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REPORT

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

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GLOSSARY

ANSD	Agence Nationale de la Statistique et de la Démographie
CAPI	Computer-assisted personal interviewing
CR	*Communautés Rurales*
DID	Difference-in differences
ERR	Economic rate of return
GIE	*Groupement d'Intérêt Économique* (economic interest groups made up of members with common business interests that aim to improve their industry)
GPF	*Groupement de Promotion Féminine* (women's groups that promote the interests of women in rural areas)
IRB	Institutional Review Board
IWRM	Irrigation and Water Resource Management
LTSA	Land Tenure Security Activity
MCC	Millennium Challenge Corporation
MDI	Minimum detectable impacts
PAP	Project-affected people
PEA	Project Evaluability Assessment
PPP	Purchasing power parity
SAED	*Société Nationale d'Aménagement et d'Exploitation des Terres du Delta*
SRV	Senegal River Valley
WUA	Water user association (groups that manage water systems and are often responsible for the maintenance of infrastructure and for collecting water user fees from members)

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I. INTRODUCTION

Agriculture plays a central role in the livelihoods of millions in Senegal. It provides sustenance and incomes for around 75 percent of the population.(Sylla 2015; FAO Statistical Database 2015). However, the agricultural sector accounted for only 15 percent of Senegal's gross domestic product in 2015 and is unable to meet the country's consumption needs (Sylla 2015). As a result, the country continues to import nearly 75 percent of its rice, Senegal's primary staple, making the country vulnerable to price shocks (Sylla 2015). In addition, poverty, subsistence farming practices, environmental damage and recurring natural disasters affect agricultural production, leaving the majority of the population chronically malnourished, and nearly half of all households food insecure (WFP 2015).

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

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

To address the potential of and challenges facing agriculture in Senegal, improve agricultural productivity, increase rural employment and incomes, and improve the competitiveness of the agricultural sector in the SRV, the Millennium Challenge Corporation (MCC) invested in the Irrigation and Water Resource Management (IWRM) Project. MCC's Compact with the government of Senegal, which began on September 23, 2010, included three activities: (1) the Delta Activity, (2) the Podor Activity, and (3) the Land Tenure and Security Activity (LTSA). A fourth planned activity, the Social Safeguard Activity, was not implemented. The Delta Activity rehabilitated the existing irrigation and drainage infrastructure in the Senegal River Valley Delta and the Podor Activity constructed a new irrigation perimeter in Ngalenka in the Department of Podor. The LTSA supported the creation of a comprehensive land occupancy and use inventory; developed an inclusive process for allocating land that prioritized customary claimants, women, and landless farmers; allocated parcels and formalized land rights through the provision of titles; and trained local officials to better administer land rights. Project activities were completed and the five-year Compact closed on September 23, 2015.

Mathematica Policy Research is designing and implementing an evaluation of the IWRM Project's three activities to determine their impact on agriculture production, use and availability of water, household income, land security and conflicts, and land administration and governance. The IWRM Project evaluation, described in this Evaluation Design Report, will address research questions on project outcomes, implementation, and sustainability. We propose a mixed-methods evaluation that employs quantitative and qualitative evaluation methods. To estimate causal impacts of IWRM Project activities, we will employ an impact analysis using a difference-in-differences (DID) approach. We will estimate impacts separately for the Delta and Podor regions at the household level. To examine the effects of project activities that cannot be analyzed using an impact analysis, such as understanding why impacts occurred and what factors were driving those results, we will conduct a descriptive outcomes and implementation analysis that combines quantitative and qualitative research methods. The evaluation will draw on an array of data sources, including a baseline survey conducted over three agricultural seasons between 2012 and 2013, project administrative data, and new quantitative and qualitative data collected in follow-up surveys beginning in 2017.

This design report provides context for the evaluation of the IWRM Project and describes the evaluation design in detail. In Chapter II, we introduce the Compact, the IWRM Project, and the project activities, and describe the program logic. In Chapter III, we review the existing literature on irrigation infrastructure and land tenure security and administration interventions, discuss the gaps in the literature, and describe how the IWRM Project evaluation seeks to address those gaps. In Chapter IV, we outline the research questions that the evaluation aims to answer, present our analysis of existing evaluation evidence and how the results of that analysis affect our design approach, and describe our proposed evaluation design and the data sources we plan to use. In Chapter V, we discuss several evaluation administration-related issues including Institutional Review Board (IRB) requirements, the data anonymization process, our dissemination plan, and evaluation team roles and responsibilities.

II. OVERVIEW OF THE COMPACT, IWRM PROJECT, AND ACTIVITIES

In this chapter, we provide context for the evaluation of the IWRM Project by describing the Senegal Compact, the IWRM Project, the project activities, and the mechanisms through which they are expected to affect outcomes, as set out in the program logic. We also describe the ex-ante economic rate of return (ERR) that MCC calculated to compare the expected benefits and costs of the project, as well as the beneficiary analysis, which estimated the distribution of income in the areas where the investments will be made.

A. Overview of the Compact

On September 16, 2009, MCC signed a $540 million Compact agreement with the Republic of Senegal. The Compact, which entered into force on September 23, 2010 (meaning the five-year timeline for implementation began and Compact funds were formally obligated), aimed to "enable improved agricultural productivity and expand access to markets and services through critical infrastructure investments in roads and irrigation sectors." The five-year agreement consisted of two projects: (1) the Roads Rehabilitation Project, which aimed at expanding access to markets and services by reducing transportation time and costs through improvements in strategic roads, and (2) the IWRM Project, which aimed to improve the productivity of the country's agricultural sector by improving the quality and reach of irrigation in agriculture-dependent areas in the north. The Compact was completed on September 23, 2015; implementation activities and funding, which totaled $432 million, ended at that time. This evaluation covers the IWRM Project.

B. Overview of the Irrigation and Water Resources Management (IWRM) Project activities and program logic

In line with Senegal's 1998 Master Plan for poverty reduction and agricultural development in the Senegal River Valley (SRV), the IWRM Project was designed to address the poor quality and lack of existing irrigation and drainage infrastructure, increase the volume of irrigated water in the SRV, develop newly irrigated land, and eliminate the risk of abandonment of existing irrigable land to increase agricultural productivity. The project also aimed to enable a secure land tenure environment for all those living and farming in the region directly affected by the project by supporting the third phase of Senegal's decentralization policy, adopted in 2013, which shifted land governance authority to local governments and aimed to integrate decentralization into local land governance (World Bank 2015).[1] The IWRM consisted of four activities: (1) the Delta Activity, (2) the Podor Activity, (3) the Social Safeguard Activity (which was not implemented), and (4) the LTSA. This evaluation covers the Delta Activity, the Podor Activity, and the LTSA.

The program logic, presented in Figure II.2, describes the problem that motivates the project, lists the activities, subactivities, and outputs, and links them to short- and long-term outcomes and impacts. The problems the project aimed to address were low agricultural yields

[1] The formal name of the Decentralization Act is "Loi n°2013-10 du 28 décembre 2013 portant Code général des Collectivités locales." The Act extends the decentralization legislation that was adopted in 1972 and 1996 that sets out the structure of decentralized governance in Senegal.

and abandonment of land due to poor existing irrigation and drainage infrastructure in the Delta region, nonexistent irrigation infrastructure in Ngalenka, and low investment in the areas due to the insecurity of property rights and the high potential for land conflicts. The IWRM Project endeavored to reach 268,000 beneficiaries, increase household income by 35 percent and improve food security 10–20 years after the start of the project.

The Delta Activity aimed to increase the amount of irrigable and thus cultivable land in the Delta by rehabilitating existing irrigation and drainage infrastructure, to increase crop intensity (the ratio of crop area cultivated each year to the total irrigated area, including repeat cropping over the same area in the given year) and production, earnings, and employment for rural farmers, and competitiveness for Senegal's agricultural sector, particularly for rice. The Delta Activity took place in the northwestern section of Senegal. The project targeted 31,080 hectares of potentially irrigable land in the Delta, only 11,800 hectares of which were being cultivated at any point over the course of the year due to insufficient water supply and poor drainage. The program logic anticipated the outputs of the activity to include the creation of temporary employment, the creation of 17 water control structures, construction of 36 kilometers of new canals, the rehabilitation of 149 kilometers of canals, and the construction of 8 kilometers of protection dikes. As of the close of the Compact, the activity had rehabilitated or constructed over 221 kilometers of canals (exceeding the goal of 185 total kilometers). Short-term outcome goals of the activity included an increase in total area of irrigable land to 39,300 hectares, and by the end of the Compact, the activity had covered a total of 35,480 hectares with improved irrigation. Other short-term goals of the activity included having 42,030 hectares under cultivation, increased water flow of $65m^3$ per second, and the establishment of an effective drainage system. Beneficiaries of the Delta Activity were defined as "households, owners or shareholders of farming enterprises, and households that have individuals employed in the operation of enterprise farms" within the area covered by the activity.

The Podor Activity aimed to install new irrigation and drainage infrastructure in one of the identified sites in Senegal's 1998 Master Plan: Ngalenka. Ngalenka, an area in the Podor region south of the capital town of Podor and north of Route Nationale 2, was chosen because of its high potential for rice production, sufficient level of water resources, large farming population, cost-effectiveness of expanded irrigation that could attract private sector and donor investment, and small number of existing irrigation facilities (MCC 2009). The activity consisted of the construction of a new irrigated perimeter with an anticipated short-term outcome of 440 hectares of cultivable land. The anticipated outputs of the activity included the construction of 6 kilometers of protection dikes, 23 kilometers of primary and secondary canals, 14 kilometers of access paths, and two pumping stations. Beneficiaries of the Podor Activity were defined as "households, owners or shareholders of farming enterprises, and household that have individuals employed in the operation of enterprise farms" within the area covered by the activity.

As of the end of the Compact, the Podor Activity had leveled land, constructed water pumping stations and created a six kilometer protection dike, 24 kilometers of canals, and 34 kilometers of access paths, in addition to turning 450 hectares into cultivable land. Complementing the new infrastructure, the activity also included support for the resettlement of affected households, a reforestation program, and training for water user groups provided by independent contractors (called *opérateurs)* funded by the Government of Senegal. Following the construction of the new irrigation infrastructure in Ngalenka, 53 economic interest groups (commonly referred to in Senegal as "groupements d'intérêt économique," or GIE), consisting of over 2,200 individuals and 13 women's groups (commonly referred to as "les groupements de promotion feminine," or GPF) cultivated rice in the first growing season in 2014.

Prior to the IWRM Project, many occupants of parcels in the Delta, where the IWRM Project rehabilitated existing irrigation perimeters, held a *titre d'affectation* (or formal, revocable use or rights title that have been provided since the mid1960s) for parcels that had been assigned to them or their GIE or GPF through a government-sponsored process. However, due to the deterioration of the existing irrigation perimeters in the Delta, in many cases the parcels had been abandoned or had informally changed hands. Therefore, to a large extent current occupation and land rights were informal, although those who had record of a *titre d'affectation* held formal rights to their parcels. In Podor, occupants had claims to land that were defined by custom and informal practice, or were farming land to which they had no claim. Informal or unclear land rights in both Podor and the Delta resulted in land conflicts, lack of incentive to properly manage the land, and higher investment risks (Elbow 2016). Furthermore, improved irrigation under the project was anticipated to lead to increased land conflicts and potential abuses as the land became more productive. To address these challenges, **the LTSA** was implemented to reduce conflict, ensure protection of landholder rights, and improve the investment climate in the project area. Overall, LTSA was designed to support the creation and implementation of fair, efficient, and transparent processes for allocating land, offer equitable access to newly irrigated perimeters, and strengthen local land governance. The anticipated outputs of the LTSA included an inventory that clarified the status of land use and occupancy in the project area, landholding maps that would cover 55,303 hectares of land, and the issuance and registration of land title certificates for 3,440 hectares. It also aimed to establish nine Technical Support Committees, train 600 individuals in land tenure security tools, establish 33 WUAs, and create 9 land registries, a land information system, and a land allocation procedures manual to improve the administration of land rights and support land rights for vulnerable groups.

The LTSA consisted of two phases. During Phase I – the *Research Phase* – the activity conducted an exhaustive inventory of existing occupation patterns, land use, and property rights claims in the area of IWRM irrigation investments. The land rights inventory methodology was designed to document both the formal (administrative) and informal (customary), land property rights of all landholders. In all, during the first phase the activity documented the land rights claims and mapped over 60,000 hectares of farmland.

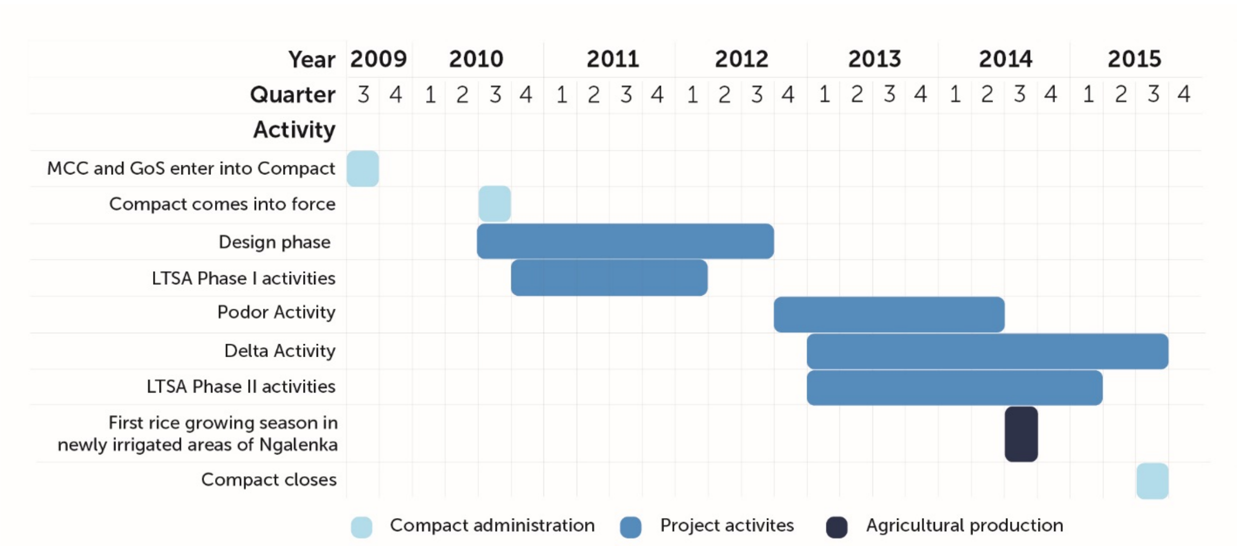
During Phase 1 LTSA also conducted research to reveal, for public discussion, the land access challenges for all users of natural resources, including those of ethnic groups, families, clans, landless farmers, herders, women, and youth. The results of the research provided a baseline for participatory development of inclusive, community-established land allocation procedures and principles for all nine communes under the LTSA.[2] In the case of Ndiayène Pendao (the commune that includes Ngalenka), fundamental to the allocation of parcels was the decision, adopted through a participatory process involving local stakeholders, to allocate 60 percent of the Ngalenka perimeter across the three ethnic groups exerting historical claims, 20

[2] The nine communes include Gamadji, Podor, Ndiayene Pendao (which includes the Ngalenka "cuvette"), Guede Village, and Dodel in the Podor Department; Ross Bethio, Ronkh, and Diama in the Dagana Department in the Delta; and Gandon in the Saint-Louis Department in the Delta.

percent of the land to local landless populations, and 10 percent to women's groups, while reserving 10 percent for the farmers that had occupied and farmed approximately 79 ha of the 450 ha perimeter prior to its development.

Phase II, which began in 2012, included five key tasks: (1) the clarification and formalization of land rights throughout the nine communes in the LTSA intervention area, and the allocation of land and delivery of land titles in Ngalenka following the allocation procedures and principles developed during Phase I; (2) completion and application of land management and planning tools (POAS) and the Charter for Irrigation Development for the Senegal River Valley; (3) training of local administrators to increase the capacity for local land governance, including land management, planning, and allocation; (4) establishment of geospatial databases for land rights and land use at the local government level; and (5) adoption of improved land registries, allocation procedures manuals and conflict resolution processes at the local government level. During the course of the Project, 8,655 farmers, farmer groups, or corporate entities" in the intervention area received land use rights titles covering 15,246 hectares of land—far exceeding the goal of 3,440 hectares. This includes both farmers in Ngalenka who received newly allocated land and titles through farmer groups (GIEs), and also others who sought to formalize their land titles (Elbow 2016). In addition, 5,018 stakeholders were trained in the use of land tenure security tools, including registries, procedures manuals, and databases. Additionally, in Ngalenka, the LTSA facilitated the official delivery of land titles to 53 GIEs and assisted the groups in obtaining loans required for the purchase of seeds, fertilizers, and pesticides. A timeline of the implementation of the activities is presented in Figure II.1.

Figure II.1. Timeline of IWRM Project activities



MCC identified at least 1,200 individuals who were economically and/or physically displaced as a result of the project. Over the course of over a dozen meetings with project-affected people (PAPs), and input from project participants, MCC learned that in addition to physical relocation due to infrastructure work, individuals also lost income due to improper training and farming techniques for irrigated rice cultivation in Ngalenka, and may have been affected by issues with the infrastructure such as slow release of water from dispersion basins, among other issues. In response, MCC provided compensation for PAPs in the IWRM Project area, including constructing major housing compounds to house the physically displaced, and cash payments totaling around $5 million. Furthermore, some of the funds allocated to the original Social Safeguard Activity of the Compact, which was not implemented, were redirected in the form of benefits to project areas.

Figure II.2. IWRM program logic

<table>
<tr><th></th><th>Problem</th><th>Activity/ subactivity</th><th>Outputs (years 1-5) 2010-2015</th><th>Short-term outcomes (year 5) 2015</th><th>Medium/long-term outcomes (years 6-10) 2016-2020</th><th>Impacts (years 10-20) 2020-2030</th></tr>
<tr><td rowspan="2">Delta Activity ($159.4m)</td><td rowspan="3">- 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, insufficient delivery of available water to agricultural areas, and lack of an appropriate drainage system (leading to soil salinity).</td><td>- Construction in the Delta</td><td>- Creation of temporary employment
- 17 water control structures created
- 149 km of canals rehabilitated</td><td rowspan="3">- Increase in potentially irrigable land to 39,300 ha
- Increase amount of land under production to 42,030 ha
- Increased water flow (65m3 per second)
- Establishment of satisfactory drainage system (number of ha drained)</td><td rowspan="4">- Increased cropping intensity (Delta, Ngalenka)
- Increased agricultural production
- 263,000 tons of paddy rice
- 132,000 tons of tomatoes
- 73,000 tons of onions
- Improved employment opportunities in the agricultural sector
- Improved access to land
- Improved land investment security
- Improved maintenance of infrastructure
- Contribution to investments in the agriculture sector</td><td rowspan="4">- 268,000 beneficiaries of the project
- 35% increase in household income
- Improved food security</td></tr>
<tr><td>- Environmental and Social Mitigation
- Social and Gender Integration</td><td>- Implementation of the RAP
- Implementation of social and gender aspects</td></tr>
<tr><td>Podor Activity ($6.8m)</td><td>- Construction of a new irrigated perimeter with 440ha of cultivable land</td><td>- 6 km of protection dikes constructed
- 23 km of primary and secondary canals constructed
- 14 km of access paths constructed
- 2 pumping stations created
- 450 ha of cultivated land</td></tr>
<tr><td>Land Tenure Security Activity ($3.9m)</td><td>- Low investment climate due to insecure property rights and increased potential for land conflict due to increased demand for irrigated land as a result of IWRM Project.
- Recurring land conflicts
- Low formalization of rights of occupation
- Lack of tools for land management
- Land stakeholders’ misunderstanding of tools and institutional framework for managing the land</td><td></td><td>- Land rights are known and clarified
- 55,303 ha mapped
- Land rights formalized (3,440 ha formalized)
- Support for land rights for vulnerable groups
- 9 Technical Support Committees established and functional
- 7 land registers and 2 land journals created, updating of the POAS, creation of a land information system, and creation of land allocation procedures manuals
- 600 individuals trained in land tenure security tools
- Creation of 33 Water User Associations</td><td>- Improved local land governance
- Continued use of improved land security tools
- Reduction of land conflicts
- Land authorities have access to ongoing technical support and tools
- Land conflicts are managed and resolved</td></tr>
</table>

Source: Millennium Challenge Corporation

C. Economic rate of return (ERR)

MCC's investment in the IWRM Project was expected to benefit farmers by improving their access to irrigation and securing their land rights in order to increase investment, reduce land conflicts, improve crop production, and increase farmer incomes. To assess the potential benefits of the project against its costs, MCC calculated the project's ERR. As part of our evaluation, we will update the ERR model based on findings from our evaluation. In a separate memo, we will describe our plans to update the ERR, and will integrate them into the design report upon review. Below, we describe the initially estimated ERR, as it relates to the project goals and anticipated outcomes.

The ERR informs investment decisions by helping to determine an investment's economic merits. Conceptually, it is the discount rate at which the benefits of an intervention are exactly equal to its costs. The higher the benefits of a project relative to its costs, the higher the ERR. MCC developed ex-ante estimates of the ERR of the IWRM project during the development of the Compact, using expected or anticipated costs and benefits. MCC's ERR analysis, found in the Investment Memorandum on Senegal's Proposed Compact (2009), and assessed the potential additions to income resulting from net expansions in irrigated land. MCC calculated the estimated income gains from increased agricultural production for the crops most likely to be cultivated in the IWRM area on the hectares of cultivated land. These include rice in the rainy months and vegetables in the dry seasons. To calculate the potential income increase for vegetable crops, industrial and table tomatoes and onions were used as proxies.[3]

Based on planned activities, MCC estimated that the average net revenue of farmed land would increase from about US$1,660 in purchasing power parity [PPP]) to US$2,240 PPP per hectare, resulting in an increase of about US$580 PPP per hectare. Regarding program costs, MCC took into account all costs of the project, including Compact administration costs, those associated with the LTSA, and costs related to environmental and social mitigation plans, which totaled US$8,485 per hectare, on average, for the Delta Activity. For the Podor Activity, financial and technical risks, in addition to added costs of the LTSA in Ngalenka resulted in an estimated cost of US$17,200 per hectare.

The period of analysis for the ERR was 20 years, and the ERR was estimated for the entire IWRM Project to be 17 percent on a weighted-average basis, exceeding MCC's ERR threshold for Senegal of 12 percent. MCC estimated the ERR to be 18 percent for the Delta Activity and between 7 and 8 percent for the Podor Activity. However, MCC noted that the estimated per-hectare cost for the Podor Activity were highly conservative and that the actual costs could have been lower than those estimated.

D. Beneficiary analysis

The beneficiary analysis for the IWRM Project estimated the distribution of income using both national and local investment area-specific information (see Appendix A for the IWRM Project Poverty Scorecard). Below we provide a brief summary of MCC's beneficiary analysis.

[3] To the best of our knowledge, this is the most recent ERR analysis that was conducted for the project.

Beneficiaries are defined as households, owners or shareholders of farming enterprises and households that have individuals employed in the operation of enterprise farms. The IWRM Project was estimated to benefit approximately 22,390 households, or 269,260 individuals, through their work in agriculture. Based on the average farming revenue explained above, and assuming that households would cultivate an average of two hectares of irrigated land, average post-investment revenues were estimated to be US$4,470 PPP, which is a US$1 PPP per person per day increase in income. It was estimated that approximately 20 percent of beneficiaries of the IWRM Project were extremely poor, 15 percent were poor, and 42 percent were near poor.[4] MCC also estimated that the project would provide employment for 8,880 households or 104,950 individuals. Assuming an average provision of 335 labor-days per household, these households would, on average, earn around US$1,740 PPP per year.

As part of our evaluation activities, we will work to identify the subcategories of beneficiaries who may have been differently affected by project activities, and will prioritize the most important subcategories in our analyses. Our plans are described in greater detail in Section IV.C.

[4] Poverty designations are as follows: "extremely poor" households are those that consume less than US$1.25 PPP per person per day, "poor" households are those that consume around US$2 PPP per person per day, and "near poor" households are those that consume between US$2 and US$4 PPP per person per day.

III. LITERATURE REVIEW

In Senegal, more than 75 percent of the labor force works in the agricultural sector (Sylla 2015). Some research shows agriculture to be the most effective sector for reducing poverty for the poorest; it is believed that the poor stand to gain more from GDP growth from agriculture than from other sectors (Christiaensen et al 2011; De Janvry and Sadoulet 2010). However, the full potential of agriculture to improve economic growth and reduce poverty has not been realized. Agricultural yields in Africa specifically have been low and growing at a slow rate over the past 40 years (Udry 2010). Two of the main inhibitors of agricultural growth and productivity are inadequate irrigation on otherwise arable land and a lack of property rights (Hussain and Hanjra 2014; Goldstein and Udry 2008).

The evaluation of the IWRM Project will contribute to the evidence on the effectiveness of the two types of agricultural interventions implemented under the project: (1) irrigation infrastructure and (2) land tenure security and administration. To provide context for the evaluation, we review the existing evidence relevant to these interventions. We then describe how the IWRM Project evaluation will contribute to this literature.

A. Irrigation infrastructure

Despite the fact that much of Sub-Saharan Africa relies on agriculture as an important driver of economic growth and poverty reduction, much of the subcontinent lacks the necessary inputs to improve agricultural productivity. Irrigation, specifically, has been found to increase agricultural production and incomes (Hussain and Hanjra 2004). In Senegal, sufficient irrigation from the Senegal River, improved water delivery and drainage, and appropriate inputs, harvesting, and transportation have the potential to increase domestic rice production in the Senegal River Valley and, in turn, to broaden food security in Senegal (Matsumoto-Izadifar 2009). Moreover, areas with irrigation infrastructure are associated with higher cropping intensity, land productivity, employment of farm labor, and agricultural wages, and households in irrigated areas also experience higher incomes, lower income inequality, and lower poverty than those in rain-fed settings (Hussain and Hanjra 2004).

Yet despite the large potential benefits of irrigation, the large majority of farmers still depend on rain-fed agriculture, even though it has become increasingly unreliable as Senegal has seen a significant decline in overall rainfall coinciding with an increase in average national temperatures (USGS 2012). As of 2002, only 4 percent of arable land in Sub-Saharan Africa was irrigated (Udry 2010). Rain-fed sustenance production dominates agriculture throughout Senegal, including in the SRV; only half of Senegal's 240,000 hectares of land suitable for irrigation is irrigated (Food and Agriculture Organization Statistical Database 2015; Ndiaye 2007).

Janaiah et al. (2004) found that three irrigation-related interventions (rehabilitated infrastructure, improved management, or both) reduced the input costs of agricultural production, increased agricultural yield 13 to 22 percent for paddy crops, and had positive impacts for nonrice crops. In Sub-Saharan Africa, Kuwornu and Owusu (2012) show that access to irrigation increased cropping intensity (the number of times a crop is planted) in Ghana by 73.6 percent for rice, 32.1 percent for pepper and 33.3 percent for okra, and improved yields of rice and pepper.

Duflo and Pande (2007), however, found mixed results in India based on location relative to the infrastructure. They found that the construction of a large dam for irrigation increased production of water intensive crops downstream by 0.6 percent in downstream districts, but did not find any significant effects on agricultural production in upstream districts. Similarly, a study on the distributional effects of large dams on upstream versus downstream communities in Nigeria and South Africa shows that large-scale dam projects had a positive impact on the agricultural productivity of downstream regions, increasing total agricultural production by 1 percent, but no significant impact in upstream regions (Strobl and Strobl 2011). That increase in production of 1 percent was significant: it provided up to 12 percent of minimum per-capita daily calorie needs of the study population (Strobl and Strobl 2011).

Irrigation infrastructure improvements have also been found to have positive impacts on incomes and reduced poverty. In the Duflo and Pande (2007) study mentioned above, the authors found that the construction of a dam was associated with a .15 percent decrease in poverty headcount ratio in downstream districts in India. Janaiah et al. (2004) found even greater impacts on poverty. They show that rehabilitated irrigation infrastructure and improved management of irrigation decreased poverty rates by 12 percent in Vietnam.

Evaluations in Africa also show poverty reduction gains from irrigation. Van Den Berg and Ruben (2006) evaluated the effect of Ethiopia's national irrigation improvements on income inequality by examining ex-post outcomes and found that households with irrigation had higher expenditures and lower dependence on public programs than households without irrigation, after accounting for preexisting differences. Tucker and Yirgu (2010) also evaluated the impact of irrigation in Ethiopia and found that households experienced a 20 percent increase in annual income. They used quasi-experimental approaches to examine how the redistribution of water to canals (through motorized pumps) affects poverty, agricultural production, and nutrition; over the eight-year evaluation period, they found that households with this type of irrigation access showed higher household consumption, agricultural production, and caloric and protein intake than households without access. They also tended to save more and share more of their resources with fellow village members.

There is also growing evidence on the difference in impacts on farmers' production and consumption between large- versus small-scale irrigation schemes, as determined by the area of land they cover. While schemes of any size provide access to irrigation, large-scale irrigation schemes can lead to greater improvements in farming outcomes by increasing market integration and increasing the dispersion of agricultural knowledge or technology as larger number of farmers are brought together (Lipton et al 2003). Smaller-scale irrigation schemes, however, may require lower participation costs for farmers and provide farmers more influence over the management of the scheme (Dillon 2010).Dillon (2010) assessed the differences in household production and consumption among those with access to small-scale (covering 50 hectares or less) and large-scale (covering more than 300 hectares, in this study specifically) irrigation infrastructure to examine whether the scale of an irrigation project increases household welfare in Mali. Using propensity score matching, he found that small-scale irrigation has a larger effect on agricultural production and agricultural income than large-scale irrigation, but large-scale irrigation has a larger effect on consumption per capita. In Senegal, Sakurai (2015) compared the impacts of large-scale (which cover, on average, 761 hectares) versus small-scale (which cover, on average, 27 hectares) irrigation schemes in the Senegal River Valley and found that farmers in large-scale irrigation schemes achieved significantly higher yields and profits than those in small-scale irrigation schemes.

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

B. Land tenure security and administration

Agricultural investment and productivity has been shown to be influenced by property rights. Existing evidence suggests that there are three mechanisms through which a lack of land tenure can negatively affect investment and productivity and, in turn, influence economic outcomes (Ahmed and Ahmed 2015): (1) without confidence in his or her land tenure security, a farmer may be less inclined to make investments in the land since the insecurity of his or her right to the land may result in the loss of it, (2) a farmer that does invest in his or her land may not be able to realize the full gains from the investment as he or she cannot sell or rent it out, and (3) a farmer may be unable to use his or her land as collateral to access credit without formal rights to it, though the link between rural land formalization and increased credit had not been fully established (Udry 2010).

Until recent decades, land formalization efforts showed little impact on economic growth due to their failure to recognize customary land rights, a lack of transparency in land allocation procedures, and insufficient participation from affected groups (Deininger et al. 2011). However, given the great potential of formal land rights to increase investment in the land, increase productivity, improve incomes, and reduce poverty, over the past two decades governments and donors have renewed efforts to formalize land rights (Diouf and Elbow 2016). For example, in addition to this Compact, MCC's five-year Compact in Burkina Faso that ended in 2014 worked to apply the country's 2009 Rural Land Tenure Law (Diouf and Elbow 2016), and MCC's Compact in Benin reinforced the Benin Rural Landholding Law of 2007 (MCC 2016). In Niger, a number of donor investments have helped to develop the institutional framework of the 1993 Orientation Framework for a new Rural Code, resulting in the establishment of large numbers of decentralized Land Commissions (Diouf and Elbow 2016).

Several studies provide evidence of the positive impact of land formalization on investment. Chankrajang (2015) found that the provision of even partial land rights increased investments, land use intensity, and soil quality in Thailand. In Africa, Goldstein and Udry (2008) and Klaus et al (2008) found a very large impact of property rights on investments in Ghana and Uganda, respectively. Similarly, Goldstein et al. (2015) found early evidence that an MCC-funded land formalization project in Benin, whereby communities demarcated land parcels that were eventually to be legally documented, led to increased investment in land parcels that could provide longer term gains. These investments, however, had not yet led to short-term gains in agricultural productivity, though on average, the demarcation activities had been complete for only 11 months. Particularly relevant to the LTSA in Senegal, Deininger (2008) found that the impact of property rights on investment is larger when land holders understand their legal rights. In Rwanda, Ali et al (2014) found that the nationwide land tenure regularization program to adjudicate and register land had a very large impact on investments and maintenance of soil conservation measures, among other benefits, especially for female-headed households. Deininger et al (2011) found that land certification in intervention areas in Ethiopia increased the propensity to invest in new or repaired land structures by 30 percentage points and farmers spent twice as many hours working on those investments than was found in control areas in Ethiopia.

The literature also points to positive impacts of property rights on productivity. Banerjee et al (2002) found that a limited but large tenancy reform policy that gave sharecroppers permanent and inheritable tenure on the land they sharecropped had a positive effect on agricultural productivity in West Bengal, India, even though sharecroppers were required to pay 25 percent of outputs to landlords. In Africa, Goldstein and Udry (2008) found that insecure land tenure in Ghana was associated with greatly reduced farm productivity due to the lack of investment in land and poor land fertility. They found that holding property rights had a very large impact on productivity, but also found that women earn much lower farming profits than their husbands. To the contrary, Bellemare (2013) found that formalization of land rights in Madagascar had no impact on productivity, but informal land rights had heterogeneous impacts, and found a negative association between the right to lease out land and agricultural productivity. He attributes this to the manner in which property rights were formalized during and after colonization.

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

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

With regard to land tenure security and administration, although many studies have assessed the impact of improved land tenure in developing countries, there is currently scant evaluation evidence on the impact of land tenure on agricultural outcomes and poverty in West Africa. The evaluation of MCC's IWRM Project will add to the limited evidence on the effects of the formalization of land rights, perceptions of land tenure security and the strengthening of land management institutions. A number of evaluations are underway, including impact evaluations of MCC investments in Burkina Faso and Ghana, though none have been finalized to date. These evaluations, in addition to the evaluation of the LTSA, will provide robust evidence on the impacts of different land tenure security efforts in West Africa on agricultural investment, production, and incomes.

Furthermore, MCC's LTSA in Senegal provides a unique opportunity to understand the potential of comprehensive and inclusive land tenure efforts. The LTSA addresses many of the sustainability issues that have impeded the longevity of the impact of earlier land tenure initiatives, including sufficient training, ongoing technical support, and local buy-in (Diouf et al. 2015). It also aims to effectively formalize informal land rights through a transparent and participatory process that combines the land tenure and land allocation principles set out by the UN[5], national Senegalese policy, and customary land claims specific to the region.

[5] The "Voluntary Guidelines for the Responsible Governance of Tenure of Land, Fisheries, and Forests in the Context of National Food Security," which is an internationally negotiated document developed by the UN Food and Agriculture Organization's Committee on World Food Security and adopted in 2012.

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IV. EVALUATION DESIGN

The evaluation of the IWRM Project activities will address a wide range of questions related to improvements in water use and availability, agricultural production, and income, as well as land security and governance. In this chapter, we describe our proposed design to evaluate IWRM Project activities in the Delta and Podor regions. We begin by presenting our proposed research questions. We then describe our analysis of existing evidence regarding the project and previous evaluation efforts. Next, we describe our mixed-methods evaluation design and analysis approach. We continue by explaining our data collection plan for both quantitative and qualitative data sources, and conclude with a section identifying risks and challenges to the evaluation and our plans to address them.

A. Overview of evaluation strategy

Our goal is to propose the most rigorous and feasible evaluation design that answers the research questions of interest to MCC. Table IV.1 provides a list of research questions and our analytical approach by study topic area.

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

	Analytical Method	
Research Question	Impact[a]	Descriptive[b]
Agriculture Production		
Have there been changes in the amount of land used for agricultural production? Is land being used for production in different seasons than before?	X	
Has crop production improved? Have production methods, including the choice of inputs, changed? Have there been changes to the types of crops produced?	X	
What factors are contributing to or constraining changes in agriculture inputs and production? Why are households changing or not changing agriculture production decisions, and how do those reasons vary depending on crop type, growing season, or income level?		X
How have changes differed by gender and among different income levels?	X	
Use and availability of water		
Have there been changes in the sources of water used for agricultural production?	X	
How has water availability changed, and have barriers or costs to accessing irrigation been reduced? Has the water supply become more reliable?		X
Has the amount of irrigated land increased?	X	
Has the role of WUAs changed and how do they impact the use and availability of water?		X
Income		
Have household income levels changed, including changes in components of household income, and has income shifted between agricultural and nonagricultural sources?	X	X
Do farmers perceive an improvement in their living standards?		X
Have agricultural profits changed?	X	

TABLE IV.1. *(CONT)*

Research Question	Analytical Method	
	Impact[a]	Descriptive[b]
Land security and conflicts		
Have perceptions of land tenure security changed? Is there increased confidence in the land tenure system? If so, why?	X	X
Has the extent of land formalization changed? Is there greater awareness of the process for formalizing land?	X	X
Has demand changed for formalized land rights and are the costs of formalizing land rights perceived as reasonable?		X
Has the number or severity of land conflicts reduced? Has the type or nature of land conflicts changed?	X	X
How has the IWRM Project affected women's access to land and irrigation? How has it affected the landless?		X
How have changes in land security perceptions, formalization, conflict, or conflict management affected investments on land?		X
What have been the constraints or barriers to land access? Do these differ depending on gender, income levels, or age?		X
Land administration and governance		
Have local government agencies become more effective at land management, including land allocation, land formalization, and conflict resolution? Is there greater confidence in the efficacy of these institutions?		X
Do institutions receive adequate support to carry out their functions?		X
Sustainability and external impacts		
What are the prospects for the sustainability of project activities post-Compact?		X
What impacts did the project have outside of project areas?		X
Who benefitted from each IWRM activity? Where and when did each activity occur?		X

[a] Impact analysis using a difference-in-differences methodology

[b] Descriptive outcomes and implementation analysis using qualitative and quantitative methods

We will address these research questions by using two key analytical methods, as noted in Table IV.1. For some research questions, we will employ an impact analysis that uses a difference-in-differences (DID) approach to estimate the causal effects of some IWRM Project activities. Through this approach, we will compare beneficiaries (the treatment group) to nonbeneficiaries (the comparison group) before and after the intervention, using existing baseline data and data we plan to collect through two follow-up survey rounds. Due to differences between the two regions and in activities implemented, we will analyze impacts of the project separately for the Delta and Podor intervention areas, using the household as our unit of analysis.

We also will conduct a descriptive outcomes and implementation analysis that uses a combination of qualitative and quantitative methods to address additional questions of interest to complement the impact analysis. These include questions about activities that occurred before the baseline survey and those that occurred at the commune level and may have had commune-wide or institutional effects. We will also use mixed methods to examine the mechanisms that brought about project impacts and to better interpret the estimates produced through the DID analysis. For example, if we find that commune-level activities affected outcomes for both the treatment group and a portion of the comparison group, our DID impact estimates will not be able to capture the effects of these activities; instead, we will examine those commune-level activities and their effects qualitatively. Our mixed-methods analysis will draw on an array of data sources, including the household and community surveys, project documentation, secondary literature, and administrative data provided by MCC and local government agencies. In addition, we will conduct key informant interviews and focus groups with project stakeholders and beneficiary groups.

B. Analysis of previous evaluation design

To determine which analytical methods would be appropriate for evaluating the IWRM Project, we started by analyzing the design proposed by the previous evaluator, IMPAQ International, and the data collected as part of that evaluation, to assess the implications of the previous design and baseline data for our proposed evaluation. This section summarizes the previous evaluation activities conducted and our analysis of the existing evaluation evidence, describes our key findings including challenges in evaluating the IWRM activities, and discusses how our evaluation design will address those challenges.

1. Summary of previous evaluation activities

IMPAQ planned to implement a DID design to analyze the combined effects of IWRM activities. They planned to analyze impacts separately in the Delta and Podor regions, because the two regions are distinct from one another geographically, economically, and culturally. Table IV.2 provides summary statistics of households at baseline in the Delta and Podor treatment areas. Poverty levels were higher and education levels were lower, on average, in Podor compared to Delta, and households in Delta had more land and were more likely to harvest crops than households in Podor.

Table IV.2. Baseline characteristics of IWRM Project beneficiary households

	Delta			Podor [a]		
Measure	Mean or percentage	SD	Sample	Mean or percentag e	SD	Sample
Number of household members	9.9	5.7	1422	9.2	5.4	1223
Age of household head (years)	49.2	13.6	1422	49.5	13.4	1223
Household head is male	82%	0.39	1422	82%	0.39	1223
Household head received some formal education	32%	0.47	1419	12%	0.32	1215
Likelihood household lives in poverty (less than $1.25/day) [b]	22%	0.12	1401	28%	0.09	1206
Household has any land	84%	0.37	1413	73%	0.44	1216
Total area of land held (hectares)	3.2	8.1	1412	0.7	2.3	1211
Total area of land used for farming crops (hectares)	1.6	3.9	1411	0.3	0.5	1215
Household has land on an irrigation perimeter	75%	0.44	1413	70%	0.46	1216

TABLE IV.2. *(CONT)*

Measure	Delta			Podor [a]		
	Mean or percentage	SD	Sample	Mean or percentage	SD	Sample
Household has at least one land title [c]	29%	0.46	1187	64%	0.48	887
Household has titles to all plots [c]	18%	0.39	1187	58%	0.49	887
Household expressed concern about losing land [c]	38%	0.49	1187	29%	0.45	887
Household knows the deliberation process to receive a land title [c]	50%	0.50	1187	40%	0.49	887
At least one plot has access to a water source other than rainwater [d]	97%	0.18	863	99%	0.11	668
Household farmed crops	61%	0.49	1413	55%	0.50	1216
Household harvested crops	55%	0.50	1411	25%	0.43	1175
Household planted rice	49%	0.50	1422	48%	0.50	1224
Household planted onions	8%	0.27	1422	3%	0.16	1224
Household planted tomatoes	2%	0.15	1422	0%	0.06	1224

Source: IWRM Project baseline survey data

Note: All values in this table are based on non-imputed data and the sample of households that were surveyed in all three baseline waves. Values are proportions unless otherwise indicated. Agriculture data are reported from the hot season. Agriculture data on the cold and rainy seasons are reported in baseline equivalence tables in Appendix B. SD = Standard Deviation.

[a] The sample in Podor represents potential beneficiary households. Not all households were actual beneficiaries of IWRM Project activities.

[b] Poverty likelihood was calculated by using the Progress out of Poverty Index for Senegal (Schreiner 2016)

[c] Sample includes households with valid data that reported owning farm land

[d] Sample includes households that reported farming.

In addition, as described in the previous chapter, IWRM activities implemented were different in each region. The Delta Activity rehabilitated existing irrigation and drainage infrastructure. The Podor Activity constructed new irrigation and drainage infrastructure. Further, as part of LTSA, only Podor reallocated newly irrigated land to farmers.

In the Delta region, IMPAQ defined the treatment group as households in villages with access to the irrigation works that would be rehabilitated as part of the IWRM Project. In Podor, IMPAQ defined the treatment group as households that would be allocated land in the new irrigation perimeter to be constructed as part of the project. In each region, IMPAQ planned to compare the treatment group to a comparison group composed of similar households in comparison areas which were not supposed to receive IWRM activities (IMPAQ International December 2014b). MCA-Senegal selected the comparison areas to be far enough from the treatment area to limit spillover of treatment effects, but similar on key conditions, such as geographic terrain and farming and irrigation practices.[6] A map delineating the treatment and comparison areas for Delta is available in Appendix C.

To select the study sample, MCA-Senegal contracted with Agence Nationale de la Statistique et de la Démographie (ANSD), the national statistics agency in Senegal, to conduct baseline data collection. ANSD first conducted a census of all households in the treatment and comparison areas in both the Delta and Podor regions. The questionnaire used in the census included questions on household characteristics and an inventory of household members, including their age, gender, ethnicity, literacy levels, and employment status.

In the Delta region, IMPAQ used the census data to create treatment and comparison samples by matching households in the treatment area to households in the comparison area.[7] They selected a sample of 1,637 households for each group based on estimated requirements for statistical power, and asked ANSD to survey all households in these samples. In the Podor region, IMPAQ was not able to identify its treatment sample since they did not know at the time of baseline data collection which households in the treatment area would be allocated land in the new irrigation perimeter. Consequently, they asked ANSD to survey (1) all 1,617 households enumerated from the census in the treatment area, with the intent that a substantial portion of the surveyed households would eventually be treated, and (2) a random subsample of 585 households in the comparison area to meet sample size requirements from their power calculations. In both regions, ANSD attempted to survey each household in the sample frame three times at baseline, for all three agriculture seasons (cold season, hot season, and rainy season) from May 2012 through April 2013. We refer to each seasonal survey at baseline as a wave.

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

After the survey was completed, IMPAQ conducted a baseline equivalence analysis. Their results showed statistically significant differences between the treatment and comparison groups in the Delta and Podor regions on key outcomes of interest, including farming practices. Unless these differences are addressed through the evaluation design, they could introduce bias into estimates of the project's impact.

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[6] IMPAQ described this selection process as it was related by MCA-S, but was unable to determine the specific criteria that were used for selection or any details of how the process was implemented (IMPAQ International December 2014b, p. 10).

[7] IMPAQ used the following variables to construct the matched sample: age, gender, household size, number of male and female workers overall and in agriculture, ethnicity, literacy, socio-administrative status, title status of land of household head, participation in an *Organisation Paysanne*, and roof, floor, and wall material of the household (IMPAQ International December 2014b).

2. Analysis of existing evidence

To build upon the efforts undertaken by IMPAQ and its partners, and to identify the most feasible rigorous evaluation designs to answer the key research questions, we conducted a range of activities including document reviews and interviews, as well as analysis of existing data. In particular, we conducted a review of documentation describing the implementation and evaluation efforts for the project, an assessment trip to Senegal that included site visits to the Delta and Podor regions and interviews with project stakeholders, and interviews with MCC staff who worked on the Senegal Compact.

We also examined IMPAQ's baseline data and three additional sources of data: (1) the land inventory database, which listed beneficiaries from LTSA Phase I and included a parcel-level enumeration to identify farming plots, who was using the plots, what the plots were used for, and whether a government body had authorized users' claims to plots; (2) the land allocation database, which identifies beneficiaries from LTSA Phase II, listing Podor residents who received access to newly irrigated land on the Ngalenka perimeter; and (3) existing project documentation, including project completion reports from implementing contractors, IMPAQ's baseline and design reports, and MCC Compact documents.

Our analysis of IMPAQ's baseline household data allowed us to (1) understand descriptively the population targeted by the project, (2) refine our understanding of which households received which project activities and which households could potentially serve as a comparison group, and (3) reassess the equivalence of the treatment and comparison groups at baseline. We cleaned the raw baseline data files, merged the files across each survey wave, and constructed key household-level variables.

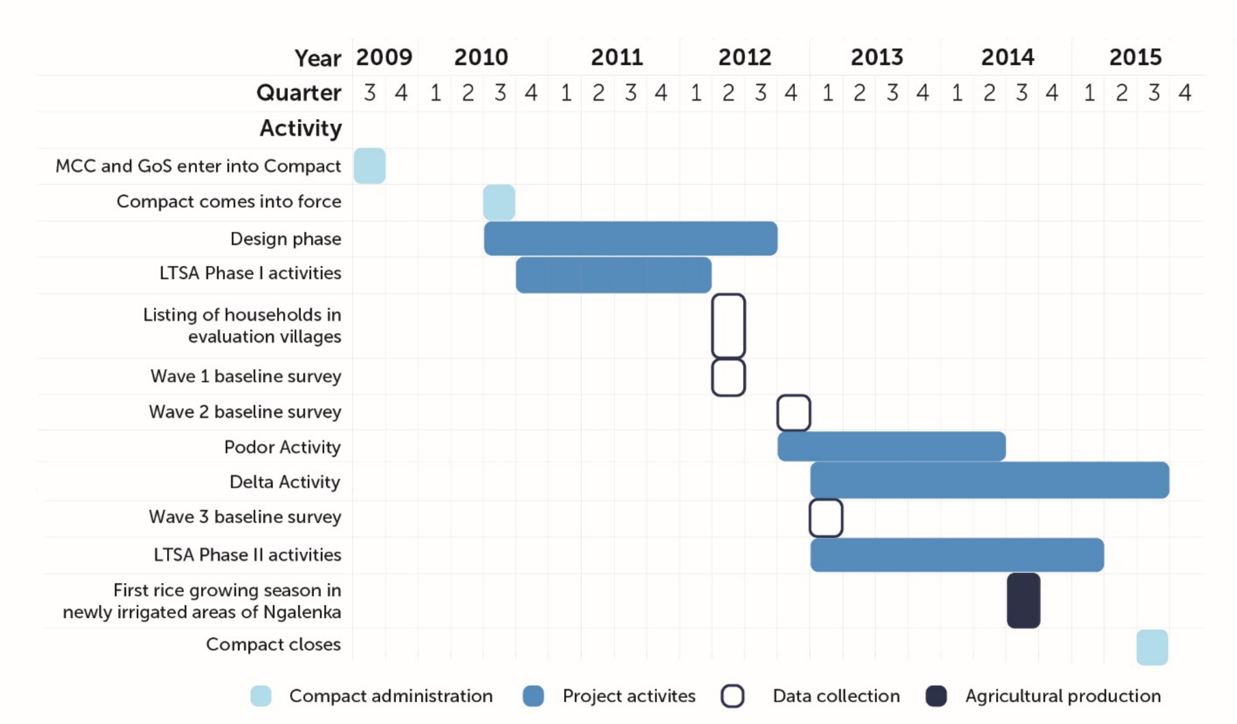
After reconstructing the baseline data file, we constructed additional variables that provide further information about equivalence between the groups, such as an indicator of the likelihood that the household lives in poverty and indicators for whether a household had farmland, farmed, harvested, or received agriculture revenue each season. We then conducted our own baseline equivalence analysis using household-level indicators so our baseline measures match our unit of analysis. We report our findings from these activities in the next section.

3. Findings from document and data review and their implications for the evaluation design

Our review of project documentation and data sources yielded important findings about the timing and location of key IWRM activities as well as the baseline data collected that have important implications for our evaluation design. We summarize these findings below.

LTSA Phase I occurred prior to the baseline survey. Field activities conducted as part of LTSA Phase I occurred between November 2010 and March 2012, prior to the baseline survey, which was conducted between May 2012 and March 2013. Figure IV.1 provides a timeline of all project and data collection activities, illustrating when specific project activities occurred in relation to baseline data collection. LTSA Phase I included an exhaustive inventory and mapping of existing land occupation patterns, land use, and property rights in the area of IWRM irrigation investments (chronicled in the land inventory database), and the development of inclusive, community-established land allocation principles and procedures. These activities sought to document beneficiaries' existing occupation patterns, land use, and property rights claims, engage communities in developing the land allocation principles that would be followed during Phase II, and strengthen their understanding of the land conflict mediation processes at the time of the baseline survey. They may also have affected beneficiaries' perception of land tenure security, increased the likelihood they would attain formal land titles, and increased future investments in the land that could improve agricultural outcomes (Goldstein and Udry 2008).

Figure IV.1. Project activities and baseline data collection timeline



LTSA Phase I and Phase II occurred in some comparison areas in the Delta and Podor regions and we cannot identify all households that were affected by these activities. From our document review and meetings with project stakeholders, we learned that LTSA Phase I activities occurred throughout the nine communes in which they were planned (see Chapter II). Table IV.3 lists the treatment and comparison areas from IMPAQ's evaluation design for the Delta and Podor regions by *Communauté Rurale* (CR).[8]

Table IV.3. Treatment and comparison areas in the previous design

Communauté Rurale	Treatment area	Comparison area
Delta region		
Diama	X	
Gandon	X	
Ronkh	X	

[8] Each *Communauté Rurale* encompasses one or more villages.

Communauté Rurale	Treatment area	Comparison area
Ross Bethio	X	
Bokhol		X
GAE		X
Rosso Senegal [a]		X
Podor region		
Ndiayene Pendao (in Ngalenka)	X	
Ndiayene Pendao (outside of Ngalenka) [b]		X
Niandane		X

[a] Around half of households in Rosso Senegal received some land tenure security activities.

[b] All households in Ndiayene Pendao received some land tenure security activities.

The baseline report produced by IMPAQ indicates that the land inventory activity conducted as part of LTSA Phase I also occurred in some areas in both regions where the comparison group is located. About half of the households in Rosso Senegal CR and all households in the portion of Ndiayene Pendao CR that is outside Ngalenka—both of which are comparison areas—were part of the land inventory activity (IMPAQ International December 2014b). Our review of the land inventory database confirmed that plots from comparison villages in Rosso Senegal and Ndiayene Pendao were inventoried in the database. In addition, several LTSA Phase II activities occurred in Ndiayene Pendao at the local government level and could have affected comparison areas in the CR as well as the treatment area in Ngalenka. These included support for the government to implement a campaign to encourage individuals to formalize their property rights; the training of local land administrators to carry out land management, planning, and allocation; the establishment of geospatial databases for land rights and land use; and the adoption of improved land registries, allocation procedures manuals, and conflict resolution processes.

To determine which households were affected by the land inventory in Rosso Senegal, we attempted to merge the land inventory database with the baseline survey by matching names. However, inconsistencies and a lack of detail in the land inventory database prevented us from successfully merging the data sources and identifying the affected households in Rosso Senegal.[9]

The findings that LTSA Phase I activities occurred prior to baseline and that some LTSA Phase I and Phase II activities occurred in comparison areas have two implications for our design. First, our DID estimates cannot capture the full effects of LTSA Phase I activities, since our baseline survey does not provide pre-intervention measures of these activities. To address this, we plan to evaluate the effect of LTSA Phase I using the mixed-methods approach described in Section C.2 of this chapter, and to minimize the influence that LTSA Phase I has on

[9] Many entries in the land inventory database did not identify individual respondents or households; instead, they listed the cooperatives that managed plots. This prevented us from identifying individual households that were affected. When we attempted a village-level merge of the data sources, we found that the database did not consistently refer to the same village administrative unit as the baseline data. While the database does include plot-level geospatial coordinates, we do not have coordinates for each plot's corresponding household. Since a household and its plots are often in different locations, we will not be able to link the plots in the land inventory database to the households in our survey sample, even after collecting household coordinates during the next survey round.

our impact measurements so that our estimates can be interpreted as the impacts of the other project activities. To do this, we will include outcomes related to land tenure security in our matching model, such as whether a household is concerned about losing land, has formal land titles to its plots, and knows the deliberation process to receive a land title, so that the comparison group chosen by the model is similar to the treatment group in terms of these outcomes at baseline. Second, because some LTSA Phase II activities occurred in a portion of the comparison households in the Podor region, any impacts resulting from these activities could be reflected only partially in our DID estimates. To ensure that we interpret our estimates accurately and study the effects of these activities carefully, we will conduct a sensitivity analysis of our results in the Podor region as described in Section C.1 of this chapter to determine whether the contamination of these activities in our comparison group affected our results.

We cannot identify the households that benefited from irrigation infrastructure improvements and land allocation activities in the Podor region using existing data sources. The baseline survey sought to interview a substantial number of households in Ngalenka—the presumed location of all beneficiaries of irrigation infrastructure and land allocation activities in Podor—because at the time of the survey, it was not known which households would actually benefit from land improvements resulting from the new irrigation infrastructure. To help identify beneficiary households (that is, those who benefited) from all households surveyed in the Podor treatment communities, we attempted to merge a subsequently compiled database of land allocation beneficiaries with the baseline survey data, to see if we could identify the beneficiary households. However, we encountered several challenges. First, we are unable to credibly merge these data sources because there is insufficient identifying information in common between them.[10] Next, our document review and analysis of the land allocation database suggest that some beneficiaries in Podor may be located outside of the surveyed villages in the treatment area of Ngalenka, due to the sampling strategy for the survey and to changes in the planned number of beneficiaries that were made after the baseline survey was conducted.[11] To identify beneficiaries of irrigation and land allocation activities in Ngalenka, we plan to include a module in the

[10] The land allocation database contains names of beneficiaries and their associated GIE or GPF. Most GIE members also have birthdates and national identity card numbers. The baseline survey data contain respondent names, ages, genders, and village identifiers. To merge household-level data in the land allocation database into the baseline survey data, we attempted to identify villages in the land allocation data based on GIE and GPF groups, and to then identify matching households based on the names of individuals, their villages, and their ages. However, these data were insufficient to produce unique matches, due to the number of repeated names within each village, the fact that village names did not always match between data sets, and the lack of consistently available additional data in common between the data sources.

[11] When sampling households for the baseline survey, ANSD conducted an extensive enumeration in Ngalenka, but did not ultimately survey every treatment area household in Ngalenka. At baseline, the project anticipated providing newly irrigated land to 440 households in Ngalenka (IMPAQ International December 2014b). However, the process for allocating land to households changed after the baseline survey was conducted, and included a larger number of beneficiary households (Elbow 2016). These findings are consistent with our analysis of the land allocation database and the implementer completion report: the land allocation database lists 1,673 land recipients. Although some of these beneficiaries likely belong to the same household, they likely represent more than 440 households in total. In addition, the land allocation database and the implementer completion report both reference villages that were beneficiaries of LTSA Phase II but that do not match villages in our surveyed treatment sample. These villages could be (1) in Ngalenka but not surveyed at baseline, (2) outside of Ngalenka and not initially expected to receive project activities, or (3) in our surveyed treatment sample but referred to in each data set by different names.

follow-up survey for treatment area households that will help us determine whether the household received access to newly irrigated land as part of LTSA Phase II. We describe our plans for the module in further detail in Section D of this chapter.

The baseline data show statistically significant differences on key socioeconomic variables and outcome measures between treatment and comparison areas in both Delta and Podor. In both regions, we find statistically significant differences on important socioeconomic indicators between the treatment and comparison groups. Comparison households have a higher average level of education and are less likely to live in poverty than treatment households (see Appendix B). We also find significant differences in land use and agriculture production, including in amount of land held, land farmed, and land located on an irrigation perimeter, as well as the percentage of households that harvest crops, receive revenue from crop sales, and invest in their farm plots. We find statistically significant differences on many more variables than we would expect to see by chance alone. In the Delta region, these differences could be due to the limited number of variables used in the matching model, and survey attrition. In Podor, as described previously, the treatment and comparison samples were not matched at all. Because we found statistically significant differences at baseline between potential treatment and comparison households, we plan to use statistical techniques to re-match our sample in the Delta region to improve baseline equivalence, and to construct a matched sample in the Podor region once we identify project beneficiaries. Complete baseline equivalence results are included as Appendix A.

Differential attrition may have contributed to differences between groups. [12] There was notable differential attrition in both regions: 10 percentage points in Delta and 27 percentage points in Podor. Even if the matched samples in Delta were initially similar, differential attrition could result in the surveyed samples showing significant differences.

We uncovered potential data quality issues. When examining measures of agricultural revenue and production costs, crop production, and land areas held and used for growing crops, we found standard deviations that were orders of magnitude larger than we expected based on evidence in existing literature. For example, we calculate that the ratio of the standard deviation to the mean for rice yields in the Senegal River Valley was 0.22, based on data reported in Poussin et al. (2005). By contrast, the same ratio in the baseline data is about 24 in Delta and about 2 in Podor, which indicate standard deviations between 9 and 109 times as large as those in Poussin et al. (2005), relative to the mean. We explored several methods to identify if outliers were driving the results and if we could appropriately remove those outliers, including setting maximum thresholds of three times the standard deviation or the interquartile range. These methods confirmed that a small group of outliers were not driving the results but rather that there were likely to be more pervasive data quality issues with these variables. The large variance in these measures could be due to a variety of factors, including measurement error and miscommunication with the respondents about the units of measurement. Due to potential data quality issues with key outcome measures of interest, we will explore implementing several

[12] Differential attrition is the difference in attrition rates between the treatment and comparison groups. If one group has a much lower response rate than the other group, there will be large differential attrition. If groups are similar prior to a survey, then a differential response rate can lead to the surveyed groups no longer being similar on observable characteristics.

corrective measures, including an analysis of whether the units of measurement reported are inaccurate, and using regression-imputed values for outliers. We will also consider asking respondents for retrospective data on these measures during the follow-up survey, requesting land titles to verify land measurement and title status data, and evaluating these outcomes qualitatively.

C. Approach to the evaluation

This section details our evaluation approach that takes into account the implications from our analysis of the previous evaluation design. We propose two types of analysis: an impact analysis and a descriptive outcomes and implementation analysis. We first provide an overview of our impact analysis design, including which research questions this design can answer. We discuss the details of the design, the sample frame, the outcomes for which we anticipate being able to detect impacts, and our analytical model. We then describe our descriptive outcomes and implementation analysis, which will use a variety of quantitative and qualitative data sources and analytical methods to evaluate research questions we cannot fully answer with an impact analysis.

1. Difference-in-differences quantitative impact analysis

We will employ a difference-in-differences design with a matched comparison group, providing causal estimates of project impact and answering the impact research questions listed in Table IV.1. These research questions include:

- Have there been changes in the amount of land used for agricultural production? Is land being used for production in different seasons than before?
- Has crop production improved? Have production methods, including the choice of inputs, changed? Have there been changes to the types of crops produced?
- Have there been changes in the sources of water used for agricultural production?
- Has the amount of irrigated land increased?
- Have household income levels changed, including changes in components of household income, and has income shifted between agricultural and nonagricultural sources?
- Have perceptions of land tenure security changed? Is there increased confidence in the land tenure system?
- Has the extent of land formalization changed? Is there greater awareness of the process for formalizing land?

We identified these questions as those that can potentially be addressed through an impact evaluation, based on our assessment of program documentation and baseline data and our assessment of how we can modify the originally proposed evaluation design to provide rigorous estimates of program impact. For some outcomes, such as agricultural profits and household income, we may have insufficient sample sizes to detect impacts. We will use qualitative methods to better understand the effects of the project on these outcomes, as well as to understand mechanisms, barriers, and facilitating factors driving our impact estimates, as described below in Section C.5.

This impact design will effectively compare the changes in outcomes for households in areas that were exposed to the project's irrigation and land tenure security activities (the treatment group) to outcome changes for similar households that were not exposed to these activities (the comparison group). We will use changes in outcomes for the comparison group to estimate the counterfactual (that is, the changes that would have occurred for the treatment group in the absence of the activities); any difference in outcome changes between the two groups will then be attributed to the IWRM activities that occurred in the treatment areas but not in the comparison areas. Because the Delta and Podor regions differ substantially, and because each region received a different set of interventions, we will compare the treatment area in each region with a matched comparison group taken from comparison areas within the same region, and will conduct analyses of impacts separately for Delta and Podor.

The key assumption for unbiased impact estimates in a matched DID design is that any changes in outcomes due to external factors unrelated to the IWRM Project, such as land quality, levels of rainfall, market conditions, and other interventions, are not systematically different between the two groups. Therefore, the internal validity of the design depends on the similarity of the treatment and comparison groups prior to the intervention in terms of characteristics that could influence outcomes. If the comparison group provides a good approximation of the counterfactual (that is, if it is balanced on observable baseline characteristics with the treatment group), it will account for time-varying external factors that could affect outcomes.

a. Our approach to creating balanced treatment and comparison groups

Previously, treatment and comparison areas were chosen only with respect to the project's irrigation activities and ultimately did not account for the locations of land tenure security activities (IMPAQ International December 2014b). As described in Section B.3, our analysis of baseline data and documentation illustrated three main challenges for identifying appropriate treatment and comparison groups: (1) it is unclear which surveyed households in the Podor region benefited from irrigation and land allocation activities, (2) some comparison areas in each region received activities undertaken in LTSA Phase I and LTSA Phase II, and (3) the previously defined treatment and comparison groups in the Delta region are not similar on key baseline characteristics.

To address the challenge of determining which households benefitted from irrigation activities in Podor, we will include a module in the follow-up survey scheduled for spring 2017, as detailed in Section D below, which will identify households that received access to newly irrigated land on the Ngalenka perimeter. We will then use baseline survey data to conduct propensity score matching to select a comparison group from among the households in comparison areas and untreated households in the treatment area. Propensity score matching is a statistical technique that uses available observable baseline characteristics to construct treatment and comparison groups that are similar at baseline on outcome measures of interest and variables that predict treatment status. Data included in the matching model result in a propensity score for each household that can take into account multiple baseline measures. Then each household that was treated is matched to the most similar household that was not treated, as determined by the propensity score.

While propensity score matching can account for pre-existing differences between the treatment and comparison samples, including any effects of LTSA Phase I activities that took place before the baseline survey, a remaining challenge in Podor is that some members of the comparison group—those in Ndiayene Pendao—subsequently received LTSA Phase II activities. Consequently, comparisons between the treatment group and this portion of the comparison group will not capture the effects of these activities. While the remainder of the comparison group—those households in Niandane—did not receive any Project activities, this group is small in size, and we may be unable to detect impacts if we focused our impact analysis on this group alone (see Table IV.5 for sample sizes, and Table IV.6 for minimum detectable impacts). To address this challenge, we plan to report outcomes separately when comparing the treatment group to the entire comparison group, and when comparing the treatment group to the portions that did and did not receive these activities. In our analysis, we will discuss how varying exposure to Project activities affects the interpretation of our findings in Podor.

In the Delta region, to improve balance between the treatment and comparison groups that were previously selected, we will re-match the groups using data from the baseline survey. Because the baseline data set contains richer data on project outputs and outcomes than the census data the previous evaluator used for its matching model, we anticipate being able to construct more similar treatment and comparison groups. Table IV.4 lists potential matching variables we will consider using in both the Delta and Podor regions.

Table IV.4. Potential matching variables

Variable name
Number of household members*
Age of household head*
Gender of household head*
Likelihood that the household lives on less than $2.50 a day
Household head received some formal education
Amount of land held by household
Amount of land used by the household for farming
Number of plots owned by the household
Number of plots used by the households for farming
Household has land on an irrigation perimeter
Household is satisfied with its irrigation system for farming
Household harvested from its land
Household received revenue from farming
Household planted rice
Household planted tomatoes
Household planted onions
Household has a formal land title for at least one of its plots
Household has formal land titles for all of its plots
Household is concerned about losing land
Household knows the deliberation process to receive a land title

*Variable was used by IMPAQ in its propensity score matching model

We selected these variables as candidates for matching because they are correlated with outcomes of interest such as farming practices, crop yields, irrigation access, and land tenure security, and because we have quality data on these measures from the baseline survey. We paid particular attention to variables that could differ between treatment and comparison areas, such as socioeconomic status, land use, land tenure security, and land investments. We included land tenure security and land investment variables, in particular, because LTSA Phase I activities occurred prior to the baseline survey and may therefore differ between treatment and comparison groups in the survey data.

To determine which of the candidate variables will be used in the matching model, we will first conduct an iterative analysis to uncover which variables best predict treatment status. We will also take steps to reduce the amount of missing data in matching variables, to ensure the largest possible sample size and maximize our statistical power to detect impacts. Our preliminary analysis does not show widespread missing data for potential matching variables. However, to ensure we are using as many surveyed households as possible in the matching model, we will impute missing baseline data for these variables using statistical techniques such as single stochastic regression imputation (Tuttle et al. 2015).

After estimating propensity scores separately for our Delta and Podor samples, we plan to match households in the treatment group with comparison households that have the most similar propensity scores. To maximize our total sample size, improve the quality of our matches, and account for differences in sample sizes between the treatment and comparison groups, we plan to match with replacement. Specifically, we will allow several households in the comparison group to potentially be matched to a single household in the treatment group, or vice versa. We will conduct exploratory propensity score matching on the Delta sample prior to the follow-up survey. This will allow us to test the feasibility of our approach to construct a matched sample with a sufficient sample size for analysis that is equivalent at baseline. We will construct our final matched group after the follow-up survey to ensure that our matched sample only includes households that can be reached and have valid outcome data at follow-up.

Matching will be an iterative process. After matching is initially completed, we will verify that the treatment and comparison groups have an adequate area of common support—that is, we will ensure that there is a sufficiently large sample in both the treatment and comparison groups that matches along key variables. We will also examine the extent to which groups are balanced by testing whether there are any statistically significant differences between groups for the matching variables. If necessary, we will re-match to improve balance and sample sizes by adjusting the matching parameters, such as by changing the required magnitude of propensity score differences between households to be eligible for a match, adjusting the number of matches one household can have, adjusting the list of matching variables, and imposing or relaxing restrictions that require perfect matches on specific variables. When analyzing impacts, we will use data on the baseline levels of outcomes and other household- and community-level characteristics to statistically adjust for any remaining observable treatment-comparison differences that could be related to outcome measures.

b. Study sample

In order to control for baseline differences between the treatment and comparison groups and to be able to estimate changes over time, we will restrict our study sample to households that were surveyed at baseline in all three waves; these are the households we will seek to locate for follow-up data collection. Table IV.5 reports the size of the study sample surveyed at baseline, divided by treatment status and region.

Table IV.5. Sample sizes surveyed at baseline, by treatment status and region

Treatment status and region	Sample size
Delta region	
Treatment sample	1,422
Comparison sample	1,264
Total	2,686
Podor region	
Treatment sample[a]	669
Comparison sample[b]	900
No project benefits	240
LTSA Phase II	660
Total	**1,569**

Source: ANSD baseline survey data

[a] 669 is the estimated number of households in Podor that were surveyed in the treatment area at baseline and were ultimately beneficiaries of the irrigation activity. 1,224 total households were surveyed in the treatment area, but not all of them were beneficiaries of the irrigation activity.

[b] The comparison sample includes the 345 households surveyed in the comparison area in Podor, plus the 555 households that were surveyed in the treatment area but did not receive benefits from the irrigation activity. The comparison sample is divided into two groups: those that received no project benefits (in Niandane) and those that received LTSA Phase II benefits (in Ndiayene Pendao). All of the 555 households in the comparison sample that were surveyed in the treatment area are included in the group that received LTSA Phase II benefits.

In line with our discussion of creating balanced treatment and comparison groups above, the comparison sample in Podor is divided into two subsamples, those that did and did not receive LTSA Phase II activities. Also, as mentioned in Section B, in Podor, only those households that were allocated land in the new irrigation perimeter are considered to have been treated. To estimate the size of the treatment sample in Podor, we assumed that two-thirds of all the beneficiary households in Podor were surveyed by IMPAQ, based on IMPAQ's response rate and evidence in the land allocation database. Other households surveyed in the treatment area in Podor would be eligible to be included in the portion of the comparison sample that received LTSA Phase II activities, increasing the pool of possible comparison matches.

Our final analysis sample size will include the subset of the households surveyed at baseline that (1) are matched by our propensity score matching model, and (2) can be located and interviewed during the follow-up survey. Two challenges may make it difficult to locate these households. First, we currently have limited information that can be used to locate and identify them. For example, although the baseline data contain the names of individuals within a household and the names of the villages in which they are located, they do not contain any additional location or contact information such as GPS coordinates, directions to a household, or mobile phone numbers. Second, since years will have passed between wave 3 of the baseline survey and wave 1 of the follow-up survey, households may have relocated or respondents previously surveyed may no longer be a part of the same household. This is of particular concern for households that were physically resettled due to project activities. We considered conducting a plot-level analysis so that we could measure changes to land use and productivity along the irrigation perimeter regardless of whether households moved during the study period. However, we could not identify a way to track the same plots identified in the baseline survey at follow-up, given the information collected in the baseline survey.

We are attempting to identify additional sources of identifying information to reduce the risk that we cannot locate previously surveyed households during our follow-up survey, such as the locations of households that were resettled. While conducting the survey, we will also work with our local data collection firm to ensure we leverage the demographic information available in the baseline data, and we will seek to access local resources to help find respondents. For example, the team will use respondents' gender and age to distinguish individuals with similar names in the same village, and we will meet with village leaders, including contacts for local GIE or GPF groups, to seek their support and assistance in identifying respondents and encouraging them to participate in the survey.

c. Key outcomes, statistical power, and analytical methods

Our impact evaluation seeks to measure short-term and longer-term outcomes that could reflect progress toward the project's ultimate goals of increasing household income and improving food security, and which can be measured before final impacts materialize (see Figure II.2). Table IV.6 presents estimates of the minimum detectable impacts—the smallest impacts on key outcomes that our design will be able to detect statistically—on key short- and longer-term outcomes.

Table IV.6. Minimum detectable impacts (MDIs) for key outcome measures

	Delta	Podor – all comparison areas	Podor – Niandane only
Outcome (units)WH	MDI (% of baseline mean)	MDI (% of baseline mean)	MDI (% of baseline mean)
Land area under production (ha)[a]	26	34	50
Rice produced (kg)[a]	25	33	48
Rice yield (kg/ha) [a]	10	13	18
Agricultural profit per hectare (FCFA/ha) [a]	33	44	58
Proportion of plots with titles (%)	33	22	30
Satisfied with irrigation system (%)	24	24	31

Sources: Sample sizes and means were estimated using data from the baseline survey. The coefficient of variation, which is the ratio of the standard deviation to the mean and is used to compute MDIs, was taken from Diagne et al (2013) for "Land area under production," "Rice produced," and "Rice yield;" from Blanc et al. (2016) for "Agricultural profit per hectare;" and, from baseline survey data for "Proportion of plots with titles" and "Satisfaction with irrigation system."

Notes: MDIs are for a two-tailed test with 80 percent power and a 95 percent level of significance.

Sample sizes are restricted to households that were surveyed in all three waves at baseline. Sample sizes, means, and standard deviation values for each variable reflect the hot season (wave 2) in 2012. In addition, sample sizes are restricted in the following ways: "Satisfied with irrigation system" and "Agricultural profit

TABLE IV.6. *(CONT)*

per hectare" values are calculated for households that grew crops, "Proportion of plots with titles" values are calculated for households that had land use rights for at least one plot, and "Rice yield" values are calculated for households that grew rice.

The calculations assume that covariates explain 30 percent of the variation in the outcome. The calculations further assume that covariates explain 20 percent of the variation in treatment receipt.

[a] Because of the concern that these values may be erroneous in the baseline data, the coefficients of variation used to calculate MDIs for "Land area under production", "Rice produced", "Rice yield", and "Agricultural profit per hectare" were obtained from external studies that report these values for households in the Senegal River Valley.

To estimate these MDIs, we used sample sizes based on the households that were surveyed in all three waves of the baseline survey, as described in Table IV.5, and assumed that 10 percent of the sample would be removed during the matching process between treatment and comparison samples and that an additional 25 percent would not be surveyed during the final follow-up round. This attrition rate accounts for the limited amount of contact information available for each household, the challenge of locating households that were physically resettled during the Compact, and the amount of time that will have passed between the baseline survey and the follow-up surveys.

For land area under production, we estimate that we will be able to detect a 26 percent change from the mean in Delta, and a 34 percent change in Podor using the entire comparison group. For the amount of rice produced, we estimate that we will be able to detect a 25 percent change from the mean in Delta, and a 33 percent change in Podor. Since the Compact's goal is to increase the annual quantity of rice cultivated by about 378 percent over five years in irrigated areas, and this change is largely driven by increases in the area under production, we expect that we will have adequate statistical power to detect project impacts on both of these indicators (MCC Senegal Compact 2009).

For rice yields, we estimate that we will be able to detect a 10 percent change from the mean value in Delta and a 13 percent change from the mean value in Podor. While changes in yields are not the key mechanism anticipated by MCC for achieving changes in rice production, we anticipate that rice yields may indeed increase as beneficiaries of new or renovated irrigation infrastructure gain access to a source of irrigation that potentially has greater capacity, is more reliable, and is less costly than previously existing sources. For agricultural profit per hectare, we estimate that we will be able to detect a 33 percent change from the mean value in Delta and a 44 percent change from the mean value in Podor. We estimate that we will be able to detect a change of about 9 percentage points in the number of households that have titles to all of their land in Delta and a change of 14 percentage points in Podor; these represent a change of 33 percent and 22 percent relative to their current mean values. For households' satisfaction with the irrigation system, we expect that we will be able to detect an impact of 13 percentage points in Delta and 16 percentage points in Podor; these both represent a change of 24 percent from their respective mean values. It is less clear whether impacts on these indicators are detectable, since our review of the literature did not reveal credible impact estimates for similar interventions on similar indicators in comparable settings.

When analyzing outcomes using only the portion of the comparison sample in Niandane that did not benefit from any project activities, MDIs are nearly fifty percent higher for most indicators, compared to MDIs using the entire comparison sample. This reflects the substantially reduced size of the comparison sample for these analyses (see Table IV.5).

For some indicators, our ability to estimate impacts depends not only on the true impacts being larger than the MDIs, but also on whether our efforts to correct data quality issues are successful. As discussed previously, the baseline data on land areas, crop production, revenue, and costs currently show unusually high standard errors. These affect several indicators of interest, including land area under production, rice production and yield, and agricultural profit per hectare. If we are unable to adjust the baseline data using the methods proposed in Section B.3 of this chapter, or find that these values accurately reflect the standard deviations in our sample, we will be unlikely to detect impacts for these indicators.

In addition to the outcomes listed in Table IV.6, we will study outcomes that vary per parcel per household, such as the percent of each household's parcels that are managed by women. We will also attempt to measure impacts for other key outcomes such as total agricultural profit and household income using DID analysis. However, we expect these to be difficult to evaluate using impact evaluation methods. Total agricultural profit varies more than agricultural profit per hectare because of differences in the amount of land used to grow crops among households; it is consequently more difficult to detect impacts for this indicator. Because changes in household income may be offset by reductions in nonfarm income, if resources are shifted away from non-agricultural activities, we expect smaller changes in household income relative to the changes anticipated for agricultural profit. Additionally, all sources of household income may not be encompassed by the baseline survey.[13] For similar reasons, previous attempts to detect changes in household income due to agricultural interventions have been unable to detect impacts (Millennium Challenge Corporation 2012). To measure key outcomes whose impacts cannot be detected through the impact evaluation, we will rely on qualitative methods that include examining changes in outcomes over time, how the IWRM project has contributed to these changes, and what key factors are causing them.

We will estimate impacts separately for Delta and Podor using the following regression model:

$$Y=\alpha+ \beta_1\tau_1+\beta_2 IWRM + \beta_3\tau_1 IWRM +\bar{X}+ \varepsilon \qquad \text{Eq. 1}$$

Y is the outcome measure of interest; *IWRM* indicates whether a given household received Project activities; τ_1 is the time period; α is the intercept term representing the average Y value for the comparison group at baseline; β_1 is the effect of time on the comparison group; β_2 is the fixed effect of being in the treatment group; β_3 is the coefficient of interest, the marginal impact of irrigation and land tenure security activities that occurred after baseline; $\bar{X}$ is a vector of control variables; and ε is a random error term.[14]

[13] The baseline survey measures five sources of household income: labor income, rental income, equipment leasing income, the sale of durable goods, and agricultural income.

[14] As noted previously, in Podor, some comparison group members received LTSA activities. To account for this and study impacts separately for groups that did and didn't receive LTSA activities, we will include specifications of the equation for Podor in which *IWRM* is a vector of indicators that describe whether a household received all

This equation represents impact estimates from our DID evaluation for all project activities that occurred between the baseline and follow-up surveys. As mentioned above, we cannot use this analysis to estimate the effects of any project activities that occurred before baseline, such as LTSA Phase I, as part of the impact analysis. As part of the vector of control variables, we will include baseline variables used to construct the propensity score for matching. This will help control for any remaining treatment and comparison differences between the matched groups. We also seek to control for other factors that are correlated with outcomes of interest and which may have differed across groups. For example, we are aware that other donor-funded activities may have taken place in our study area between the baseline and follow-up surveys, such as irrigation projects, sometimes including a land tenure security component, in the Delta or Podor supported by the World Bank, AFD and the Government of Japan (Elbow 2016). We will attempt to identify the locations of these activities so that we can control statistically for their presence, reducing bias in our impacts estimates. In addition, we will use village-level variables from the community survey, such as availability of local government services, access to irrigation infrastructure, types of crops harvested, and the property rights environment, to control for village-level differences.

To check the validity of our matched-comparison group design, we will also conduct a series of sensitivity analyses to see if our results are robust to varying matching specifications and baseline data imputation methods. We will also assess whether our estimates in Podor fully account for LTSA Phase II activities in the region, due to the fact that LTSA Phase II activities that occurred at the local government level in Ndiayene Pendao may have affected the outcomes of the comparison households located there. To do this, we will compare the treatment households in Podor separately to the comparison households in Ndiayene Pendao and to the comparison households outside Ndiayene Pendao (which were not exposed to the government-level activities) and assess whether the comparisons yield similar results.

2. Descriptive outcomes and implementation analysis

a. Key research questions

As discussed in Section A, although we can answer some research questions using our DID model, we plan to employ a combination of qualitative and quantitative methods and analysis to answer questions that cannot be fully answered through impact analysis as well as other project research questions. This mixed-methods approach, which we refer to as a descriptive outcomes and implementation analysis, will allow us to evaluate activities that cannot be addressed through the impact analysis, such as the effects of LTSA Phase I, which occurred prior to the baseline survey. This approach will also allow us to investigate longer-term impacts of the project that are beyond the reach of the impact analysis, such as changes in household income. Table IV.1 lists the research questions we will answer with this analytical approach, including:

- What factors are contributing to or constraining changes in agriculture inputs and production? Why are households changing or not changing agriculture production decisions, and how do those reasons vary depending on crop type, growing season, or income level?

Project activities, just LTSA activities, or no project activities; and β_2 and β_3 are vectors of the effects for these differing levels of treatment.

- How has water availability changed, and have barriers or costs to accessing irrigation been reduced? Has the water supply become more reliable?
- Do farmers perceive an improvement in their living standards? How has the IWRM Project affected women's access to land and irrigation? How has it affected the landless?
- How have changes in land security perceptions, formalization, conflict, or conflict management affected investments on land?
- Have local government agencies become more effective at land management, including land allocation, land formalization, and conflict resolution? Is there greater confidence in the efficacy of these institutions? What are the prospects for the sustainability of project activities post-Compact?

b. Data sources and sample

Qualitative research will be essential to learn more about how the activities were implemented and the differential effects of the activities for households that differed by location, demographic characteristics, or behavior.[15] This component of the study will draw on information collected through focus groups with GIE and GPF members, and individual interviews with key stakeholders including village leaders, SAED headquarters and extension staff, WUA leadership, land managers, and land committee members. We will purposively select at least four of the nine communes that received both LTSA and irrigation activities – two to three in the Delta and one to two in the Podor region–in which to conduct data collection. We will seek communes where the full suite of interventions were implemented in order to get the clearest picture possible of the implementation process and effects of the interventions and to ensure that key features and populations are included in the analysis. Within each selected commune, we will interview village leaders, SAED extension staff, WUA leadership, land managers, and land committee members. We will also conduct land tenure dossier reviews in these communes. Having data from multiple perspectives in the same communes will allow us to triangulate information and understand the reasons and mechanisms for the outcomes we do or do not find. In addition, we will interview SAED headquarters staff and use findings from observations of irrigation works and rice perimeters conducted in these and other intervention communes to further complement our analyses. Table IV.7 displays our proposed data collection sources, collection methods, number of participants or groups, and proposed sample. All data sources will be sampled from treatment areas of two to three communes in the Delta and one to two communes in Podor unless otherwise noted in the sample column. Following the table, we describe in more detail the focus of each type of interview, the sampling method, and the selection criteria we will use.

[15] Potential differential effects include: different ethnic groups and genders having different experiences with the LTSA and irrigation activities in each region; farmers using different crop production techniques may have experienced different income benefits from the irrigation activities; farmers operating under GIEs, GPFs, or other producer groups may have had different capacities to invest in their land; and, the security of an individual's land holdings may differ based on whether she or he holds a formal land title, whether there is effective customary land management, or the conditions that apply to his or her land rights.

Table IV.7. Qualitative data collection specifications

Data source	Data Collection Method	Number	Sample
Members of GIEs in areas that benefitted from the interventions	Focus group discussions	Delta: 4 Podor: 3	Members with knowledge of the interventions and their effects
Members of GPFs in areas that benefitted from the interventions	Focus group discussions	Delta: 3 Podor: 2	Members with knowledge of the interventions and their effects
Community members in areas that benefitted from the interventions who do not belong to GIEs and GPFs	Interviews	Delta: 4-6 Podor: 3-5	Community members who are eligible for membership but are not members
Village leaders	Interviews	Delta: 5-7 Podor: 3-5	Village leaders with knowledge of the interventions and their effects
Land manager	Interviews	Delta: 4 Podor: 3	Local commune land managers who are implementing the land tenure policies
Administrative data	Conflict and land transaction volume data)	All 9 communes	n/a
Land committees	Group interview	Delta: 2-3 Podor: 1-2	Local commune committees involved in finalizing land use certificates and implementing the land tenure policies
Commune-level land tenure files	Dossier review	Delta: 2-3 Podor: 1-2-	A random selection of land tenure files
Water user association leaders	Interviews	2-3	Leaders of WUA in target communes
SAED engineers and extension staff	Interviews	Delta: 1 Podor: 1	SAED engineers responsible for irrigation works maintenance and extension staff responsible for conducting Water User Association training and providing technical assistance to farmers
SAED headquarters staff	Interviews	1	SAED staff whose experience implementing the IWRM activities includes thorough knowledge of changes. These staff will not be in the target communes.
Irrigation works and rice perimeter sites	Observation	Delta: 4 Podor: 2	These sites will be in the target zones as well as elsewhere

- **Members of GIEs and GPFs.** We will carry out 12 focus groups with members of GIEs and GPFs in the three selected three treatment areas of Delta and Podor to investigate which project-related factors caused changes in agriculture production decisions, perceptions of water reliability and land tenure security, barriers to accessing irrigation for crops, and the composition of household income. We will seek to understand their perspectives regarding their interest in investing in the newly irrigated land, any obstacles they faced in obtaining access, and their perceptions of costs and benefits related to access. We will conduct focus groups separately in the Delta and in Podor, and separately for GIEs (mainly male members) and GPFs (all female members). In the GPF focus groups, we will include women from female-headed households as well as women from male-headed households, and will examine women's particular points of view and the potential differential effects of the interventions on them. For all 12 focus groups, we will ensure representation across regions, demographic and socioeconomic strata (including gender, ethnicity, age, and income levels), farming experience, and access to water sources.

- **Community members who do not belong to GIEs and GPFs.** We will conduct interviews with seven to ten community members who are eligible but do not belong to a GIE or GPF to compare their experiences and perceptions of the project to GIE/GPF members'. At least one respondent will be female. While these respondents are not direct beneficiaries of the project, as members of the community they are stakeholders.
- **Village leaders, commune-level land managers, and land committees.** We will interview seven local commune land managers and conduct three to five group interviews with land committees involved in finalizing land use certificates to learn how the land formalization process has changed, how governing institutions have altered their approach to land management, and what have been the constraints and barriers to land access. We will pose parallel questions to about 10 village leaders to assess differing perceptions of the process on the part of those seeking formalization of their land use. We will also collect administration data from the land managers on land conflicts and land transaction volume.
- **Land tenure documents.** We will carry out a deep-dive review of a selection of land tenure files in the selected communes to gain an understanding of how land managers grant to individuals, households, and producer enterprises or associations the rights of occupancy and use of land in the form of *titres d'affectation,* how they survey and record land rights, and how they accommodate transfer of land rights. These data will also allow us to verify the land tenure status of respondents to the household survey who are also in the communes selected for the deep-dive review, if the data contain information that permits identifying individuals.
- **Water user association leadership.** We will interview two to three leaders of water user associations in Delta to learn more about whether and how water use has changed, how the roles of WUAs have changed, and whether water availability, access, and supply has changed. Questions about changes in the amount of irrigated land will also be probed. (GIE leaders in Podor will provide similar information via focus groups).
- **Interviews with SAED engineers and extension teams.** We will conduct interviews with staff at SAED, including engineers responsible for irrigation works maintenance, and extension staff responsible for conducting Water User Association training as well as for providing technical assistance to farmers in the Delta and Podor regions. We will seek to refine our understanding of where and when the implementation of LTSA and irrigation activities took place and who benefited from these activities in order to identify the project activities to which our impact estimates can be attributed.
- **SAED headquarters staff.** We will conduct an interview with SAED headquarters staff whose experience implementing the IWRM activities includes thorough knowledge of changes at all administrative levels and across activities. This interview will be held at SAED headquarters in St. Louis.

- **Observations of infrastructure.** Along with the project's irrigation engineer, we will observe key features of the irrigation implementation, including whether pumps are functional, canals are maintained, the perimeters are properly connected to the drainage system, and perimeters are under production during the growing seasons. These observations will be done prior to the follow-up surveys to ensure perimeters are connected to the drainage system.

In addition to the qualitative methods and sources listed above, we will also gather administrative data from SAED, such as water flow rates and maintenance action plans, and administrative data from the communes or higher administrative level authorities on land registration rates, land transfers, land disputes and dispute resolution. We will also draw on data collected as part of the community survey and the household survey to provide additional information on agriculture production, irrigation practices, and land access and conflicts. We may identify additional data sources through engagement with stakeholders over the course of the evaluation.

c. Analysis plan

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

Thematic framing. To better uncover patterns, themes, and issues in the data, we will develop a coding scheme with a hierarchy of conceptual categories and classifications linked to the research questions and the logic model. We will update this coding framework as we systematically review and assess our data according to the project's theory of change and program logic. Results from the household and community surveys will also inform our coding scheme. Using NVivo software to assign codes to the qualitative data will enable us to access data on a specific topic quickly, and organize information in different ways to identify themes and compile evidence supporting them. For instance, farmers might describe their reasoning to change their farming practices in language that has similar underlying themes. Our coding structure will capture those similarities. Conversely, how local government officials view changes in land investment could differ from how community leaders view those changes; our coding structure will classify those different perspectives in a concrete manner. Those divergent perspectives might also illustrate challenges in project implementation. Further, the software allows respondents to be categorized by gender, age, geographic location, or other salient characteristics to permit analysis by group.

Data triangulation. Because our analysis will incorporate data from several different sources, including household survey data, focus groups, key informant interviews, administrative data, and project documentation, we will test for consistency and discrepancies in findings across these data sources by triangulation. This process facilitates confirmation of patterns or findings and the identification of important discrepancies. A coding hierarchy will also enable us to integrate quantitative results and apply quantitative attributes to qualitative data and support triangulation across data sources and types. For example, when investigating the project's impact on land conflicts, we will triangulate among survey data on land disagreements, results from focus groups on perceptions of land security, and data from government documents about the land formalization process.

D. Quantitative and qualitative data collection plan

We propose an integrated data collection plan to collect data that will allow us to answer research questions using both quantitative and qualitative analytical methods. Our first activity will be to conduct a trip in fall 2016 to gather information that will help us plan future data collection and analysis activities. During the trip, we will conduct meetings and interviews with local stakeholders to (1) investigate whether other activities took place in the treatment and comparison areas during the period of our study that could affect the outcomes we wish to study; (2) attempt to determine more precisely the location and timing of Project activities; (3) gather data in Podor that will improve our ability to match the land allocation database to the baseline survey data, such as GIE and GPF member lists and the locations of villages specified in the roster and the survey data; and (4) identify the key subgroups of beneficiaries for each major project activity among which impacts could differ. We will also conduct observations of the irrigation activities, particularly verifying whether the perimeters were connected to the drainage system.

1. Household survey

To estimate impacts of the IWRM project, we will use existing baseline data collected by ANSD and hire a local data collection firm to conduct two rounds of follow-up data collection: an initial round focusing on intermediate outcomes and a final round focusing on longer-term outcomes. Table IV.8 lists the modules and key topics that will be covered in the follow-up surveys.

Table IV.8. Overview of impact evaluation household survey modules

Module	Key topics covered
Household roster	Demographic information on all household members such as age, sex, and education
Household assets	Lodging attributes and assets owned, including farm animals
Job and work activities	Labor industries such as commerce, artisanal, or farming; membership in agriculture organizations
Non-agricultural household income	Non-agriculture income, such as labor activities, rent, pensions, and social programs
Household expenses	Consumption costs for goods and services, including food
Farm plot information	Plot-level details on property rights, locations, and uses
Land security and conflicts	Perceptions and experiences with land disputes and resolutions
Agriculture production	Crop choice, irrigation schemes, production costs, harvest quantities, and agriculture revenue
Fishing and forestry	Fishing and forestry practices and revenue

Each survey round will encompass three survey waves, interviewing households during each agriculture season over a 12-month period: the cold season, hot season, and rainy season. We plan to survey both treatment and comparison households that were surveyed in all three waves at baseline. Conducting a separate survey for each agriculture season allows us to capture and compare to the baseline changes in agriculture production and farming behavior for each season, while limiting recall bias. To reduce respondent burden and increase data collection efficiency, only the first wave of data collection per round will involve face-to-face interviews. The second and third waves will be conducted via mobile phone, as has been implemented in rural Senegal by the World Bank and Senegal's ANSD (Dabalen et al. 2016). Although mobile phone penetration appears to be near 100 percent in Senegal (Central Intelligence Agency 2016; World Bank 2016), we will pilot this methodology before deploying it to the full sample. We anticipate conducting initial face-to-face interviews after the cold season in spring 2017. If we learn through further discussions with agriculture extension officers, GIE and GPF members, and community leaders that there is a more optimal time to conduct in-person interviews, we will adjust our survey schedule appropriately. All surveys will be conducted in either Wolof or Pulaar, depending on the respondents' primary language. Table IV.9 details our data collection schedule.

Table IV.9. Proposed data collection schedule

Survey	Dates	Recall season/purpose	Interview method
Household survey (wave 1, round 1)	April–June 2017	Cold season (December–March)	In person
Qualitative focus groups and key informant interviews	May–July 2017	IWRM project intervention	In person
Community level survey	June–July 2017	IWRM project intervention	In person
Household survey (wave 2, round 1)	July–August 2017	Hot season (April–June)	Phone
Household survey (wave 3, round 1)	December 2017–January 2018	Rainy season (August–November)	Phone
Household survey (wave 1, round 2)	April–June 2019	Cold season (December–March)	In person
Household survey (wave 2, round 2)	July–August 2019	Hot season (April–June)	Phone
Household survey (wave 3, round 2)	December 2018–January 2019	Rainy season (August–November)	Phone

We will align our follow-up surveys with the baseline survey as well as we can in order to have comparable data to measure impact. However, we will make adjustments to the survey based on the results of our baseline data review. Changes to the survey will include fixing skip patterns, adding specify questions for when a respondent's answer is marked "other" to a categorical question, adding clear section gateway questions to ensure inclusion of all households eligible to answer each section; removing questions that are not needed for analysis, ensuring consistency in the level of a question between survey waves (that is, information at the plot, person, or household level), clarifying the wording of questions to ensure respondents are clear on the meaning, adjusting response options to better fit likely responses, and adding new retrospective questions that are needed to construct matching variables for our propensity score matching model. To improve the ability of the data collection firm to find respondents for the final survey round, they will also collect household GPS coordinates and written directions to the household, being sure to acquire proper consent and adhere to local norms.

In addition, as discussed in Section B.3, above, our review of baseline data revealed some concerns about data quality. In particular, we found very large standard deviations for crop yields, agriculture production costs, and agriculture revenue that may be driven by measurement error. To improve data quality, we plan to require that the data collection firm use computer-assisted personal interviewing (CAPI) and we will construct and program crosswalks of local units to standardized units. We will also make adjustments to the survey questions and interviewer training protocols based on what we learn from analyzing baseline data of these measures, including revising options for units of measure and detailing interviewer probing strategies for these questions.

As previously noted, we do not know which households in Podor are beneficiaries of the irrigation and land allocation activities. Because we cannot link the land allocation database to our baseline sample frame, we will include an additional module in the survey of treatment area households in Podor to identify which households were beneficiaries of the irrigation and land tenure security activities. In addition to asking questions about the benefits received by household members, this module will include questions on how long a household has lived in the area, which GIE and GPFs its households members belong to, their national identification number, and any alternative names used by household members so that we can cross-reference responses between the survey data and the land allocation database.

The first round of quantitative follow-up data collection will concentrate on intermediate impacts, since it is occurring about 18 months after the end of Compact activities. It can take multiple agriculture seasons to observe changes in farming behavior (Millennium Challenge Corporation 2012). Because of the longer feedback loop in agriculture evaluations, we plan on conducting the final round of follow-up data collection two years after the first round. Mathematica staff and a local data collection team will lead key informant interviews and focus groups.

2. Qualitative data collection

For the descriptive outcomes and implementation analysis, we will conduct one round of a short village-level interview with community leaders during the follow-up data collection period. The community leader survey will provide village-level data on irrigation infrastructure, agriculture crops, local government services, other donor projects in the area, and the land rights environment. We will draw on the community survey developed by the previous evaluator, but plan to create a more targeted interview that will provide data specific to our research questions, allowing us to explore village-level perceptions of how the IWRM project activities were implemented. We will conduct these interviews in treatment areas and villages bordering treatment areas in the two regions. We will select non-treatment villages for their geographical proximity to treatment areas in order to gauge spillover effects.

For the qualitative data collection, we will conduct the focus group discussions, key informant interviews, documentary review, and other data collection to inform the descriptive outcomes and implementation analysis alongside the in-person household survey in 2017, being mindful of planting seasons and other periods in which potential respondents are less available. We will develop focus group discussion guides that elicit participants' perceptions of the implementation activities and that promote open discussion of both benefits and drawbacks of the changes in their communities. Our semi-structured instruments for key informant interviews will allow us to gather targeted information to understand project implementation and outcomes while permitting expanded conversation that can lead to unanticipated insights. We plan to leverage the same data collection firm to facilitate focus group discussions in local language in each of the regions, and hope to create efficiencies with interviewer training and travel. Conducting much of the data collection in a concentrated period will lessen burden on farmers and reduce disruptions to communities.

E. Risks, challenges, and next steps

Our evaluation is subject to several risks and challenges that have been discussed in previous sections. Table IV.10 summarizes them and the next steps we plan to take to mitigate the risks and respond to the challenges.

Table IV.10. Evaluation risks and mitigation plan

Risk/challenge	Mitigation plan
Attributing impact estimates to the right set of project activities. Our impact estimates will not account for any activities that occurred prior to the baseline survey, and must identify impacts of IWRM activities separately from other activities that may have occurred during the same time period.	Through qualitative data collection, including key informant interviews, site visits, and reviewing project documentation, we will develop a more complete understanding of the scope of project implementation, including where and when activities took place. This will help us to identify the project activities to which our impact estimates can be attributed.
Other donor activities that affect our study outcomes of interest could have occurred between the baseline and follow-up surveys in our study areas, such as irrigation projects in the Delta funded by the Government of Japan and the World Bank. If we cannot identify which households these activities affected, our impact estimates for the project will be confounded by the impacts of these other activities.	We plan to employ qualitative methods to understand what related activities may have been going on in our study area. We will also consider adding questions to the follow-up survey to gauge which households (or villages) may have been affected by such activities. We can then use this information to control for these activities in our impact model or to interpret our results.
We do not currently know which Podor households in our survey sample received access to newly irrigated land. After analyzing the land allocation database, we determined we do not currently have sufficient identifying information to link that database to our baseline survey sample.	We will include an additional module in the follow-up survey for treatment area households that will help identify whether the household received access to newly irrigated land on the Ngalenka perimeter under this project. We will cross-reference these survey results with the land allocation database.
Sample attrition at the follow-up survey will reduce our ability to detect statistically significant effects. Due to population mobility (about four years will have elapsed between the baseline and follow-up surveys) and limited respondent identifying information (we have name, age, village, and gender, but no GPS coordinates or house directions), it may be difficult to find and survey all baseline respondents, resulting in a smaller analytic sample.	We will institute data collection protocols to limit sample attrition, including (1) using all relevant baseline data to identify respondents, including gender and age; (2) meeting with village chiefs to help locate households; (3) meeting with leaders of GIEs and GPFs to encourage their members to participate in the survey and to help locate respondents; (4) coordinating with agriculture extension officials to ensure we are conducting surveys at a time of year and time of day that maximizes respondent availability; and (5) returning to households several times if respondents are initially absent. We will also collect additional identifying information at the follow-up survey to ensure we can easily find respondents for future surveys, such as GPS coordinates and directions to their house.

Risk/challenge	Mitigation plan
Potentially poor quality of baseline data on agriculture production, revenue, and costs limits our ability to produce impact estimates for these outcomes. Our review of baseline data shows unreasonably large standard deviations for these variables, possibly due to measurement error.	We will explore several strategies to evaluate and correct these baseline measures including (1) conducting an analysis of the units of measurement used, (2) using regression-imputed values for outliers, (3) focusing on collecting high quality outcome data during follow-up surveys, and (4) evaluating these outcomes using qualitative methods.
The period of study may not include sufficient time for detectable changes to have occurred in farming behavior, production, and revenue. The first follow-up survey is scheduled for about 18 months after the Compact ended.	We plan to focus on intermediate outputs in the initial follow-up survey and wait to field the final survey round until two years after the first follow-up to measure longer-term impacts.

V. ADMINISTRATION

Given the complexity of this multicomponent project and evaluation, careful management of the evaluation and timeline is essential. In this section, we discuss several administrative issues relevant to the conduct of the evaluation and present a time line for evaluation activities.

A. Summary of IRB requirements and clearances

Mathematica is committed to protecting the rights and welfare of human subjects by obtaining approval from an Institutional Review Board (IRB) for relevant research and data collection activities. IRB approval requires three sets of documents: (1) a research protocol, in which we describe the purpose and design of the research and provide information about our plans for protecting study participants, their confidentiality and human rights, including how we will acquire consent from study participants for their participation; (2) copies of all data collection instruments and consent forms that we plan to use for the evaluation; and (3) a completed IRB questionnaire that provides information about the research protocol, how we will securely collect and store our data, our plans for protecting participants' rights, and any possible threats to participants resulting from any compromise of the confidentiality of the data. We anticipate the IRB review of this study to qualify for expedited review as it presents minimal risk to participants. IRB approval is valid for one year, and we will submit annual renewals for subsequent year approvals as needed.

We will also ensure that the study meets all U.S. and local research standards for ethical clearance, including submitting our study for local IRB review, if required. Mathematica will submit the research protocols and instruments to our U.S.-based IRB and our local survey firm hired by Mathematica will obtain permits or clearances from the relevant national and/or local government offices before starting the field work. If either the U.S. IRB or local authorities recommend changes to protocols or instruments, the survey firm, MCC, and Mathematica will work together to accommodate the changes, and all parties will agree on the final protocol before data collection begins.

B. Data access, privacy and file preparation

All data collected for this evaluation will be stored on Mathematica's secure server and will only be accessible to project team members who use the data. After producing and finalizing each of the final evaluation reports, we will prepare corresponding de-identified data files, users' manuals, and codebooks based on the quantitative survey data. We understand that these files could be made available to the public, therefore these data files, user manuals, and codebooks will be de-identified according to the most recent guidelines set forth by MCC. Public use data files will be free of personal or geographic identifiers that would permit unassisted identification of individual respondents or their households, and we will remove or adjust variables that introduce reasonable risks of deductive disclosure of the identity of individual participants. We will also recode unique and rare data using top and bottom coding or by replacing these observations with missing values. If necessary, we will also collapse any variables that make an individual highly visible because of geographic or other factors into less easily identifiable categories.

C. Dissemination plan

To ensure that the results and lessons from the evaluation reach a wide audience, we will work with MCC to increase the visibility of the evaluation and findings targeted to the agricultural sector, particularly for policymakers and practitioners. During the first year of the evaluation, we will release outreach materials based on our final design report to inform and engage stakeholders in the evaluation process. We will present these materials to stakeholders during our trip to Senegal in fall 2016. We will ensure these materials are distributed to the Ministry of Agriculture, SAED and local authorities involved in land tenure activities, and other representatives of the government of Senegal. The findings from the interim report will also be presented to MCC in Washington, DC, and, if possible, to key stakeholders in Senegal. The interim and final evaluation reports will be available online on the MCC website within six months of the drafts being submitted.

We expect the broader research community to have strong interest in the findings from the evaluation. To facilitate wider dissemination of findings and lessons learned, we will collaborate with MCC and other stakeholders to identify additional forums—conferences, workshops, and publications—to disseminate the results and encourage other donors and implementers to integrate the findings into their programming.

D. Evaluation team: roles and responsibilities

Our team will contribute our extensive experience and expertise to meet MCC's evaluation needs. **Dr. Sarah Hughes** leads the team as the program manager and oversees the design and implementation of the evaluation. She assumes primary responsibility for coordinating deliverables and for ensuring the on-time completion of tasks within budget and with high quality. **Dr. Aravind Moorthy** directs the development of the evaluation design and is the team's lead economist. **Mr. Thomas Coen** supports Dr. Moorthy in the technical design process. **Dr. Kristen Velyvis** will direct the data collection activities and support the team in interim and final analyses. **Ms. Katie Naeve,** an analyst on the team, conducted the Project's Evaluability Assessment and supports other evaluation activities. **Mr. Jeremy Brecher-Haimson** manages the project internally for Mathematica and supports research tasks. **Mr. Ahmadou Kandji**, a statistician, is a local consultant and works closely with Mathematica and local stakeholders to facilitate logistics for data collection, including on-the-ground oversight of all surveys and qualitative data collection. **Mr. William Valletta**, an expert on land tenure with a focus on West Africa will provide guidance on land security and institutional change associated with the land tenure activities, **Dr. Harounan Kazianga**, an economist at the University of Oklahoma, provides feedback on the evaluation design, agricultural economics, and land tenure issues in West Africa, and **Dr. Mamadou Baro**, an anthropologist at the University of Arizona whose work focuses on land security in the Senegal River Valley, will assist in reviewing deliverables to ensure the evaluation accurately captures the local context for agricultural and land tenure change.

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APPENDIX A

POVERTY SCORECARD

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Figure A.1. IWRM Project Poverty Scorecard

MCC Cost (Millions USD)	**140.5**	**Overall Cost (Millions constant USD)[1]**			**191.4**
20-Year ERR	**17.4%**				
Present Value (PV) of Benefit Stream (Millions USD)	**436.5**				
		Consumption per day (PPP $)			
Beneficiaries	**Total**	**< $1.25**	**< $2 [2]**	**$2-$4**	**> $4**
Beneficiary Households in Year 20 (#)	22,388				
Beneficiary Individuals in Year 20 (#)	268,657				
National Population in Year 20 [3] (#)	23,361,295				
Beneficiary Population by Poverty Level (%) [4]		20%	35%	42%	23%
National Population by Poverty Level [5] (%)		34%	60%	29%	11%
The Magnitude of the Benefits					
PV of Benefit Stream Per Beneficiary (USD)	$1,631	$1,033	$1,551	$1,886	$1,291
PV of Benefit Stream as Share of Annual Income (%)	20%	23%	31%	18%	8%
Cost Effectiveness					
PV of Benefit Stream/Project Dollar (USD/USD)	3.11	0.39	1.04	1.50	0.57
Percent of Project Participants Who Are Female	52%				
GNI per capita [6] (USD)	$820				
Current National Population	13,711,597				

NB: all benefits incremental; PVs based on 10% discount rate and exclude MCC costs but net out any local costs

1 Present value of MCC investment costs and costs of tertiary system development, expressed in mid-2009 values

2 The beneficiaries and population living on less than $2 per day include those under $1.25 per day

3 Based on estimated 2009 population (CIA World Factbook), projected to Year 20

4,5 Based on National income distribution figures from ESPS 2005-2006 data

6 See MCC 2009 Scorecard

Source: MCC

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APPENDIX B

DETAILED BASELINE EQUIVALENCE ANALYSIS

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This appendix expands upon the baseline equivalence analysis results that were summarized in Chapter IV. We present eight detailed tables of our findings on the comparability of the treatment and comparison groups, separately for the Delta and Podor samples, for four categories of baseline characteristics: (1) household characteristics, (2) land possession and irrigation practices, (3) agriculture production, and (4) land tenure security characteristics. The treatment group in the Podor region represents potential beneficiary households. At the time of the baseline survey, the previous evaluator could not determine which households in the Podor treatment area would be actual beneficiaries of IWRM Project activities. Overall, we find significant differences between groups in all four categories of characteristics in both the Delta and Podor regions. We find statistically significant differences on many more variables than we would expect to see by chance alone.[16] Unless these differences are addressed through the evaluation design, they could introduce bias into estimates of the project's impact, causing over- or underestimates of the project's true impact.

Table B.1. Baseline equivalence results for household characteristics (Delta region)

	Treatment group		Comparison group			
Baseline measure	Mean	Sample size	Mean	Sample size	Difference	P-value
Number of household members	9.87	1,422	10.43	1,264	-0.56*	0.020
Age of household head (years)	49.22	1,422	49.99	1,264	-0.77	0.127
Household head is male	0.82	1,422	0.81	1,264	0.00	0.748
Household head knows how to read and write	0.50	1,417	0.56	1,259	-0.06**	0.001
Household head received some formal education	0.32	1,419	0.38	1,257	-0.06**	0.002
Likelihood household lives in extreme poverty (less than $1.25/day)	0.22	1,401	0.16	1,248	0.05**	<0.001
Likelihood household lives in poverty (less than $2.50/day)	0.69	1,401	0.65	1,248	0.04**	<0.001

Source: IWRM Project baseline survey data (wave 1).

Note: All values in this table are based on non-imputed data and the sample that was surveyed in all three baseline waves. Values are proportions unless otherwise indicated. Due to rounding, the value reported in the difference column may differ slightly from the difference between the values reported in the mean treatment and mean comparison columns.

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

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

[16] Using a 5 percent significance threshold, we would expect that about one out of 20 variables tested would show a statistically significant difference due to chance.

Table B.1 provides baseline equivalence results for household characteristics in the Delta region. We find statistically significant differences on important socioeconomic indicators between the treatment and comparison group. Comparison households in the Delta region have a higher average level of education and are less likely to live in poverty than treatment households.[17] Age and gender of the household do not show any statistically significant differences, perhaps because they were among the characteristics used by the previous evaluator to create a matched comparison group. Households in the comparison area are slightly larger on average than households in the treatment area.

Results for the unmatched sample of households in the Podor region, detailed in Table B.2, are similar, though we also find a statistically significant difference in the number of male-headed households between the treatment and comparison group. Sample households in the Podor region are socioeconomically worse off than sampled households in Delta, with lower average levels of education and a higher likelihood of living in poverty.

Table B.2. Baseline equivalence results for household characteristics (Podor region)

	Potential treatment group		Comparison group			
Baseline measure	Mean	Sample size	Mean	Sample size	Difference	P-value
Number of household members	9.17	1,223	10.29	345	-1.12**	0.001
Age of household head (years)	49.51	1,223	50.56	345	-1.06	0.164
Household head is male	0.82	1,223	0.87	345	-0.05*	0.025
Household head knows how to read and write	0.40	1,212	0.52	345	-0.12**	<0.000
Household head received some formal education	0.12	1,215	0.17	343	-0.06*	0.011
Likelihood household lives in extreme poverty (less than $1.25/day)	0.28	1,206	0.23	343	0.05**	<0.000
Likelihood household lives in poverty (less than $2.50/day)	0.76	1,206	0.72	343	0.04**	<0.000

Source: IWRM Project baseline survey data (wave 1)

Note: All values in this table are based on non-imputed data and the sample that was surveyed in all three baseline waves. Values are proportions unless otherwise indicated. Due to rounding, the value reported in the difference column may differ slightly from the difference between the values reported in the mean treatment and mean comparison columns.

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

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

[17] To estimate the likelihood that a household is living on less than $2.50 or $1.25 a day, we constructed a Progress out of Poverty Index for Senegal following a validated measure from the Grameen Foundation using the baseline data set. This index provides an easy way to quickly capture poverty likelihood and includes conversions to compare results across countries. Combining several closely related indicators of poverty into one measure also reduces measurement error, captures the breadth of the construct, and maximizes reliability. For further information, see Schreiner (2016).

Table B.3. Baseline equivalence results for land possession and irrigation practices (Delta region)

	Treatment group		Comparison group			
Baseline measure	Mean	Sample size	Mean	Sample size	Difference	P-value
Cold season (wave 1)						
Land use [a]						
Household has any land	0.81	1,421	0.74	1,259	0.07**	<0.001
Household farmed crops	0.60	1,421	0.68	1,259	-0.08**	<0.001
Household has land on an irrigation perimeter	0.71	1,421	0.72	1,259	-0.01	0.601
Total area of land held (hectares)	3.18	1,421	2.1	1,259	1.08**	0.003
Total area of land used for farming crops (hectares)	1.82	1,421	1.82	1,259	0.00	0.994
Access to water sources [b]						
At least one plot with access to a river/lake	0.98	858	0.95	859	0.03**	0.001
At least one plot with access to a well, bore well, dam, or other	0.04	858	0.06	859	-0.02*	0.040
All plots have access only to rainwater	0.00	858	0.00	859	0.00	0.318
Hot season (wave 2)						
Land use [a]						
Household has any land	0.84	1413	0.7	1,239	0.14**	<0.001
Household farmed crops	0.61	1413	0.56	1,239	0.05*	0.012
Household has land on an irrigation perimeter	0.75	1413	0.68	1,239	0.06**	<0.001
Total area of land held (hectares)	3.21	1412	1.52	1,239	1.69**	<0.001
Total area of land used for farming crops (hectares)	1.56	1411	1.14	1,239	0.42*	0.033
Access to water sources [b]						
At least one plot with access to a river/lake	0.94	863	0.98	697	-0.04**	<0.001
At least one plot with access to a well, bore well, dam, or other	0.03	863	0.03	697	0.00	0.578
All plots have access only to rainwater	0.03	863	0.00	697	0.03**	<0.001
Household is satisfied with the irrigation system [c]	0.57	863	0.53	697	0.04	0.148

TABLE B.3. *(CONT)*

Baseline measure	Treatment group		Comparison group			
	Mean	Sample size	Mean	Sample size	Difference	P-value
Rainy season (wave 3)						
Land use [a]						
Household has any land	0.83	1,418	0.7	1,263	0.13**	<0.001
Household farmed crops	0.42	1,418	0.49	1,263	-0.06**	0.001
Household has land on an irrigation perimeter	0.74	1,418	0.68	1,263	0.06**	<0.001
Total area of land held (hectares)	3.64	1,417	3.12	1,263	0.51	0.711
Total area of land used for farming crops (hectares)	0.85	1,418	0.78	1,263	0.07	0.563
Access to water sources [b]						
At least one plot with access to a river/lake	0.73	601	0.99	613	-0.26**	<0.001
At least one plot with access to a well, bore well, dam, or other	0.02	601	0.00	613	0.01*	0.048
All plots have access only to rainwater	0.26	601	0.00	613	0.25**	<0.001

Source: IWRM Project baseline survey data

Note: All values in this table are based on non-imputed data and the sample that was surveyed in all three baseline waves. Values are proportions unless otherwise indicated. Due to rounding, the value reported in the difference column may differ slightly from the difference between the values reported in the mean treatment and mean comparison columns.

[a] Sample includes all surveyed households with valid data.

[b] Sample includes households that farmed land that season.

[c] Data on satisfaction with the irrigation system are only available for the hot season.

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

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

Beyond socioeconomic differences between the treatment and comparison group, we also find significant differences related to land use and irrigation practices in the Delta region. Table B.3 details baseline equivalence on these measures for the sample of households in the Delta region. We find significant differences on three out of five measures of land use in the cold season and the rainy season and significant differences on all five measures in the hot season. More treatment households have farm land but are less likely to actually farm the land during the cold and rainy seasons than is the case with comparison households. During the hot and rainy season, more treatment households have land on the irrigation perimeter relative to comparison households. However, land holdings appear to fluctuate substantially across seasons in the comparison group. For example, average land holdings in the comparison group more than double between the hot season (1.52 ha) and rainy season (3.12 ha). Since land holdings were self-reported by respondents and not measured by interviewers, measurement error may account for part of the change in land holding size.

Although almost all households in the sample have similar levels of access to irrigation sources, there are some significant differences between the groups. For example, during the rainy season, more than a quarter of treatment households rely exclusively on rainwater to irrigate all of their plots, whereas almost all comparison households use river or lake water for irrigation.

In the Podor region, significantly fewer households in the treatment group own farm land and farm the land, and they are less likely to have land on an irrigation perimeter. The amount of land held and farmed by treatment households is also significantly smaller than the comparison group. It is possible treatment area households underreported land holdings because they knew that the land allocation criteria for the IWRM Project favors households with less land. There are a few significant differences in the types of water sources to which households have access in each season. However, across all seasons, households in both groups overwhelmingly have access to irrigation from rivers or lakes. Comparison farming households are more satisfied with their irrigation system than treatment households by 9 percentage points. Table B.4 lists the full Podor results.

Table B.4. Baseline equivalence results for land possession and irrigation (Podor region)

	Potential treatment group		Comparison group			
Baseline measure	**Mean**	**Sample size**	**Mean**	**Sample size**	**Difference**	**P-value**
Cold season (wave 1)						
Land use [a]						
Household has any land	0.74	1,218	0.9	343	-0.16**	<0.001
Household farmed crops	0.55	1,218	0.88	343	-0.33**	<0.001
Household has land on an irrigation perimeter	0.72	1,218	0.88	343	-0.16**	-0.16
Total area of land held (hectares)	0.64	1,216	1.03	343	-0.39**	<0.001
Total area of land used for farming crops (hectares)	0.35	1,216	0.99	343	-0.64**	<0.001
Access to water sources [b]						
At least one plot with access to a river/lake	0.98	672	0.92	301	0.06**	<0.001
At least one plot with access to a well, bore well, dam, or other	0.03	672	0.09	301	-0.06**	<0.001
All plots have access only to rainwater	0.00	672	0.00	301	0.00	0.318
Household is satisfied with the irrigation system						
Hot season (wave 2)						
Land use [a]						
Household has any land	0.73	1,216	0.88	342	-0.15**	<0.001
Household farmed crops	0.55	1,216	0.77	342	-0.22**	<0.001

TABLE B.4. *(CONT)*

Baseline measure	Potential treatment group Mean	Potential treatment group Sample size	Comparison group Mean	Comparison group Sample size	Difference	P-value
Household has land on an irrigation perimeter	0.70	1,216	0.85	342	-0.14**	<0.001
Total area of land held (hectares)	0.66	1,211	0.73	342	-0.07	0.458
Total area of land used for farming crops (hectares)	0.33	1,215	0.55	342	-0.22**	<0.001
Access to water sources [b]						
At least one plot with access to a river/lake	0.96	668	1.00	264	-0.04**	<0.001
At least one plot with access to a well, bore well, dam, or other	0.03	668	0.00	264	0.03**	<0.001
All plots have access only to rainwater	0.01	668	0.00	264	0.01	0.149
Household is satisfied with the irrigation system [c]	0.66	668	0.75	264	-0.09**	0.008
Rainy season (wave 3)						
Land use [a]						
Household has any land	0.77	1,172	0.93	343	-0.16**	<0.001
Household farmed crops	0.51	1,172	0.87	343	-0.36**	<0.001
Household has land on an irrigation perimeter	0.73	1,172	0.89	343	-0.16**	<0.001
Total area of land held (hectares)	0.79	1,167	1.07	343	-0.28**	0.004
Total area of land used for farming crops (hectares)	0.44	1,169	0.9	343	-0.46**	<0.001
Access to water sources [b]						
At least one plot with access to a river/lake	0.89	592	0.93	297	-0.05*	0.016
At least one plot with access to a well, bore well, dam, or other	0.05	592	0.03	297	0.02	0.143
All plots have access only to rainwater	0.08	592	0.06	291	0.01	0.446

Source: IWRM Project baseline survey data

Note: All values in this table are based on non-imputed data and the sample that was surveyed in all three baseline waves. Values are proportions unless otherwise indicated. Due to rounding, the value reported in the difference column may differ slightly from the difference between the values reported in the mean treatment and mean comparison columns.

[a] Sample includes all surveyed households with valid data.

[b] Sample includes households who farmed land that season.

[c] Data on satisfaction with the irrigation system are only available for the hot season.

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

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

Table B.5. Baseline equivalence results agriculture production (Delta region)

Baseline measure	Treatment group: Mean (standard deviation)	Treatment group: Sample size	Comparison group: Mean (standard deviation)	Comparison group: Sample size	Difference	P-value
Cold season (wave 1)						
Overall agriculture production [a]						
Household harvested crops	0.28	1,411	0.39	1,232	-0.11**	<0.001
Household had any agriculture revenue7	0.26	1,375	0.37	1,210	-0.12**	<0.001
Total agriculture revenue per hectare (CFA) [c]	537 (7,431)	1,375	404 (996)	1,210	-133	0.512
Household had any farm investment costs	0.6	1,421	0.67	1,255	-0.07**	<0.001
Total agriculture investment costs per hectare (CFA) [c]	3,587 (35,721)	1,421	3,150 (89,612)	1,255	438	0.871
Total agriculture profit per hectare (CFA)[c]	-3,097 (31,094)	1,374	-281 (3,213)	1,209	-2,816**	<0.001
Rice production [b]						
Household planted rice	0.44	1,422	0.51	1,264	-0.07**	<0.001
Area of rice planted (hectares)	3.47	628	2.44	647	1.02*	0.014
Household harvested any rice	0.34	628	0.11	647	0.24**	<0.001
Rice yield (KG) per hectare [c]	10 (204)	628	0.5 (1.8)	647	9.9	0.225
Household had any rice revenue	0.31	628	0.09	647	0.23**	<0.001
Rice revenue per hectare (CFA) [c]	134 (810)	628	24 (108)	647	111**	0.001
Household had any rice investment costs	1.00	628	0.98	647	0.01*	0.022
Cost to farm rice per hectare (CFA) [c]	5018 (38,346)	628	6026 (124,832)	647	-1008	0.845
Hot season (wave 2)						
Overall agriculture production [a]						
Household harvested crops	0.55	1,411	0.55	1,263	-0.01	0.712
Household had any agriculture revenue	0.53	1,370	0.52	1,187	0.01	0.714
Total agriculture revenue per hectare (CFA) [c]	415 (2,119)	1,370	357 (1,886)	1,187	58	0.467
Household had any farm investment costs	0.58	1,411	0.55	1,239	0.03	0.081

TABLE B.5. *(CONT)*

Baseline measure	Treatment group: Mean (standard deviation)	Treatment group: Sample size	Comparison group: Mean (standard deviation)	Comparison group: Sample size	Difference	P-value
Total agriculture investment costs per hectare (CFA) [c]	1,697 (38,173)	1,411	1,667 (27,797)	1,239	30	0.981
Total agriculture profit per hectare (CFA) [c]	-1,293 (387,294)	1,370	-1,346 (28,444)	1,187	53	0.968
Rice production [b]						
Household planted rice	0.49	1,422	0.49	1,264	0.01	0.778
Area of rice planted (hectares)	2.97	703	2.07	618	0.9*	0.025
Household harvested any rice	0.9	703	0.97	618	-0.08**	<0.001
Rice yield (KG) per hectare [c]	6.9 (26)	703	39 (774)	617	-32	0.300
Household had any rice revenue	0.85	703	0.89	618	-0.03	0.069
Rice revenue per hectare (CFA) [c]	575 (2,814)	703	589 (2,572)	618	-14	0.926
Household had any rice investment costs	0.98	703	1.00	618	-0.02**	<0.001
Cost to farm rice per hectare (CFA) [c]	3328 (54,050)	703	3311 (39,305)	618	17	0.995
Rainy season (wave 3)						
Overall agriculture production [a]						
Household harvested crops	0.24	1,379	0.25	1,264	-0.01	0.637
Household had any agriculture revenue	0.21	1,322	0.25	1,255	-0.04*	0.034
Total agriculture revenue per hectare (CFA) [c]	105 (520)	1,322	110 (292)	1,255	-5	0.776
Household had any farm investment costs	0.41	1,416	0.49	1,263	-0.08**	<0.001
Total agriculture investment costs per hectare (CFA) [c]	193 (2,727)	1,416	178 (278)	1,263	15	0.835
Total agriculture profit per hectare (CFA) [c]	-75 (2,700)	1,321	-71 (374)	1,254	-4	0.957
Rice production [b]						
Household planted rice	0.27	1,422	0.24	1,264	0.03	0.058
Area of rice planted (hectares)	2.37	384	2.71	301	-0.34	0.465
Household harvested any rice	0.41	384	0.97	301	-0.56**	<0.001
Rice yield (KG) per hectare [c]	1.7 (3.3)	384	4.9 (3.0)	301	-3.2**	<0.001
Household had any rice revenue	0.4	384	0.94	301	-0.55**	<0.001

TABLE B.5. *(CONT)*

Baseline measure	Treatment group Mean (standard deviation)	Treatment group Sample size	Comparison group Mean (standard deviation)	Comparison group Sample size	Difference	P-value
Rice revenue per hectare (CFA) [c]	168 (361)	384	376 (234)	301	-209**	<0.001
Household had any rice investment costs	0.97	384	1.00	301	-0.03**	<0.001
Cost to farm rice per hectare (CFA) [c]	617 (5208)	384	341 (226)	301	275	0.301

Source: IWRM Project baseline survey data

Note: All values in this table are based on non-imputed data and the sample that was surveyed in all three baseline waves. Values are proportions unless otherwise indicated. Due to rounding, the value reported in the difference column may differ slightly from the difference between the values reported in the mean treatment and mean comparison columns.

[a] Sample includes all surveyed households with valid data

[b] Sample includes only households that planted rice that season except for the indicator variable for whether a household planted rice

[c] Variable has values are displayed in 1000s and include standard deviations (in 1000s) in parentheses.

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

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

Table B.5 displays baseline equivalence results for measures of overall agriculture production in the Delta region, including revenue and costs, as well as detailed results for rice production for each growing season. In the cold season, we find that treatment households are less likely to harvest crops, receive any agricultural revenue, or incur any agricultural costs, relative to the comparison group. However, those differences largely disappear during the hot and rainy seasons, except that comparison households are eight percentage points more likely to incur agricultural costs and four percentage points more likely to receive revenue from selling agriculture goods in the rainy season.

When looking specifically at rice production, we find notable differences during the rainy and cold seasons. In the rainy season, although a similar percentage of households planted rice in both groups, only 41 percent of treatment households that planted rice harvested any rice, compared to 94 percent of comparison households (with similar numbers for rice revenue). During the cold season, we see the opposite pattern. A larger percentage of comparison households planted rice, but of the households that planted rice, more treatment households harvested and sold rice (by 24 and 23 percentage points respectively). Given that IWRM activities sought to improve rice production, large baseline differences between the treatment and comparison groups raises a concern about the selection of the comparison area.[18]

Table B.5 also includes continuous measures of overall revenue, investment, and profit, as well as rice yields, revenue, and investment. We included standard deviations in parentheses for

[18] We also examined baseline levels of tomato and onion production. There were some differences between the treatment and comparison groups, but the percentage of households that planted and harvested these crops each season was small. We therefore focused this analysis on rice production, which was more widespread.

these measures and display results in 1000s. This is to illustrate a few points. The standard deviations for these measures are very large, even for a measure like rice yield per hectare, which we expect to have a narrow range within a confined geographic area.[19] Other measures show questionable mean values, such as large negative means for agriculture profit per hectare. We explored several methods to identify if outliers were driving the results and if we could appropriately remove those outliers, as discussed in Section B.3. As a result of our data quality concerns with these measures, we focus our analysis on binary variables indicating whether a household had any agriculture investment costs or revenue.

In the Podor region, we see large, statistically significant differences in aggregate agriculture production during the cold and hot season. A larger percentage of comparison households incur agricultural costs, receive agricultural revenue, and harvest crops than treatment households. During the rainy season, comparison households were much more likely to incur farm costs relative to treatment households, though agricultural revenues and the percentage of households that harvested crops were not significantly different between groups. When considering rice production, we see similar group differences to those seen in overall agricultural production. Agriculture production results for the Podor region are shown in Table B.6.

Table B.6. Baseline equivalence results for agriculture production (Podor region)

	Potential treatment group		Comparison group			
Baseline measure	Mean (standard deviation)	Sample size	Mean (standard deviation)	Sample size	Difference	P-value
Cold season (wave 1)						
Overall agriculture production [a]						
Household harvested crops	0.50	1,215	0.87	344	-0.37**	<0.001
Household had any agriculture revenue	0.48	1,166	0.86	323	-0.38**	<0.001
Total agriculture revenue per hectare (CFA) [c]	656 (4,174)	1,166	756 (920)	323	-10	0.452
Household had any farm investment costs	0.54	1,216	0.87	343	-0.33**	<0.001
Total agriculture investment costs per hectare (CFA) [c]	2,277 (31,141)	1,218	585 (2,193)	343	1,692	0.061
Total agriculture profit per hectare (CFA) [c]	-1,785 (31,805)	1,163	270 (738)	323	-2,055*	0.028

[19] We calculate that the ratio of the standard deviation to the mean for rice yields in the baseline data is about 20 in Delta and about 3 in Podor. By contrast, based on data reported in Poussin et al. (2005), the same ratio for rice yields in the Senegal River Valley is 0.22. This indicates that standard deviations for rice yields in our baseline data are between 13 and 91 times as large as those in Poussin et al. (2005), relative to the mean.

TABLE B.6. *(CONT)*

Baseline measure	Potential treatment group: Mean (standard deviation)	Potential treatment group: Sample size	Comparison group: Mean (standard deviation)	Comparison group: Sample size	Difference	P-value
Rice production [b]						
Household planted rice	0.12	1,224	0.55	345	-0.43**	<0.001
Area of rice planted (hectares)	0.48	148	1.04	189	-0.56*	0.037
Household harvested any rice	0.57	148	0.94	189	-0.37**	<0.001
Rice yield (KG) per hectare [c]	6.2 (30)	148	7.2 (22)	189	-0.9	0.735
Household had any rice revenue	0.28	148	0.71	189	-0.43**	<0.001
Rice revenue per hectare (CFA) [c]	133 (340)	148	368 (984)	189	-235**	0.002
Household had any rice investment costs	0.99	148	1.00	189	-0.01	0.319
Cost to farm rice per hectare (CFA) [c]	4,838 (39,664)	148	594 (2,919)	189	4244	0.196
Hot Season (wave 2)						
Overall agriculture production [a]						
Household harvested crops	0.25	1,175	0.71	331	-0.46**	<0.001
Household had any agriculture revenue	0.17	1,063	0.69	308	-0.52**	<0.001
Total agriculture revenue per hectare (CFA) [c]	93 (538)	1,063	321 (567)	308	-228**	<0.001
Household had any farm investment costs	0.53	1,216	0.77	342	-0.24**	<0.001
Total agriculture investment costs per hectare (CFA) [c]	3,418 (73,518)	1,216	284 (293)	342	3,135	0.137
Total agriculture profit per hectare (CFA) [c]	-3,032 (74,839)	1,060	3 (469)	308	-3,035	0.187
Rice production [b]						
Household planted rice	0.48	1224	0.63	345	-0.15**	<0.001
Area of rice planted (hectares)	0.61	582	0.64	217	-0.03	0.414
Household harvested any rice	0.34	582	0.82	217	-0.48**	<0.001
Rice yield (KG) per hectare [c]	1.7 (4.2)	582	3.7 (2.4)	217	-1.9**	<0.001
Household had any rice revenue	0.17	582	0.7	217	-0.53**	<0.001
Rice revenue per hectare (CFA) [c]	45 (142)	582	173 (178)	217	-128**	<0.001
Household had any rice investment costs	0.97	582	1.00	217	-0.03**	<0.001

TABLE B.6. *(CONT)*

Baseline measure	Potential treatment group		Comparison group			
	Mean (standard deviation)	Sample size	Mean (standard deviation)	Sample size	Difference	P-value
Cost to farm rice per hectare (CFA) [c]	7,072 (106,194)	582	308 (167)	217	6764	0.125
Rainy Season (wave 3)						
Overall agriculture production [a]						
Household harvested crops	0.34	1,203	0.34	345	0.01	0.840
Household had any agriculture revenue	0.28	1,090	0.33	338	-0.05	0.095
Total agriculture revenue per hectare (CFA) [c]	116 (303)	1,090	301 (1,034)	338	-186**	0.001
Household had any farm investment costs	0.46	1,168	0.86	343	-0.39**	<0.001
Total agriculture investment costs per hectare (CFA) [c]	3,210 (48,171)	1,168	394 (377)	343	2,816*	0.046
Total agriculture profit per hectare (CFA) [c]	-3,306 (49,705)	1,096	-359 (400)	337	-2,947*	0.050
Rice production [b]						
Household planted rice	0.27	1,224	0.19	345	0.08**	0.001
Area of rice planted (hectares)	0.60	332	0.64	66	-0.04	0.460
Household harvested any rice	0.97	332	0.95	66	0.02	0.578
Rice yield (KG) per hectare [c]	6.6 (21)	332	3.0 (2.8)	66	3.5**	0.004
Household had any rice revenue	0.83	332	0.85	66	-0.01	0.773
Rice revenue per hectare (CFA)[c]	325 (379)	332	288 (253)	66	37	0.331
Household had any rice investment costs	0.91	332	0.88	66	0.03	0.480
Cost to farm rice per hectare (CFA) [c]	5,162 (64,626)	332	373 (261)	66	4788	0.178

Source: IWRM Project baseline survey data

Note: All values in this table are based on non-imputed data and the sample that was surveyed in all three baseline waves. Values are proportions unless otherwise indicated. Due to rounding, the value reported in the difference column may differ slightly from the difference between the values reported in the mean treatment and mean comparison columns.

[a] Sample includes all surveyed households with valid data

[b] Sample includes only households that planted rice that season except for the indicator variable for whether a household planted rice

[c] Variable has values are displayed in 1000s and include standard deviations (in 1000s) in parentheses.

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

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

Table B.7. Baseline equivalence results for land tenure security characteristics (Delta region)

	Treatment Group		Comparison Group			
Baseline Measure	Mean	Sample size	Mean	Sample size	Difference	P-value
Household has at least one land title	0.43	1,149	0.52	929	-0.09**	<0.001
Household has titles to all land	0.30	1,149	0.26	929	0.05*	0.014
Household expressed concern about losing land	0.42	1,149	0.61	929	-0.19**	<0.001
Household knows the deliberation process to receive a land title	0.55	1,149	0.46	929	0.09**	<0.001
Household can sell their land	0.37	1,149	0.39	929	-0.02	0.398
Household can rent their land	0.72	1,149	0.72	929	0.00	0.980

Source: IWRM Project baseline survey data (cold season, wave 1)

Note: All values in this table are based on non-imputed data and the sample that was surveyed in all three baseline waves. Values are proportions unless otherwise indicated. Due to rounding, the value reported in the difference column may differ slightly from the difference between the values reported in the mean treatment and mean comparison columns. Sample includes households with valid data who reported owning farm land during the cold season.

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

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

Table B.7 provides baseline equivalence results for measures of land tenure security. We find statistically significant differences in the majority of land tenure security measures. Of particular interest is that treatment households are 19 percentage points less likely to be concerned about losing land and 9 percentage points more likely to know the deliberation process to receive a land title relative to comparison households. These large differences could be early outcomes of the land inventory activity, since LTSA Phase I occurred prior to the baseline survey and affected some comparison areas. Although results are presented for the cold season wave of the survey, we see similar results in the other two waves except for a substantial decrease in waves 2 and 3 of the percentage of treatment households who have at least one land title (29 percent in wave 2) and have titles to all plots (18 percent in wave 2). Comparison group results are similar to those in wave 1.

In the Podor region, comparison households are more likely to have formal land titles and less likely to be concerned about losing land compared to the treatment group. Treatment households are much more likely—by 20 percentage points—to know the deliberation process to receive a land title. Some of these differences could be an effect of LTSA phase I activities that occurred prior to the survey in the treatment area and some comparison areas, but the results could also reveal other underlying differences in property rights between the Podor treatment and comparison areas. Results are broadly similar in waves 2 and 3, with no large changes in land titling percentages. Full results for wave 1 are shown in Table B.8.

Table B.8. Baseline equivalence results for land tenure security characteristics (Podor region)

	Potential treatment group		Comparison group			
Baseline measure	Mean	Sample size	Mean	Sample size	Difference	P-value
Household has at least one land title	0.57	896	0.67	308	-0.10**	0.002
Household has titles to all land	0.46	896	0.56	308	-0.10**	0.003
Household expressed concern about losing land	0.27	896	0.19	308	0.08**	0.004
Household knows the deliberation process to receive a land title	0.41	896	0.21	308	0.20**	<0.001
Household can sell their land	0.49	896	0.50	308	-0.01	0.811
Household can rent their land	0.71	896	0.74	308	-0.03	0.298

Source: IWRM Project baseline survey data (cold season, wave 1)

Note: All values in this table are based on non-imputed data and the sample that was surveyed in all three baseline waves. Values are proportions unless otherwise indicated. Due to rounding, the value reported in the difference column may differ slightly from the difference between the values reported in the mean treatment and mean comparison columns. Sample includes households with valid data who reported owning farm land during the cold season.

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

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

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APPENDIX C

MAPS

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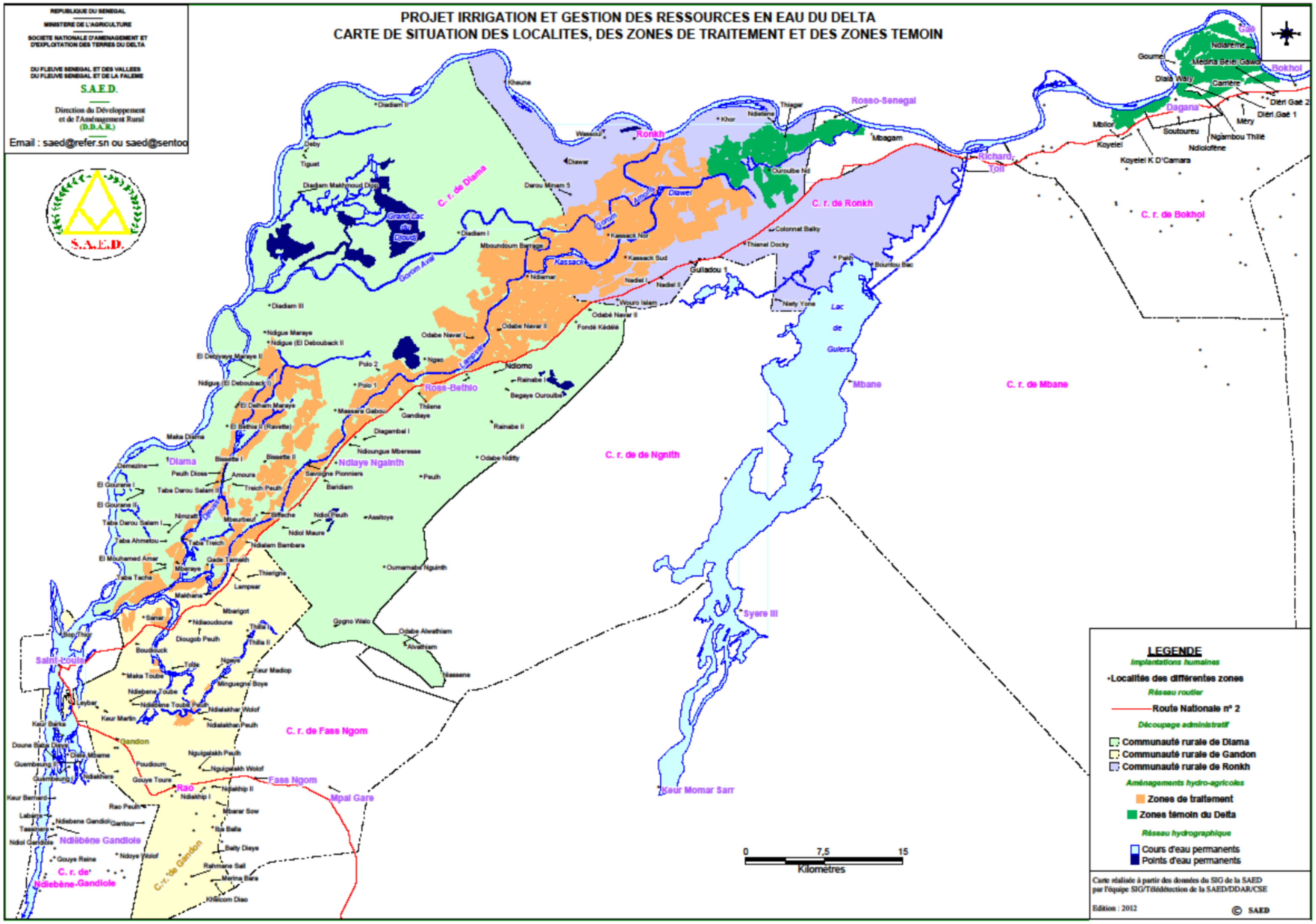
Figure C.1. Map of Senegal

The IWRM Project took place in the Senegal River Valley (SRV) in Northern Senegal. Figure C.1 details a map of Senegal that highlights the location of the SRV. This evaluation occurred in two areas of the SRV: the Delta and Podor regions. Figure C.2 shows the treatment areas in orange and the comparison areas in dark green for the Delta region. The map, produced by SAED, also details other geographical features of interest, including *communautés rurales*, villages, and water sources. We do not have a map for Podor that accurately reflects how land was allocated to beneficiaries.

Figure C.2. Map of the Delta region



APPENDIX D

ADJUSTMENTS TO THE EVALUATION STRATEGY FOR THE IWRM PROJECT IN SENEGAL

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MEMORANDUM

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TO: Julian Glucroft, MCC

FROM: Mathematica Policy Research **DATE:** 3/16/2017

SUBJECT: Adjustments to our strategy for the evaluation of the Senegal Compact's Irrigation and Water Resource Management (IWRM) Project

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A key element of the evaluation strategy for the IWRM project has been a difference-in-differences analysis that compares changes in treated households to changes in a group of comparison households that are chosen using propensity score matching to ensure that they are as similar as possible to the treated households. On a recent trip, we found that the farming conditions in comparison areas are different from those in treatment areas, which could affect the validity of our approach under certain circumstances. This memo provides background on our recent findings, their implications for our evaluation strategy, and our proposed response. Overall, we plan to continue with our original analysis and supplement it in two ways. First, we will conduct qualitative research to investigate the validity of the propensity score matching method. Second, we will conduct a simple, unmatched difference-in-differences analysis as a sensitivity test for our matching design.

Background

In December 2016, the Mathematica evaluation team traveled to Senegal to assess the evaluation design and learned that, before the project was implemented, the comparison areas for the difference-in-differences evaluation of the IWRM project were substantially different from the treatment areas before the project was implemented. Local stakeholders consistently described comparison areas as having better farming conditions than treatment areas, citing their superior access to irrigation, publicly managed institutions to assist farmers, and a history of agricultural development. These descriptions are consistent with evidence from the baseline survey of treatment and comparison households, which showed that comparison households were more likely to plant, harvest, and receive revenue from crops, particularly in seasons other than the rainy season.

Furthermore, a former member of the team responsible for selecting comparison areas[1] told us that these areas were selected expressly because their characteristics were similar to the

[1] The team responsible for deciding how the comparison group would be chosen consisted of staff at the Millennium Challenge Account—Senegal (MCA-Senegal)—along with members of the Société Nationale d'Aménagement et

outcomes that the project hoped to achieve in the treatment areas. The finding that comparison areas were different at baseline—and that they may have been intentionally different —has implications for how we interpret the results of our difference-in-differences analysis.

Implications for our evaluation strategy

We originally proposed to conduct a difference-in-differences analysis in which the treatment and comparison groups were matched at baseline using propensity scores.[2] This strategy ensures that project effects are estimated by comparing treatment households to comparison households that were similar in observable characteristics before the project was implemented. For estimates of project impacts to be unbiased using these methods, a key assumption is that characteristics that were *not* observed at baseline but that affect outcomes were similar as well. These unobserved characteristics include features of the farming environment such as the quality of access to irrigation and the presence of publicly managed institutions to assist farmers. As discussed above, these characteristics were recently found to be broadly different between the treatment and comparison areas. However, the characteristics are not available at the household level because they were not included in the baseline survey of households.

Propensity score matching may help to balance these unobservable characteristics by selecting comparison households that did not benefit from the improved farming environment that characterized the majority of the comparison areas. However, it may also select comparison households that were in a better farming environment but whose other unobservable characteristics attenuated the benefits of their environment. For example, a comparison household that is matched to a treatment household with similar observable farming outcomes may have been in a favorable farming environment but realized low crop yields due to other unobservable circumstances such as poor soil. If such unobserved differences exist systematically between the matched treatment and comparison households, our estimates of the project's impacts could be biased.

Adjustments to our evaluation strategy

We believe that propensity score matching on observable baseline characteristics still provides the best means of reducing differences between the treatment and comparison groups by ensuring that that at least the observable characteristics were similar at baseline. However, we are mindful of the possibility that unobservable baseline characteristics could differ as discussed

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d'Exploitation des Terres du Delta du fleuve Sénégal et des Vallées du fleuve Sénégal et de Falémé (SAED) who formed a project management unit that was embedded in MCA-Senegal during the Compact. The team worked with members of Agence Nationale de la Statistique et de la Démographie (ANSD) to choose comparison households for the baseline survey sample.

[2] Moorthy, A., T. Coen, K. Naeve, J. Brecher-Haimson, and S. Hughes. "Evaluation of the Irrigation and Water Resource Management Project in Senegal: Design Report." Report for the Millennium Challenge Corporation. Princeton, NJ: Mathematica Policy Research, August 2016.

above. Our adjusted strategy is therefore intended to retain the benefits of this matching technique while addressing the possibility that this technique might match households whose unobservable characteristics are not similar.

We will estimate project effects using a difference-in-difference approach with propensity score matching as planned, but we will complement our analysis in two ways. First, we will explore qualitatively whether households in comparison areas that appeared similar to treatment households at baseline were actually in similar environments or had other unobserved reasons for realizing similar outcomes. To do this, we will first examine the results of the propensity score matching to determine the locations of comparison households whose observable characteristics were similar at baseline to the characteristics of the treatment households. We will then interview local government officials and village leaders in these areas and in treatment areas to learn more about the environment in these areas at baseline. In particular, we will explore whether comparison households in these areas were likely to be similar to treatment households in terms of their access to government and donor assistance, the quality and extent of the existing irrigation infrastructure, and the methods and technologies (such as the type of pump) they typically use to access irrigation. This investigation will provide suggestive evidence of the validity of the matches created using propensity scores. In addition, the qualitative analysis may provide information that can be used to create retrospective questions in our endline survey that improve our ability to identify which comparison households were the most similar to treatment households at baseline. For example, we may learn the names of specific irrigation perimeters in comparison areas in which the farming environment was similar to the farming environment of the treatment areas at baseline. We could then ask at endline whether households farmed land in those perimeters at baseline and incorporate the responses into our propensity matching strategy to identify comparison households that are more similar to treatment households.

Second, we will complement the original analysis with a simple difference-in-differences analysis that includes all households in the treatment and comparison groups that were identified at baseline and does not use matching techniques or regression controls to account for characteristics that differed between groups. The analysis will estimate the following equation:

$$Y=\alpha+ \beta_1\tau_1+\beta_2 IWRM + \beta_3\tau_1 IWRM + \varepsilon$$

Y is the outcome measure of interest; *IWRM* indicates whether a given household was in a treatment area; τ_1 is the time period; α is the intercept term representing the average Y value for the comparison group at baseline; β_1 is the effect of time on the comparison group; β_2 is the fixed effect of being in the treatment group; β_3 is the coefficient of interest, the marginal effect of project activities; and ε is a random error term.

This simpler analysis provides a sensitivity test for the results of the propensity score matching model. To determine whether our findings are sensitive to the characteristics of the groups, we will examine whether and how the results of this analysis differ from the propensity score matching analysis and also how the characteristics of the groups used for this analysis differ from those in the propensity score matching analysis. To present the results of the analysis, we will discuss the estimates and the statistical significance of the project's effects. We will also use graphs to show how the treatment and comparison group outcomes changed over time.

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