as input data. These pixels are based on a review the time series of images that we manually tagged[31] as being one of five different land types. These are: cultivated, non-cultivated parcel, water or river, bare land, and shrub, trees or riparian vegetation. The random forest classifier selects the bands and values that best classify the overall image using the points that we have manually identified and uses the information from each pixel to assign a land use type.

[31] We tagged five or more pixels per class. Cultivated pixels were manually tagged by reviewing the evolution of the imagery over the course of each growing season. The cold dry season usually begins in the last months of the previous year. As an example, for 2018, we viewed the RGB image from October 2017 to December 2018. Cold dry season cultivation usually involves vegetable production and the cropping period can overlap with land preparation for Hot season cultivation. Hot season cultivation is clearly identifiable because the land around cultivated parcels is dry, especially in May and June. We use this to distinguish cold dry season plots from hot season plots. During the rainy season it can be challenging to distinguish cultivated land from general vegetation growth due to rain. This is most challenging during the July - September period. However, rainy plots are most easily identified just prior to the harvest period, which can occur from mid-October to November.

Fourth, we reviewed the classified image and identified areas where crops were potentially misclassified. We added additional training points at this stage and re-ran the model. In order to assess the model prediction accuracy, we set aside a random subset of the training points as a validation data set. After settling on a final model, we estimated accuracy metrics based on predicting land classes based on the validation data. The accuracy metrics are fairly high (greater than 90 percent), which is likely an artifact of the small number of training points and polygons we use. Although each analysis includes more than 150 training points for each land class, the points are often drawn from polygons. It is likely that the accuracy against a set a point from outside the training or validation set would be somewhat lower.

Figure A2.2 shows an example of the output of the land classification.

Figure A2.2. Training points and land classification output for hot dry season 2018



Note: Dark markers indicate points or polygons that have been identified as cultivated in the hot dry season. Lighter markers indicate points or polygons that have been identified as uncultivated farmland. Other classes not shown include river, bare land, forest and wetland. The basemap underneath the land use mask shows the difference between maximum and minimum values for the NDVI index across the hot dry season. Positive pixel values are shown in middle shades of gray (values with a large increase in the value of NDVI) and pixels with no change in NDVI are shown in white (or lighter shades).

E. Extraction of area estimates

At the end of this process, we extract an image which includes a band containing the land classification for the specified season and year. We then combine these images into a single image where each pixels is classified as cultivated in the hot season, cultivated in the rainy season, cultivated in both seasons or not cultivated (this latter category contains river, bare land, forest, wetland and non-cultivated plots). Finally, we extract estimates of the area under production for these different classes for defined region of the Delta Activity area. The area is defined as the area that was expected to benefit from the improvements to irrigation drawn from compact documents.

Podor perimeter

In principle, a similar type of analysis could be done for the Podor Activity area. However, given the small size of the perimeter it is straight forward to assess visually what is happening, especially across the two rice growing seasons. Figure A2.3 shows a satellite color image of the extent of cultivation in the Ngalenka perimeter (shown in black) and the surrounding area. Cultivation patterns between 2017 and 2018 – 2021 have switched: the perimeter itself is being cultivated **in the rainy season only**, while cultivation may be expanding outside of the perimeter in the hot season. Further investigation could allow for estimates of how much land is farmed in each season within and outside of the perimeter.

Figure A2.3. Images of the Ngalenka perimeter.

Year	Hot season	Rainy season
2017		
2018		
2019		
2020		
2021		

Annex 3: Additional tables for evaluation CBA

This annex provides additional analysis of the evaluation CBA not included in the main body of the report. First, we provide additional results from the Delta Activity area CBA, including a comparison of key parameters between the MCC closeout CBA and the evaluation CBA and additional sensitivity analysis. Second, we provide the same information for the Podor Activity CBA model.

A. Delta Activity evaluation CBA model

Explanation for difference between evaluation CBA and MCC ex-ante ERR

The ERR for the evaluation CBA is 1.8 percent, which is lower than the 15.9 percent estimated in MCC's ex-ante CBA. Table A3.1 compares the key parameters in the benefit streams across both models. The parameters for the MCC closeout CBA model are largely from 2014, although some of the assumptions around crop production are the same as MCC's ex-ante CBA model. Many of the assumptions, including the anticipated area under cultivation and yields, are based on information from prior to the completion of the irrigation infrastructure. The parameters we use in the evaluation CBA are based on the impact evaluation findings reported in the interim evaluation, which pertain to the 2017 agricultural year, and the post-compact indicator tracking reports, which cover the period 2016 – 2020.

One driver of the benefits of the project is the net profitability (or incremental profit) when comparing with- and without-project scenarios, which is calculated based on the cost, yield and price parameters. Profits per hectare are scaled up by the area under cultivation to generate the aggregate contribution to benefits in each season. Incremental profits generate benefits on land that was used both in the with- and without project scenarios. However, benefits are also generated on newly cultivated land – that is, land that was reclaimed or rehabilitated due to the project. The aggregate with-project benefits generated on this type of land are determined by the overall level of profits in the with-project scenario. Although profit levels are higher in the evaluation CBA for rainy and hot season rice production, the assumptions around onion production in the MCC closeout CBA are extremely influential on the overall results. The overall contribution of onions to annual benefits in the MCC closeout CBA is nearly $9 million dollars per year (calculated as net area under production multiplied by 5,300,000 FCFA/ha profits), which is larger than the $6.9 million dollars generated by new land under production in the rainy season.

Table A3.1. Comparison of key parameters in benefit stream across MCC closeout CBA and evaluation CBA for Delta Activity

	MCC closeout CBA		Evaluation CBA	
	With project	Without project	With project	Without project
Hot dry season				
Area under cultivation (ha)	31,189	10,188	19,807	6,652
Yield (kg/ha)	7,500	6,800	5,379	4,439
Costs (FCFA/ha)	510,980	510,980	520,297	422,310
Price (FCFA/kg)	125	125	200	200
Profits (FCFA/ha) [a]	**426,520**	**339,020**	**555,503**	**465,490**
Rainy season				
Area under cultivation (ha)	27,139	13,231	10,059	3,378
Yield (kg/ha)	6,210	4,633	3,626	4,676
Costs (FCFA/ha)	510,980	510,980	249,798	302,241
Price (FCFA/kg)	129	129	200	200
Profits (FCFA/ha) [a]	**290,110**	**86,677**	**475,402**	**632,959**
Cold dry season				
Tomatoes:				
Area under cultivation (ha)	769	344	1,261	1,106
Yield (kg/ha)	22,016	22,016	n.a.	n.a.
Costs (FCFA/ha)	869,510	869,510	n.a.	n.a.
Price (FCFA/kg)	52	52	n.a.	n.a.
Profit (FCFA/ha)[a]	**275,322**	**275,322**	**135,000**	**400,000**
Onions:				
Area under cultivation (ha)	1863	834	1863	834
Yield (kg/ha)	27,486	27,486	n.a.	n.a.
Costs (FCFA/ha)	1,019,083	1,019,083	n.a.	n.a.
Price (FCFA/kg)	230	230	n.a.	n.a.
Profit (FCFA/ha) [a]	**5,302,697**	**5,302,697**	**135,000**	**400,000**

Note: Both models assume that the area under cultivation converges to a steady long-run level, which is the level we report in this table. Costs reported in this table for the evaluation ERR are reported as economic costs. Both models assume an exchange rate of 580 FCFA/USD. Profits for the cold dry season are not reported separately by crop in the interim report—our model assumes that profits are the same for both tomatoes and onions and we list the yield and cost information as n.a.

[a] Profits per hectare are calculated for each season using the data in this table, except for tomato and onion profits for the evaluation CBA where we report overall cold dry season profits reported by farmers in the survey.

n.a. = not applicable.

Sensitivity testing

In order to dig deeper into what is driving the evaluation ERR and what can explain the differences between the models, we conduct some sensitivity testing. We run two tests: i) we assess how the ERR changes if more land is put under production (increasing cropping intensity) and ii) we assess how the ERR changes if rice yields in the with-project hot and rainy season increase relative to the without project scenario.

In scenario one, we increase *land use* across all three seasons in proportion to a set factor while keeping all other parameters constant. (For example, a factor of 1.2 increase of the area under production in the hot season from 19,807 hectares to 23,768 hectares.) Table A3.2 shows how the ERR changes as this land use factor is changed and shows the area under cultivation implied by changing this factor. Increasing land under production by a factor of 1.8 across all three seasons would generate an ERR that exceeds MCC's hurdle rate of 10 percent. This is equivalent to cultivating approximately 35,500 hectares in the hot season with the project and 6,600 hectares without the project.

Table A3.2. Scenario 1: Increasing land under cultivation across seasons

Land use factor	ERR	Hot season (ha)	Rainy season (ha)	Cold season (ha)	Cropping intensity
1	**1.8%**	**19,807**	**10,059**	**3,293**	**0.84**
0.9	0.0%	17,826	9,053	2,964	0.76
1	1.8%	19,807	10,059	3,293	0.84
1.2	4.8%	23,768	12,071	3,952	1.01
1.4	7.4%	27,730	14,083	4,610	1.18
1.6	9.6%	31,691	16,094	5,269	1.35
1.8	11.6%	35,653	18,106	5,927	1.51
2	13.4%	39,614	20,118	6,586	1.68

Note: Both models assume that the area under cultivation converges to a steady long-run level, which is the level we report in this table.

[a] The overall cultivable area is 39,399, which is based on the MCC closeout CBA.

In scenario two, we increase *yields* for the hot season in the with-project case relative to the yields in the without-project case. Again, all other parameters stay the same. This time we use a factor that increases the rice yield, measured in kg/ha in the hot season in the with-project case. Table A3.3 shows how the ERR changes for a range of relative yields for hot season rice. Increasing relative yields by a factor 1.4 would generate an ERR that exceeds MCC's hurdle rate of 10 percent. This is equivalent to yields for the hot season of 7,530 kg/ha with the project and 4,439 kg/ha without the project.

Table A3.3. Scenario 2: Increasing rice yields land under cultivation across seasons

Hot season yield increase (factor)	ERR	Hot season yield with project (kg/ha)	Hot season yield without project (kg/ha)
1	**1.8%**	**5,379**	**4,439**
0.7	-15.0%	3,765	4,439
0.8	-6.4%	4,303	4,439
0.9	-1.6%	4,841	4,439
1	1.8%	5,379	4,439
1.1	4.6%	5,917	4,439
1.2	7.0%	6,455	4,439
1.3	9.1%	6,993	4,439
1.4	11.0%	7,531	4,439
1.5	12.7%	8,069	4,439
1.6	14.3%	8,606	4,439
1.8	17.1%	9,682	4,439
2	19.7%	10,758	4,439

Note: Both models assume that the area under cultivation converges to a steady long-run level, which is the level we report in this table.

B. Podor Activity evaluation CBA model

Explanation for difference between evaluation CBA and MCC ex-ante ERR

The ERR for the evaluation CBA is -7.5 percent, which is lower than the 3.5 percent estimated in the MCC closeout CBA model. Table A3.4 compares the key parameters in the benefit streams across both models. A major driver of the difference between the ERRs from the two CBA models is MCC's assumption that land will be cultivated in all three growing seasons. Between 2017 and 2021 the Ngalenka perimeter has only been used to cultivate during the rainy season, which is reflected in the evaluation CBA assumptions. In contrast, the MCC closeout CBA assumes that benefits are generated in the rainy and hot season. (The model assumes that the same area is cultivated during the cold dry season with and without the project, generating no benefits from the project).

Table A3.4. Comparison of key parameters in benefit stream across MCC closeout CBA and evaluation CBA for Podor Activity

	MCC closeout CBA		Evaluation CBA	
	With project	Without project	With project	Without project
Hot dry season				
Area under cultivation (ha)	378	0	0	0
Yield (kg/ha)	7,750	n.a	n.a	n.a
Costs (FCFA/ha)	510,980	n.a.	n.a.	n.a.
Price (FCFA/kg)	130	n.a	n.a	n.a
Profits (FCFA/ha)	496,520	**0**	**0**	**0**
Rainy season				
Area under cultivation (ha)	425	24.8	351	351
Yield (kg/ha)	6,680	5,773	3698	885
Costs (FCFA/ha)	510,980	510,980	330,264	151,371
Price (FCFA/kg)	129	129	200	200
Profits (FCFA/ha)	**350,740**	**233,737**	**372,356**	**16,779**
Cold dry season				
Tomatoes:				
Area under cultivation (ha)	14.9	14.9	0	0
Yield (kg/ha)	6,443.30	6,443.30	n.a	n.a
Costs (FCFA/ha)	869,510	869,510	n.a.	n.a.
Price (FCFA/kg)	52	52	n.a	n.a
Profit (FCFA/ha)	**-534,458**	**-534,458**	**0**	**0**
Onions:				
Area under cultivation (ha)	40	40	0	0
Yield (kg/ha)	22,333	22,333	n.a	n.a
Costs (FCFA/ha)	1,019,083	1,019,083	n.a.	n.a.
Price (FCFA/kg)	165	165	n.a	n.a
Profit (FCFA/ha)	**2,665,862**	**2,665,862**	**0**	**0**

Note: Both models assume that the area under cultivation converges to a steady long-run level, which is the level we report in this table. Costs reported in this table for the evaluation ERR are reported as economic costs. Both models assume an exchange rate of 580 FCFA/USD. Profits for the cold dry season are not reported by separately by crop in the interim report—our model assumes that profits are the same for both tomatoes and onions and we list the yield and cost information as n.a. Profits per hectare are calculated for each season.

[a] Profits per hectare are calculated for each season using the data in this table, except for tomato and onion profits for the evaluation CBA where we report overall cold dry season profits reported by farmers in the survey.

n.a. = not applicable.

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