Niger Irrigation and Market Access

Baseline Report

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List of acronyms

EDR	Evaluation design report
ERR	Economic rate of return
GDP	Gross domestic product
IMAP	Irrigation and Market Access Project
IRB	Institutional review board
IWUA	Irrigation water user association
MCA-N	Millennium Challenge Account-Niger
MCC	Millennium Challenge Corporation
NDVI	Normalized difference vegetation index
ONAHA	*l'Office Nationale des Aménagements Hydro*-*agricoles* (National Office for Irrigation Schemes)
PAP	Project affected person
PPP	Purchasing power parity
RAP	Resettlement Action Plan
RMSE	Root mean square error
SDI	Société de Développement International
WEAI	Women's Empowerment in Agriculture Index

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I. Introduction

A. Overview of the IMAP

The agricultural sector in Niger provides a livelihood for more than 80 percent of the population and contributes to approximately one-fourth of the country's gross domestic product (GDP) (CIA 2018). The majority of Niger's agricultural production is rainfed; in 2018, irrigated farmland only accounted for 0.21 percent of the total agricultural land in the country (FAO 2020b). Without access to irrigation, crop production is vulnerable to droughts, which are frequent and can cause severe crop losses. Inadequate irrigation infrastructure also constrains the growth of dry season agricultural production (World Bank 2013). Productivity gains are further hampered by farmers' lack of market access to improved seeds, low adoption of new technologies, and inadequate extension services (World Bank 2017b). As a result, Niger has one of the lowest agricultural yields in the world (FAO 2020a). Furthermore, the yields of female farmers are lower than those of male farmers. Agricultural land managed by women produce 19 percent less per hectare than land managed by men. This productivity gap is driven by challenges women face in employing male labor, lower use of inorganic fertilizer per hectare relative to men, and lower rates of land ownership among women (Backiny-Yetna and McGee 2015).

Low agricultural yields in a population highly dependent on agriculture result in high levels of food insecurity and low levels of development. More than 1.5 million people in Niger are chronically food insecure and millions more experience food shortages during the dry season. Nearly 20 percent of the Nigerien population is unable to meet their food needs, rising to 30 percent when rainfall is poor (WFP 2017).

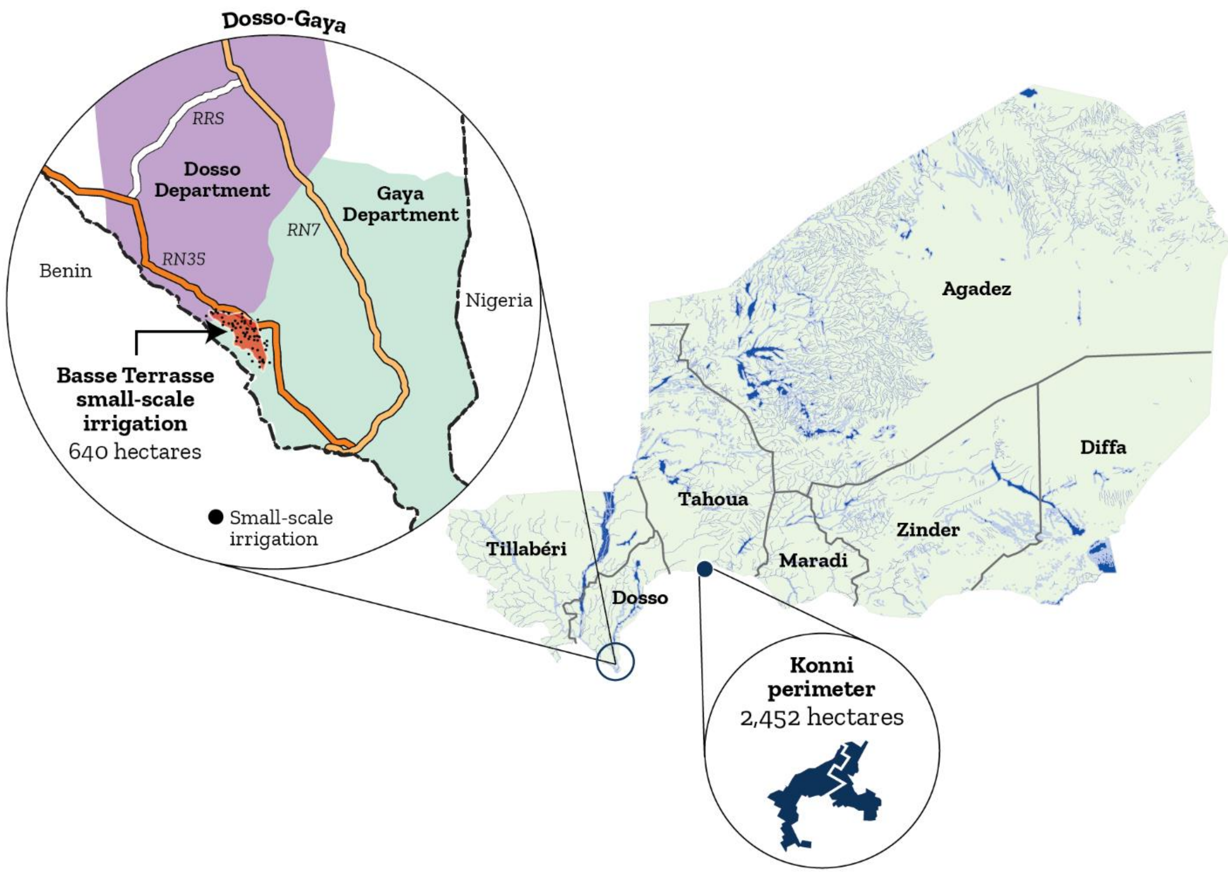
To improve Niger's agricultural productivity and increase the incomes of rural farmers, the Millennium Challenge Corporation (MCC) is partnering with the Government of Niger through the $426 million Niger Sustainable Water and Agriculture Compact. The Compact, which is being implemented from 2017 to 2022, includes (1) the Climate-Resilient Communities Project, which aims to improve agricultural productivity for small-scale farmers, preserve natural resources, and improve market sales of certain goods, and (2) the Irrigation and Market Access Project (IMAP), which aims to increase agricultural productivity and agricultural sales through complementary activities.

Four overlapping activities make up the $250 million IMAP. They are the Irrigation Perimeter Development, Management Services and Market Facilitation, Roads for Market Access, and Policy Reform activities. The first two activities are in two areas: around the town of Konni and close to the Sia Kouanza villages located in the Dosso area of Niger, as shown in **Figure I.1**.

The Roads for Market Access Activity is taking place only in the Dosso area, and the Policy Reform Activity is national. Because activities in that area are still under development, this baseline report focuses only on the irrigation perimeter in Konni.

In Konni, the Irrigation Perimeter Development Activity will rehabilitate two surface runoff dams, a reservoir, and a supply channel for approximately 2,452 hectares of an existing irrigated perimeter (MCA-N 2019). Many of these systems were built in 1976 and 1982 and now require rehabilitation and upgrades (MCC 2016). In addition, the activity will include training in soil conservation to limit siltation (accumulation of sediments in irrigation canals), as well as repair and rehabilitation of the irrigation system to limit water loss.

Figure I.1. Map of project regions



The project's theory of change stipulates that investing in large-scale irrigation infrastructure will result in increased water availability for project beneficiaries during the rainy and dry seasons (MCA-N 2019). The project will supplement the large-scale irrigation infrastructure investments with technical assistance and training in water management, savings, improved production practices, agricultural marketing, and other complementary skills designed to increase overall production and sales on the perimeters. **Figure I.3** shows the pathway from anticipated activities to short-, medium-, and long-term outcomes, which include increased crop yields, increased quantity and value of crops sold, economic empowerment of women and youth, and improved nutrition and hygiene practices of households. The ultimate goal of the project is to increase the incomes and food security of rural households. More information on the project, logic model, and theory of change can be found in the evaluation design report (EDR) (D'Agostino et al. 2019).

Figure I.2. IMAP program logic

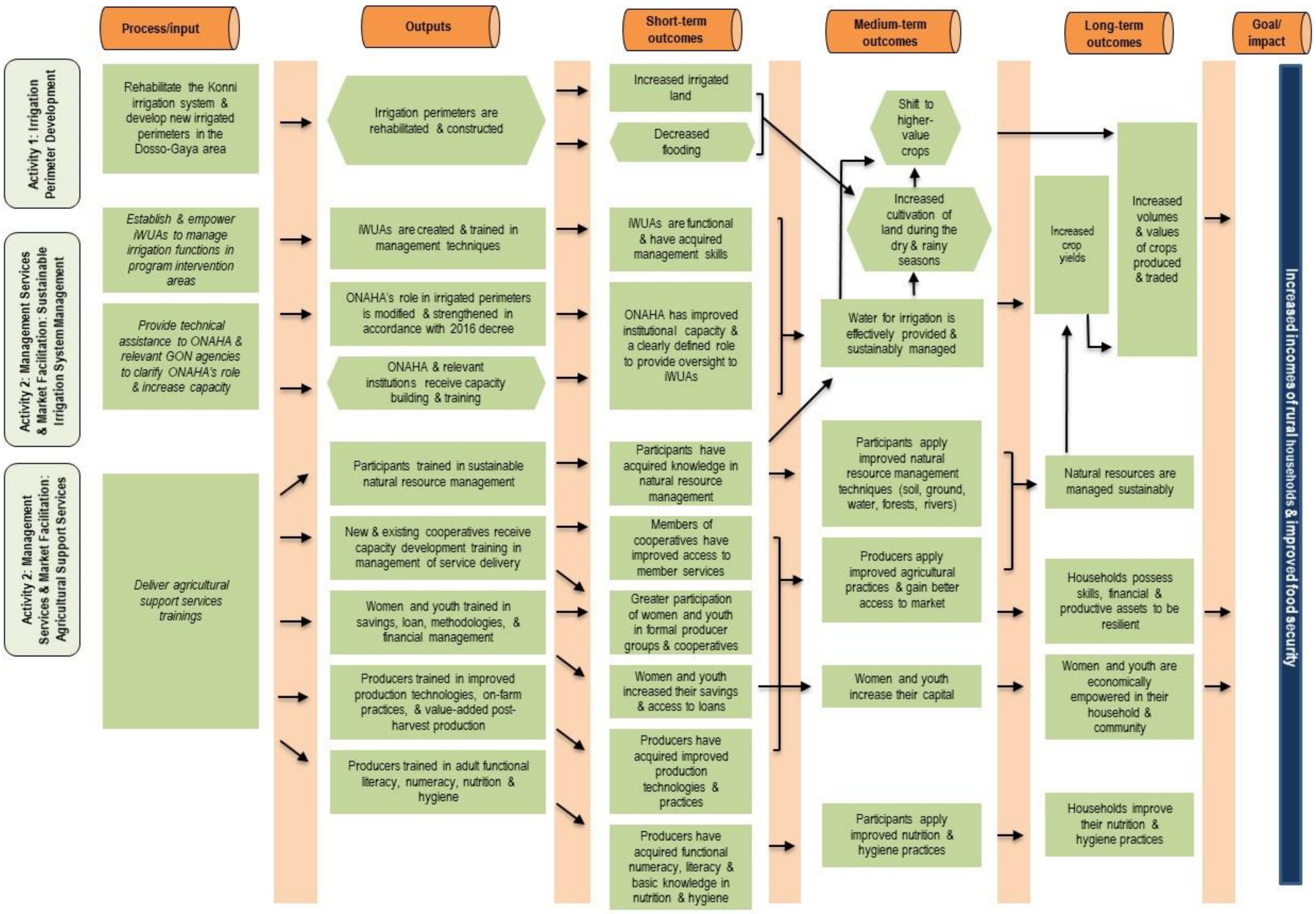
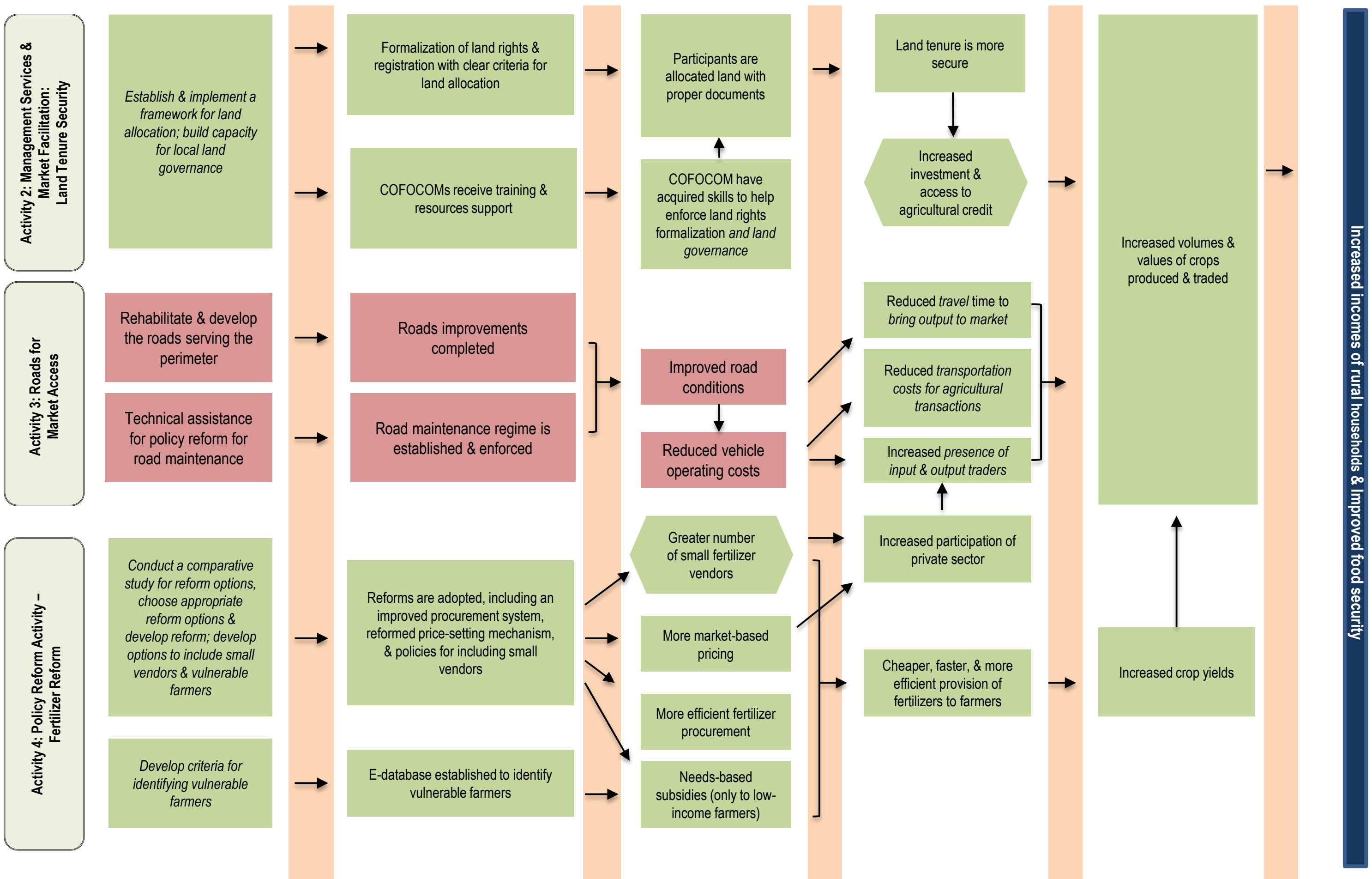


Figure I.3. IMAP program logic



Notes: The inputs, outputs, and short-term outcomes highlighted in red in the logic model pertaining to Activity 3: Roads for Market Access are beyond the scope of this evaluation. We are only assessing the effects of Activity 3 for beneficiaries in the Dosso area. The IMAP program logic was developed based on MCC (2017) and further input from MCC. IWUA = irrigation water user association, ONAHA = *l'Office Nationale des Aménagements Hydro-agricoles* (National Office for Irrigation Schemes).

B. Overview of evaluation and baseline

Mathematica developed an evaluation design to assess MCC's investments on the Konni perimeter as part of the broader IMAP EDR (D'Agostino et al. 2019). After the EDR was approved in December 2019, Mathematica conducted household surveys with 782 project-affected households in Konni in March 2020 to inform this baseline report. The EDR includes a mixed-methods approach to evaluate IMAP investments in Konni and at the national level; this report, however, focuses specifically on the quantitative performance evaluation (pre-post analysis) of project activities on the Konni irrigation perimeter using data from the household survey. The analysis presented in this report establishes a baseline to enable the estimation of changes in agricultural outcomes for beneficiary households in Konni at interim and endline.

B.1. Research questions

The EDR defines the comprehensive set of research questions that this evaluation will address. **Table I.1** sets out the research questions that are relevant to the pre-post analysis of outcomes on the Konni perimeter and for which this report will establish baseline values. In addition, **Table I.1** also presents the evaluation method used to address each research question, and the data source and type. The research questions relate to (1) changes in agricultural outcomes and household incomes, (2) outcomes related to the performance of the irrigation system, (3) outcomes related to land tenure security, and (4) the cost of fertilizer. The primary and secondary outcomes linked to these research questions are discussed in detail in **Chapter II, Section B**.

Table I.1. Evaluation design overview: Summary of research questions, methods, and data sources

Question group		Evaluation method	Data source and type
Overarching questions			
RQ3	Did PAP households experience changes in their household incomes, volumes, and value of agricultural products sold and traded, food and nutritional security, and production of cash crops?	• Pre-post analysis	• Surveys of households
Irrigation Perimeter Development Activity			
RQ12	Did irrigated land increase as expected (as a whole and per family)? If not, why not?	• Pre-post analysis	• Surveys of households
RQ13	Did the cost of irrigation water change? If not, why not?	• Pre-post analysis	• Surveys of households
Management Services and Market Facilitation Activity			
RQ22	Were the level and risk of land conflict reduced? Did land tenure security increase?	• Pre-post analysis	• Surveys of households
Policy Reform Activity			
RQ31	Have reform activities made fertilizer more affordable and accessible?	• Pre-post analysis	• Surveys of households

Notes: PAP = project affected person. See **Appendix A, Table A.2** for a full presentation of the evaluation design and research questions.

For completeness, **Table A.1** in **Appendix A** provides a comprehensive list of all the research questions related to the Konni Irrigation Perimeter Development Activity and **Table A.2** provides the complete set of research questions contained in the EDR for all subactivities. Research questions that are not relevant for the pre-post analysis are presented in italics in **Table A.2**.

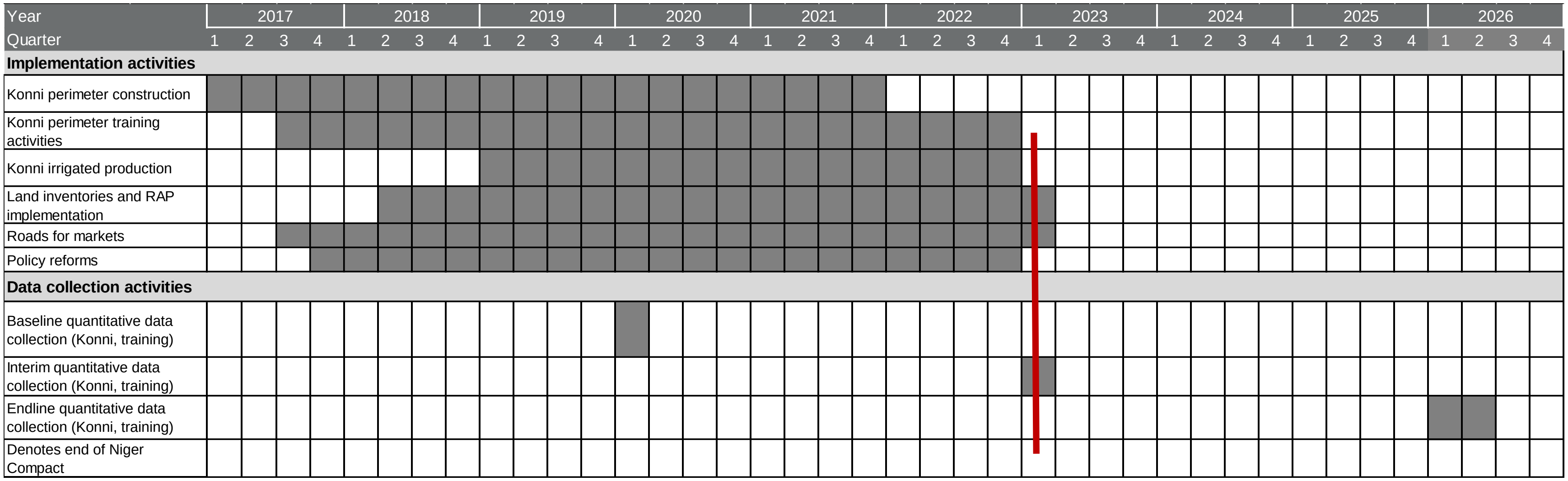
B.2. Quantitative evaluation methodology

The EDR provides information on the different methods we use to address specific research questions and the reasons for choosing a specific evaluation methodology (D'Agostino et al. 2019). Because we cannot construct a valid comparison group, our primary evaluation strategy is to conduct a pre-post analysis of those outcomes for which we can establish a meaningful baseline. This report presents the pre-intervention baseline values for the outcomes of interest at the crop, plot, individual, household, and perimeter levels, based on household survey data from the Konni perimeter. At interim and endline, we will estimate the average change in these outcomes over time. We will also estimate how outcomes differ for members of different subgroups; thus, this report also includes baseline values disaggregated by the sex of the project affected persons (PAPs) in the household (households with only female PAPs versus households with at least one male PAP), type of land tenure documentation for plots (plots with formal documentation versus plots lacking formal documentation), and access to irrigation in the dry season (for household income outcomes).

C. Timeline for data collection, evaluation, and project activities

The baseline quantitative data collection in Konni, upon which this baseline report is based, took place March 8–21, 2020. The data collection centered around measuring agricultural activities and outcomes in the dry season from October 2018–May 2019 and the rainy season from June–September 2019. **Figure I.4** presents the timeline for the implementation activities on the Konni perimeter and data collection for the evaluation, beginning in the first quarter of 2020. Given that implementation began after the end of the 2019 rainy season, the baseline survey should be well placed to serve as a true pre-intervention baseline.

Figure I.4. Timeline for planned implementation and data collection activities

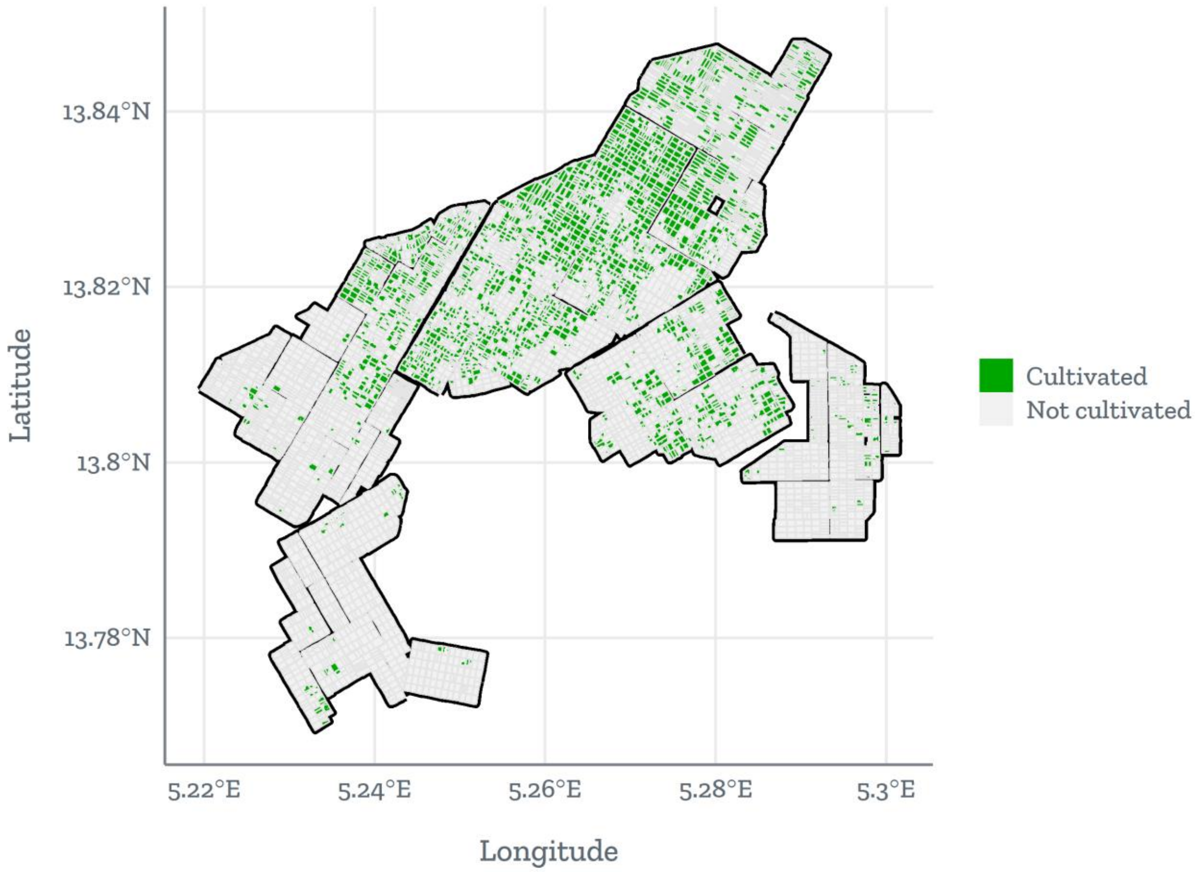


D. Key baseline findings

In this section, we provide a summary of the key findings. **Chapter II, Section C** presents all findings in more detail. The main constraint to cultivation and income-generating activity on the Konni perimeter is lack of water in the dry season. Almost all plots (97 percent) were cultivated in the past rainy season, for a total perimeter cultivation of 2,357 hectares. However, in the dry season from October 2018–May 2019, only 33 percent of plots were cultivated, resulting in only 808 hectares of dry season cultivation out of a total perimeter area of 2,558 hectares. This estimated area is based on remotely sensed indicators of cultivation, which suggest the estimate of about 70 percent for the farmer-reported cultivated area (from the household survey) is significantly over-reported. Among farmers who reported cultivation in the dry season, the majority used irrigation (80 percent); most of those using irrigation (88 percent) reported that it was available when they needed it.

This dry season cultivation pattern is clearly visible in **Figure I.5,** which provides a map of cultivation in the 2018/2019 dry season on the perimeter, based on remote sensing data. We proxy vegetation growth with normalized difference vegetation index (NDVI) values collected from Sentinel-2 satellites. Areas shaded in darker green, corresponding to higher NDVI values, indicate comparatively higher vegetation growth. Since much of dry season production is dependent on irrigation, **Figure I.5** depicts large segments of the perimeter that were either not cultivated or only partly cultivated. NDVI values are notably lower in the westernmost and southwestern parcels, the areas farthest from the reservoir.

Figure I.5. Konni perimeter area with 2018/2019 dry season cultivation



Source: Mathematica calculations using remotely sensed Sentinel-2 data.

Notes: NDVI = normalized difference vegetation index. Map values are based on whether a pixel's NDVI value ever exceeded 0.42 between January 1 and February 28, 2019. The cutoff value of 0.42 minimized the root mean square error (RMSE) between the Konni-wide predicted cultivated area using remotely sensed data alone and the observed cultivation area reported by ONAHA. NDVI is a remotely sensed proxy for vegetation.

As cash crops are primarily grown in the dry season (whereas traditional crops dominate the rainy season), households without dry season irrigation have limited opportunities to generate agricultural income. Average annual household income among households with access to dry season irrigation was 58 percent higher than in households without dry season irrigation. Average crop sales among households with dry season irrigation were more than six times that of households without dry season irrigation.

Table I.2 compares the perimeter-level yields for focus crops estimated for the 2018–2019 rainy and dry seasons in the economic rate of return (ERR) model (Turiansky et al. 2018) and the yields calculated from the baseline household survey data. In general, the baseline yields in the rainy season and the cereal yields in the dry season that inform the ERR model are lower than the yields we calculated from household survey data. For the vegetable yields in the dry season, the opposite is true. The dry season vegetable yields calculated from our baseline survey are lower in the dry season than those estimated in the ERR model. In the rainy season, all of the cereal, pulse, and vegetable yields are also higher. This is relevant to the potential benefit streams associated with provision of irrigation that underlie the ERR projections, such as expected increased yields and a shift in crop choice toward higher-value crops. Since the total rainfall received in 2019 (501 mm) approximated the region's long-term mean (494 mm), we do not see evidence for precipitation patterns being a source of any observed anomalies in crop yields against their typical values. We provide further discussion on Konni's historical rainfall levels in **Appendix E**.

Table I.2. Perimeter-level yields, CBA model values, and baseline survey values

Indicator	CBA model	Baseline survey
Yield in dry season (t/ha)		
Corn	3.25	3.77
Sorghum	3.80	4.68
Tomatoes	NA	18.52
Anise	2.05	2.96
Cabbage	48.00	33.53
Onions	32.00	19.75
Wheat	3.20	5.88
Yield in rainy season (t/ha)		
Corn	2.45	5.25
Sorghum	2.11	3.49
Tomatoes	24.00	31.68
Cowpeas	1.05	2.48
Millet	1.56	4.82

Notes: The CBA model also provides estimates for yields for dolique and cassava in the dry season and squash in the rainy season. We are not able to provide estimates for yields for these crops due to small sample sizes in the household survey. The CBA model does not provide estimates of yields for tomatoes in the dry season or groundnuts in the rainy season, which are both focus crops.

NA = not available.

E. Road map of the report

This baseline report contains three chapters. **Chapter I** provides an overview of the project and evaluation. **Chapter II** presents an overview of the sampling methodology, baseline sample, and outcome indicators, followed by crop-, plot-, household-, and perimeter-level outcomes for Konni at baseline, disaggregated by sex of household PAPs. **Chapter III** concludes the report with a discussion of the administration of the evaluation, including institutional review board (IRB) approval, data access and privacy, the dissemination plan, and the evaluation team. The appendices contain supplemental information including additional research questions (**Appendix A**); sampling probabilities, response rates, and balance (**Appendix B**); outcomes disaggregated by type of land tenure documentation (**Appendix C**); differences in area cultivated estimates between survey-based and remote sensing analysis (**Appendix D**); historical rainfall patterns (**Appendix E**); and stakeholder comments (**Appendix F**, forthcoming).

II. Konni baseline analysis

A. Overview of sampling

In this section, we outline our sampling methodology, sample weighting to achieve perimeter-level estimates, and the key characteristics of our baseline sample. We achieved very high survey response rates and our sample is representative of the population on the Konni irrigation perimeter.

A.1. Definition of sample and response rates

Using the RAP (Resettlement Action Plan) census dated November 2019 as our sampling frame, which includes all plots and PAPs on the Konni irrigation perimeter, we drew a random stratified sample of PAPs for our baseline survey.[1] We conducted sampling at the individual level and conducted interviews at the household level. We therefore effectively sampled and interviewed the household to which a sampled PAP belongs and all plot(s) associated with that household. **Figure II.1**, below, illustrates the geographic spread of sampled plots on the perimeter and shows that our sampling strategy resulted in ample geographic coverage of the perimeter.[2]

We constructed a stratified sample to ensure that our baseline survey would be representative of the perimeter as a whole and would include both male and female PAPs with landholdings of all sizes. To accomplish this, individual PAPs were first stratified by gender and total land holdings on the perimeter. The sample was then drawn at random from the RAP census for the following strata from the November 2019 census: (1) female PAP, (2) male PAPs with less than a total of 0.25 hectares of perimeter land, (3) male PAPs with at least 0.25 but no more than 1.5 hectares in total of perimeter land, and (4) male PAPs with more than 1.5 hectare in total of perimeter land.

Sampling was performed on land holding records from the RAP census collected prior to a *remembrement* (parcel consolidation) process in late-2019 that redistributed land from individuals holding more than 1.5 hectares and stipulated a 0.25-hectare minimum parcel size. As a result, land holdings reported in the baseline survey differ from the holdings listed in the RAP census data at the time of sampling. The parcel consolidation in itself does not affect our analysis because the probability of being sampled (and the associated sample weights) are unchanged by the *remembrement.* As such, all forthcoming analyses will be based on the outcomes observed for the fixed group of sampled individuals over time. However, the interpretation of the indicator for stratum 4 changes as these PAPs no longer hold more than 1.5 hectares.

The resulting sample is representative of the perimeter population and intentionally oversamples individuals in strata with few respondents (females and large landowners). Based on the RAP census, 5 percent of PAPs are female, 8 percent are males with small landholdings, 86 percent are males with medium landholdings, and less than 1 percent are males with large landholdings. From the RAP census, we selected 67 percent of women, 25 percent of men with less than 0.25 hectares, 14 percent of men owning between 0.25 and 1.5 hectares, and all men with more than 1.5 hectares for our household survey (see **Appendix B, Table B.1** for sampling probabilities). The resulting distribution of randomly sampled

[1] PAPs are project beneficiaries, defined as individuals (and members of their household) who will have access to irrigated land on the perimeter.

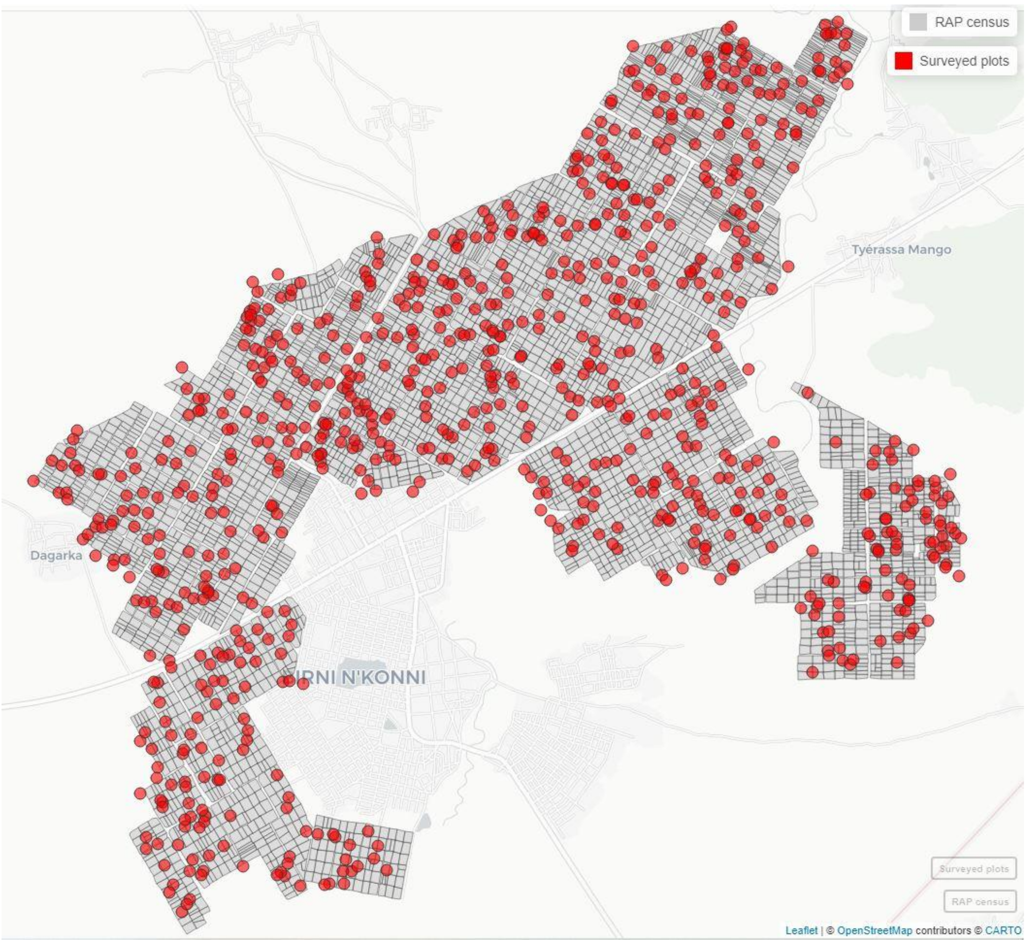
[2] To avoid revealing the identities of respondents, the exact locations of sampled plots are jittered. Although all plots are within the perimeter boundaries, the scrambling of location data leads to some plots being represented as lying outside the perimeter boundaries.

PAPs in the household survey is 19 percent female, 11 percent males with small landholdings, 66 percent males with medium landholdings, and 4 percent males with large landholdings (see **Table B.2**). Our sample has a similar distribution to that of the RAP census, features the most common type of PAP (males who own at least 0.25 but no more than 1.5 hectares), and intentionally overrepresents female PAPs (to enable gender-disaggregated analysis). It also includes all large landowners (males who own more than 1.5 hectares), given the small number of PAPs with more than 1.5 hectares on the perimeter.

To develop perimeter-level estimates from our sample, we apply strata-specific sampling weights that account for the differing probabilities of being sampled. These probabilities also effectively reflect plot sizes and the proportion of land on the perimeter they represent. Sampling weights are constructed as the inverse of strata sampling probabilities.

Our baseline survey had a very high response rate and was representative of the population of PAPs and plots on the perimeter. Column 3 of **Table B.1** shows that response rates were 97 percent or greater across all subgroups of PAPs. **Table B.2** demonstrates that the randomly drawn sample is representative of the perimeter as a whole and that the sample does not differ from the perimeter by irrigation access, how the plot was acquired, or cultivation patterns. Differences in the distribution of PAPs across the four strata are intentional and the result of our sampling methodology described above.

Figure II.1. Map of perimeter and approximate location of sampled observations



Note: A subset of sampled plots appear to be outside of the perimeter due to jittering.

A.2. Description of Konni PAPs and households at baseline

In **Table II.1**, we present weighted statistics from our baseline survey that characterize the population of PAPs and households on the Konni perimeter at the start of the IMAP. Understanding the characteristics of households at baseline, in particular their landholdings, household composition, and poverty level, is important to validate the program logic, interpret our baseline statistics, and later compare to household characteristics after the project is concluded. As discussed previously, at baseline the majority of PAPs are male (only 6 percent are female) and most male PAPs (86 percent) were drawn from the strata of observations owning 0.25to 1.5 hectares of land on the perimeter at the time of the 2019 census. Most households have only one plot on the perimeter and the average size of landholdings on the perimeter is 0.71 ha. On average, total household landholdings off the perimeter are more than twice as large, at 1.74 ha. About 70 percent of households have off-perimeter land holdings.

Table II.2. Characteristics of Konni PAPs and households at baseline

Indicator	Observations	Mean	SDs
Strata			
Female PAP (0/1)	785	0.06	0.24
Male PAP owns less than 0.25 ha (0/1)	785	0.08	0.27
Male PAP owns 0.25 to less than 1.5 ha (0/1)	785	0.86	0.35
Male PAP owns 1.5 ha or more (0/1)	785	0.01	0.09
Age of PAP	785	47.0	15.2
HH has land on perimeter (0/1)	782	1.00	0.04
Number of HH plots on perimeter	782	1.09	0.36
Total HH landholdings on perimeter (ha)	782	0.58	0.33
Total HH landholdings off perimeter (ha)	781	1.74	2.42
Total HH landholdings on and off perimeter (ha)	782	2.32	2.47
Head of HH reads or writes (0/1)	781	0.59	0.49
Female head of HH (0/1)	782	0.05	0.21
HH member is female (0/1)	3833	0.47	0.50
Number of HH members	782	10	6.63
Number of adults in HH (age 16+)	782	5	3.89
Number of children in HH	781	5	4.10
Poverty score	780	45.35	13.89
Women’s empowerment score (%)	*	0.64	NA

Notes: Information on 15-year-olds was not collected so we are unable to present the number of youth ages 15 to 35.

* The women’s empowerment score is based on responses from 755 women, each in a distinct household. For more details on the women’s empowerment score, see Table II.13.

HH = household; NA = not applicable

Households on the Konni perimeter are predominantly male-headed and larger than the average Nigerien household. Slightly less than half (47 percent) of household members are female, but only 5 percent of households are female-headed. The average household has 10 household members, 5 of whom are children under 16 years of age; this is larger than the average Nigerien household size of 6 members (Population Reference Bureau 2020).

Households on the Konni perimeter appear to be relatively well off compared to other Nigeriens. The average poverty score[3] among households on the Konni perimeter is 45.35. This score translates to, on average, a 13.5 percent likelihood of households falling below the 2011 national poverty line, and means that households have only a 4.3 percent likelihood of falling in the bottom poorest half of Nigeriens (Schreiner 2018). (See also the detailed discussion of income and poverty in Sections C.7 and C.8)

The vast majority of women on the Konni perimeter remain unempowered, defined as lacking agency and autonomy over critical parts of life, including production, resources, income, and leadership. To measure empowerment, we adapted questions from the Women's Empowerment in Agriculture Index (WEAI) and administered them to 755 women respondents, each from a distinct household. Only 21 percent of women on the Konni perimeter achieved empowerment with an average adequacy of 57 percent (out of 100 percent). Women have a multidimensional empowerment score of 64 percent (out of 100 percent). We present information on indicators of women's empowerment in more detail in **Table II.13**.

B. Data sources and levels

This section describes our household survey and the different levels of data collection and analysis, delineates the list of focal crops we emphasize, and defines the primary and secondary indicators for the pre-post analysis.

Data for the baseline report come from our survey of households that took place in Konni in March 2020. We collected information on crops, plots, household members, and the household as a whole. These core levels of data correspond closely to levels represented in the IMAP program logic (Figure I.2). The subsequent analysis presents our results at these different levels as well as for the entire perimeter. This will enable us to assess the extent to which the baseline data provide support for the constraints to agricultural production that underlie the program logic. The set of focal crops we emphasize, which stakeholders, including MCC, identified as important, include the traditional consumption crops of sorghum and millet and the following cash crops: cowpea, cabbage, anise, onion, tomato, okra, groundnut, wheat, and corn. Other crops can be considered either consumption or cash crops and are less commonly grown on the perimeter. These crops, which we classify as dual-purpose, include carrots, peppers, sesame, squash, and watermelons.

Table II.2 lists and defines the primary outcome indicators for the pre-post analysis, categorized by land security, irrigation, fertilizer, agricultural production, income, food security, and women's empowerment. We selected the primary indicators featured in the baseline report based on the IMAP program logic along with the core pre-post questions in the Indicator Tracking Table (MCA-N 2019) and the EDR (D'Agostino et al. 2019). Indicators from the remote sensing analysis are not yet available for this baseline report; nevertheless, we present them in the table because we anticipate being able to use them for the pre-post analysis.

[3] The poverty score was calculated using the Scorocs Simple Poverty Scorecard for Niger (Schreiner 2018), which aggregates nine poverty indicators to estimate consumption-based poverty rates. The nine components of the poverty score are (1) region, (2) number of household members, (3) number of rooms in house, (4) roof construction material, (5) type of toilet, (6) main source of lighting, and (7) ownership of lounge chair, (8) cell phone, and (9) a bicycle, motorcycle, or private vehicle.

Table II.3. Primary outcome indicators for pre-post analysis

Indicator	Data source	Definition
Land security and use (plot and perimeter levels)		
Formalized land rights	• Surveys of households	Indicator of formal land rights documentation and the associated land area measure
Land security	• Surveys of households	Indicators for experienced land dispute in last year, perception of involuntary loss of land over subsequent five years, and the associated land area measures
Land under cultivation	• Surveys of households • Satellite/drone imagery*	Total land under cultivation by season and crop type
Irrigation (plot and household levels)		
Use of irrigation	• Surveys of households	Seasonal indicator of use of irrigation other than rainfall
Irrigation expenditures	• Surveys of households	Annual household expenditures on irrigation and cost of irrigation per hectare
Fertilizer (plot, perimeter, and household levels)		
Fertilizer application	• Surveys of households	Seasonal indicators of fertilizer use and quantity of fertilizer applied per hectare
Fertilizer expenditures	• Surveys of households	Annual household expenditures on fertilizer and cost of fertilizer per hectare
Agricultural production outcomes (perimeter level)		
Crop yield	• Surveys of households • Satellite/drone imagery*	Seasonal productivity (t/ha) for focus crops
Crop income per hectare	• Survey of households	Seasonal income (crop sales and own consumption net of expenditures) per hectare for focus crops
Income (household level)		
Total income	• Surveys of households	Annual value of non-agricultural and agricultural income
Agricultural income	• Surveys of households	Annual income from crop sales, renting out land, and own consumption net of agricultural expenditures
Food insecurity (household level)		
Food inadequacy	• Surveys of households	Indicator of households that did not have enough food in the previous month
Hunger	• Surveys of households	Indicator of households where at least one member went to bed hungry in the previous month
Women's Empowerment in Agriculture Index (WEAI) (household level)		
Women's empowerment score	• Surveys of households	Adaptation of the Women's Empowerment in Agriculture Index (WEAI) that measures women's empowerment based on their role in four different domains: production, resources, income, and leadership

*Note: While we do analyze remotely sensed Sentinel-2 imagery, sub-meter resolution satellite and drone imagery from NASA and RTI were not available in time for the baseline analysis. Crop yields are measured in tons per hectare (t/ha).

The secondary indicators, which allow us to further explore the pre-post questions and contextualize the data, are presented and defined in **Appendix B, Table B.3.** We discuss secondary outcomes when they provide additional nuance.

C. Konni plot-, household-, and perimeter-level outcomes at baseline

In this section, we report descriptive statistics from the household survey for primary and secondary outcomes prior to the intervention. These results enable us to lay the groundwork for addressing the core pre-post questions at the heart of the quantitative performance evaluation (presented in **Table I.1**) in the future. In order to ensure the representativeness of the household survey data to the farmers on the Konni perimeter, all descriptive statistics are weighted according to each respondent's sampling probability.

We present descriptive statistics on primary and secondary indicators from the survey data for the full sample in this section. We also present descriptive statistics disaggregated by the gender of the PAPs to shed light on baseline differences in access to resources, including land and inputs, as well as agricultural outcomes. Because households might have multiple PAPs of different genders, we present information on households with only female PAPs and households with at least one male PAP (referred to in the tables as female PAPs versus male PAPs).[4] Additionally, we disaggregate results according to land tenure documentation (documented plot versus undocumented plot)[5] and present those descriptive statistics in **Appendix C, Tables C.1–C.10**. Finally, given the crucial importance of access to irrigation in the dry season for agricultural and household outcomes, we conclude this section by comparing income, revenue, and crop sales for households with and without access to irrigation in the dry season for at least one plot on the Konni perimeter (**Table II.11**).[6]

C.1. Land security, land holdings, and land use on the perimeter

A key component of the IMAP's program logic and a primary driver of the Konni perimeter's ERR are the increase in secure access to irrigated land that allows for cultivation in the rainy and dry seasons and the switch to higher-value crops.

Table II.3 presents information on plot tenure security. Fewer than half of on-perimeter plots (41 percent) have formalized land rights. Despite the lack of formal documentation for the majority of plots, land disputes and concerns over the involuntary loss of land are rare (1–2 percent). The average plot size is 0.66 ha, but plots belonging to households with only female PAPs are slightly smaller, at 0.61 ha, on average.

[4] There are 120 households with only female PAPs and 662 households with at least one male PAP.
[5] There are 344 households where at least one plot has formal land tenure documentation (referred to as households with documented plots) and 344 households where all plots are lacking formal documentation (referred to as households with undocumented plots). There are 13 households for which information on land tenure documentation was not available. Plots were considered to have formal documentation if PAPs stated that they have a contract to occupy, a contract to cultivate, a rental contract, or a sales receipt. We did not ask survey respondents to produce documentation.
[6] There are 432 households with access to irrigation in the dry season and 350 households without access.

Table II.3. Land tenure security, holdings, and use on the perimeter

Indicator	Full sample	Female PAPs	Male PAPs
Plot tenure security			
Formalized land rights for plot (0/1)	0.41	0.61	0.40
Experienced land dispute in last year over plot (0/1)	0.01	0.01	0.01
Perceived risk of involuntary loss of plot in next 5 years (0/1)	0.02	0.04	0.02
Plot holdings			
Size of plot (ha)	0.53	0.50	0.53
Perimeter			
Share of perimeter area with formal land rights (%)	0.38	0.03	0.35
Share of perimeter area under land dispute (%)	0.01	0.00	0.01
Share of perimeter area with a perceived risk of involuntary loss of land (%)	0.02	0.00	0.02

Notes: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

Table II.4 presents information on cultivation and cropping patterns in each season. Dry season cultivation is lower than rainy season cultivation, confirming the need for improved access to irrigation in the dry season through the IMAP. Almost all plots (97 percent) were cultivated in the rainy season, whereas only 33 percent were cultivated to term in the dry season. Dry season cultivation is dependent upon the continued availability of irrigation water, which is determined by the amount of rainfall and the amount of water taken from the canal before it arrives at Konni. The National Office for Irrigation Schemes (ONAHA) calculates the availability of water based on weather and water prediction models. ONAHA then determines how many hectares can be cultivated on the perimeter and which farmers will receive water. The percentage of plots cultivated during the dry season is therefore year-specific and reflects, in part, the particular level of rainfall during the 2018–2019 agricultural year.

There are significant differences in the estimated area based on remotely sensed indicators of cultivation at around 33 percent and the farmer-reported area cultivated at around 63 percent. We triangulated the estimates by comparing remotely sensed estimates with administrative information from ONAHA and conducted key informant interviews with stakeholders to determine sources of the differences and correct for over-reporting (see **Appendix D** for more details).[7] Some farmers' cultivation efforts might have been unsuccessful because irrigation water was not available throughout the season, so we qualify the remotely sensed indicators as estimating cultivation to term.

We estimate that about 2,357 hectares of land was cultivated in the rainy season compared to 808 hectares in the dry season, out of a total perimeter area of 2,558 hectares based on the RAP census. Our estimate of cultivated area in the rainy season is slightly lower than baseline value in the CBA model (2,420 ha), whereas our estimate of cultivated area in the dry season is about 50 percent larger than the baseline CBA model value (520 ha). The vast majority of land was cultivated by households with male PAPs. Female-only PAP households cultivated just 3 percent of perimeter land in the dry season and 4 percent in the rainy season, reflecting the small number of female PAPs.

[7] We also account for discrepancies in self-reported plot sizes between the household survey and cadastral measures of land sizes associated with reporting bias and double reporting of area cultivated related to inter-cropping.

ONAHA also collects statistics on cultivation and production, but estimates smaller dry season cultivation totals than we find using either the baseline survey data or remote-sensing data with the aforementioned cutoff value. They report that 400 hectares (15 percent of the perimeter area) were sown, and a slightly smaller number of hectares were harvested (ONAHA 2019a, 2019b).

Table II.4. Land tenure security, holdings, and use on the perimeter

Indicator	Full sample	Female PAPs	Male PAPs
Dry season			
Plot was cultivated based on self-report (0/1)	0.70	0.65	0.71
Plot area cultivated based on self-report (ha)	0.34	0.31	0.34
Plot was cultivated triangulated* (0/1)	0.40	0.39	0.40
Plot area cultivated triangulated (ha)	0.18	0.16	0.18
Cash crop cultivated on plot (0/1)	0.37	0.36	0.37
Plot area cultivated with cash crops (ha)	0.13	0.12	0.13
Traditional crop cultivated on plot (0/1)	0.03	0.03	0.03
Plot area cultivated with traditional crops (ha)	0.01	0.01	0.01
Dual purpose crop cultivated on plot (0/1)	0.14	0.17	0.14
Plot area cultivated with dual purpose crops (ha)	0.03	0.03	0.03
Plot was mono-cropped (0/1)	0.15	0.10	0.16
Plot was multi-cropped (0/1)	0.25	0.29	0.25
Rainy season			
Plot was cultivated (0/1)	0.97	0.97	0.97
Plot area cultivated (ha)	0.49	0.47	0.49
Cash crop cultivated on plot (0/1)	0.33	0.40	0.33
Plot area cultivated with cash crops (ha)	0.07	0.08	0.07
Traditional crop cultivated on plot (0/1)	0.88	0.85	0.88
Plot area cultivated with traditional crops (ha)	0.30	0.24	0.30
Dual purpose crop cultivated on plot (0/1)	0.60	0.70	0.59
Plot area cultivated with dual purpose crops (ha)	0.12	0.15	0.12
Plot was mono-cropped (0/1)	0.19	0.13	0.19
Plot was multi-cropped (0/1)	0.78	0.84	0.78
Plot sample size	*874*	*136*	*738*
Perimeter			
Total perimeter area cultivated in the dry season based on self-report (ha)	**Error! No document variable supplied.**	**Error! No document variable supplied.**	**Error! No document variable supplied.**
Share of perimeter area cultivated in the dry season based on self-report (%)	**Error! No document variable supplied.**	**Error! No document variable supplied.**	**Error! No document variable supplied.**
Total perimeter area cultivated in the dry season triangulated (ha)	808	37	771
Share of perimeter area cultivated in the dry season triangulated (%)	0.33	0.02	0.32

Indicator	Full sample	Female PAPs	Male PAPs
Total perimeter area cultivated in the rainy season (ha)	2,242	106	2,135
Share of perimeter area cultivated in the rainy season (%)	0.92	0.05	0.88

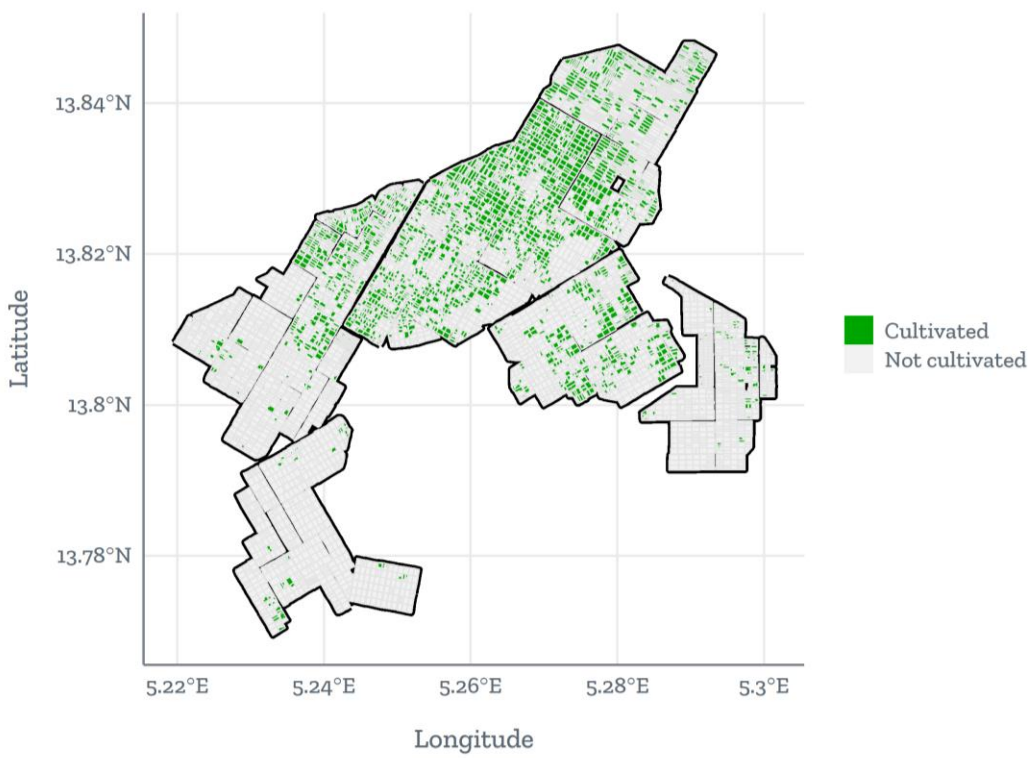
Notes: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. Cash crops are anise, cabbage, onion, okra, groundnuts, tomatoes, and wheat. Traditional crops are millet and sorghum. All others are dual-purpose crops.

* Triangulated measures incorporate information from remote sensing, administrative information from ONAHA, key informant interviews with stakeholders, and the baseline household survey to address cultivation overestimates.

The types of crops cultivated vary by season due to different water requirements for different crops. Dry season cultivation consists primarily of cash crops (anise, cabbage, onion, okra, groundnuts, tomatoes, and wheat), whereas households use the rainy season to grow traditional crops (sorghum and millet). The dry season thus presents the greatest opportunity for income-generating cultivation. Dual-purpose crops grown for both consumption and sales (such as carrots, moringa, peppers, squash, and watermelons) account for a minority of plot area in both seasons but represent a larger portion of cultivation in the rainy season relative to the dry season. In both seasons, most cultivated plots were multi-cropped; that is, households planted more than one crop on their plot. These cropping patterns were similar for plots in both female-only PAP households and households with at least one male PAP.

Satellite imagery provides information on the parts of the perimeter that were planted during the dry season (**Figure II.2**). Areas in the northeastern part of the perimeter which is closer to the reservoir and the main canal were more likely to be cultivated.

Figure II.2. Map of 2018–2019 dry season cultivated area based on analysis of NDVI time-series data



Source: Mathematica calculations using remotely sensed Sentinel-2 data.

Note: NDVI = normalized difference vegetation index. Map values are based on whether a pixel's NDVI value ever exceeded 0.42 between January 1 and February 28, 2019. The cutoff value of 0.42 minimized the root mean square error (RMSE) between the Konni-wide predicted cultivated area using remotely sensed data alone and the observed cultivation area reported by ONAHA. NDVI is a remotely sensed proxy for vegetation.

Plots with and without formal land tenure document have similar cultivation and cropping patterns across most dimensions, with the exception of dry season cultivation (**Table C.1**). Forty-four percent of documented plots were cultivated in the dry season compared to 36 percent of plots for which respondents did not have documents. This suggests that farmers were more likely to ensure they had documentation for the plots that were more likely to have access to irrigation.

C.2. Irrigation

Although most plots were not cultivated during the dry season, the majority of these that were cultivated used irrigation (80 percent). Dry season irrigation was slightly more common for plots in female-only PAP households (87 percent) compared to plots in male PAP households (79 percent). **Table II.5** provides summary statistics on irrigation use and availability in each season.

The fact that most plots were not cultivated in the dry season (60 percent, see **Table II.4**), suggests that, consistent with the CBA model, there may be considerable room for improved access to irrigation in the dry season. In **Table II.11,** we present household income, revenue, and crop sales separately for households with and without access to irrigation in the dry season.

A smaller share of plots without formal documentation, 79 percent, used irrigation in the dry season compared to 84 percent of documented plots (**Appendix C, Table C.2**).

Table II.5. Use and availability of irrigation

Indicator	Full sample	Female PAPs	Male PAPs
Plots			
Dry season			
Used irrigation, conditional on cultivation (0/1)	0.80	0.87	0.79
Irrigation always available when needed, conditional on using irrigation (0/1)	0.88	0.88	0.88
Plot sample size	*357*	*55*	*302*
Rainy season			
Used irrigation, conditional on cultivation (0/1)	0.13	0.22	0.12
Irrigation always available when needed, conditional on using irrigation (0/1)	0.83	0.83	0.83
Plot sample size	*854*	*134*	*720*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

C.3. Fertilizer

In addition to enhanced access to irrigation, the improvements in agricultural productivity on which the ERR is predicated require improved technologies and inputs, including increased use of fertilizers.

Although use of inorganic and organic fertilizer is widespread, the amount of inorganic fertilizer applied is low. **Table II.6** shows rates of inorganic and organic fertilizer application in each season. The vast majority of cultivated plots used inorganic fertilizer: 96 percent in the dry season and 83 percent in the rainy season. A majority of farmers also used organic fertilizer. Inorganic fertilizer was more common than organic fertilizer, especially in the dry season, when 96 percent of cultivated plots used inorganic fertilizer and 64 percent used organic fertilizer. Slightly higher quantities of inorganic fertilizer per hectare were applied on the perimeter in the dry season: 0.38 t/ha in the dry season and 0.25 t/ha in the rainy season. In contrast, for organic fertilizer, larger quantities per hectare were applied on the perimeter in the rainy season (9.17 t/ha) compared to the dry season (5.04 t/ha).

Although plots in both female-only and male-only PAP households are managed with relatively similar practices, male PAP households used considerably more organic fertilizer per hectare relative to female-only PAP households: 5.15 t/ha for male PAP households compared to 2.90 t/ha for female-only- PAP households in the dry season and in the rainy season 9.37 t/ha for male PAP households relative to 5.34 t/ha for female-only PAP households. This likely reflects the labor required to apply large quantities of organic fertilizer.

Inorganic fertilizer use was similar for plots with and without formal documentation; however, a larger share of undocumented plots used organic fertilizer in both seasons relative to the share of documented plots using organic fertilizer (**Appendix C, Table C.3**). Quantities of inorganic and organic fertilizer applied per hectare were relatively similar for both groups, with slightly more being used on undocumented plots.

Table II.6. Fertilizer

Indicator	Full sample	Female PAPs	Male PAPs
Plots			
Dry season			
Organic and/or inorganic fertilizer applied, conditional on cultivation (0/1)	0.98	0.97	0.98
Inorganic fertilizer applied (0/1)	0.96	0.96	0.96
Quantity of inorganic fertilizer applied (t)	0.14	0.11	0.14
Organic fertilizer applied (0/1)	0.64	0.67	0.63
Quantity of organic fertilizer applied (t)	1.72	1.31	1.75
Plot sample size	*821*	*126*	*695*
Rainy season			
Organic and/or inorganic fertilizer applied, conditional on cultivation (0/1)	0.96	0.94	0.97
Inorganic fertilizer applied (0/1)	0.83	0.87	0.83
Quantity of inorganic fertilizer applied (0/1)	0.14	0.09	0.14
Organic fertilizer applied (0/1)	0.81	0.79	0.81
Quantity of organic fertilizer applied (t)	5.04	2.90	5.15
Plot sample size	*789*	*118*	*671*
Perimeter			
Dry season			
Share of perimeter area with fertilizer applied, conditional on cultivation (%)	0.90	0.04	0.87
Share of perimeter area with inorganic fertilizer applied, conditional on cultivation (%)	0.88	0.04	0.85
Share of perimeter area with organic fertilizer applied, conditional on cultivation (%)	0.56	0.03	0.53
Inorganic fertilizer per hectare (t/ha)	0.38	0.32	0.39

Indicator	Full sample	Female PAPs	Male PAPs
Organic fertilizer per hectare (t/ha)	4.75	3.89	4.80
Rainy season			
Share of perimeter area with fertilizer applied, conditional on cultivation (%)	0.88	0.04	0.84
Share of perimeter area with inorganic fertilizer applied, conditional on cultivation (%)	0.76	0.04	0.73
Share of perimeter area with organic fertilizer applied, conditional on cultivation (%)	0.74	0.03	0.70
Inorganic fertilizer per hectare (t/ha)	0.25	0.17	0.25
Organic fertilizer per hectare (t/ha)	9.17	5.34	9.37

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

C.4. Seeds and improved agricultural practices

The IMAPs program logic anticipates that farmers will use improved farming practices and plant improved seeds to complement the increased access to irrigated land and use of fertilizer.

Table II.7 presents information on the types of seeds sowed and the prevalence of improved inputs or agricultural practices, including improved water and soil management techniques. Almost all cultivated plots sowed purchased seeds, although this was more common in the dry season (93 percent) than the rainy season (81 percent). The majority of plots (47 percent dry season, 32 percent rainy season) did not sow improved open pollinated or hybrid seeds, although improved seeds were more common in the dry season and more common among female-only PAP households compared to male PAP households.

The majority of plots (77 percent) use an improved water and soil management technique. The different types of improved water and soil management techniques are zaï, tassa, agricultural half-moon, fences, stone walls, silviculture benches, and adding lime to soil.[8] All plots applied at least one improved input or practice, with an average number of applied inputs or practices of 4.45 out of 9. The nine categories of improved inputs or practices are zero tillage land preparation, planting seeds in rows, improved open pollinated or hybrid seeds, improved water and soil management techniques (detailed above), mechanized equipment, inorganic fertilizer, pesticides or herbicides, processing crops after harvest, and storing crops in hermetic bags.

[8] Zaï, tassa, and agricultural half-moon are agricultural techniques involve digging pits in the soil prior to planting to accumulate water. Fences, stone walls, and silviculture benches reduce soil erosion by managing water flow. Adding lime to soil makes the soil less acidic which helps improve the availability of nutrients for crops.

Table II.7. Seeds and improved agricultural practices

Indicator	Full sample	Female PAPs	Male PAPs
Plots			
Dry season			
Sowed purchased seeds, conditional on cultivation (0/1)	0.93	0.97	0.93
Share of plot area with purchased seeds (%)	0.92	0.91	0.92
Sowed improved seeds (0/1)	0.47	0.60	0.47
Plot sample size	*616*	*89*	*527*
Rainy season			
Sowed purchased seeds (0/1)	0.81	0.79	0.82
Share of plot area with purchased seeds (%)	0.74	0.76	0.73
Sowed improved seeds (0/1)	0.32	0.43	0.31
Plot sample size	*853*	*134*	*719*
Annual			
Applied improved water and soil management techniques (0/1)	0.77	0.75	0.77
Applied improved inputs or practices (0/1)	1.00	1.00	1.00
Number of improved inputs or practices (out of 9)	4.45	4.33	4.46
Plot sample size	*859*	*134*	*725*

Notes: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. The different types of improved water and soil management techniques are zaï, tassa, agricultural half-moon, fences, stone walls, silviculture benches, and adding lime to soil. The nine categories of improved inputs or practices are zero tillage land preparation, planting seeds in rows, improved seeds, improved water and soil management techniques, using mechanized equipment, applying inorganic fertilizer, applying pesticides or herbicides, processing crops after harvest, and storing crops in hermetic bags.

The use of improved inputs or practices did not differ substantially between female-only and male PAP households. Seed type and other agricultural practices were generally similar for documented and undocumented plots (**Table C.4**), although improved practices were slightly more common for documented plots, suggesting that land tenure security might encourage greater investments. The largest difference between the two subgroups is with respect to sowing improved seeds in the rainy season: 40 percent of documented plots and 27 percent of undocumented plots sowed improved seeds.

C.5. Credit and expenditures

The ability to invest in agricultural inputs is key to improving agricultural outcomes and may depend on farmers' access to credit.

Although many parts of Niger lack adequate access to credit, accessing credit in Konni is common, but depends on the formality of the plot. **Table II.8** provides descriptive statistics on household access to credit, the amount of loans taken out, and total household agricultural expenditures in the past year. A minority of households could access credit (25 percent) or took out a loan (25 percent) in the past year, although access and borrowing are both more common among households with only female PAPs compared to households with at least one male PAP. Thirty-five percent of female-only PAP households could access credit and 34 percent took out a loan in the past year. Plots were rarely used as collateral for loans.

Expenditures households incur for agricultural production include expenses for irrigation, fertilizer, seeds, labor, animals, equipment, pesticides/herbicides, canal cleaning, preparation of crops for sale, and transport for sale. Total average annual agricultural expenditures were 321,000 FCFA (approximately $546 USD[9]) across all households. This represents roughly 30 percent of the value of crop sales (see **Table II.10**). Expenditures are dominated by labor, fertilizer, and seeds; expenses for irrigation are relatively low in comparison. Per hectare costs follow a similar pattern.

Expenditures are slightly higher in male PAP households compared to female-only PAP households. Male PAP households appear to spend more on fertilizer and seeds relative to female-only PAP households, whereas female-only PAP households spend more on labor. Irrigation expenditures are similar between the two groups.

Credit access and agricultural expenditures are slightly higher in households with at least one documented plot, relative to households with undocumented plots (**Appendix C, Table C.5**). Thirty percent of households with a documented plot took out a loan, compared to 22 percent of households with an undocumented plot or plots. Total average expenditures were 54,000 FCFA ($92 USD) higher for households with a documented plot.

Table II.8. Credit and expenditures

Indicator	Full sample	Female PAPs	Male PAPs
Credit (household)			
Household can access credit (0/1)	0.25	0.35	0.24
Loan taken out in the last year (0/1)	0.25	0.34	0.24
Total value of loan(s) taken out in the last year, not conditional on borrowing (FCFA)	32,000	46,000	32,000
Household sample size (credit)	*782*	*120*	*662*
Collateral (plots)			
Used plot as collateral for credit in past dry or rainy season (0/1)	0.05	0.08	0.05
Would consider using plot as collateral (0/1)	0.02	0.05	0.02
Plot sample size	*872*	*135*	*737*
Annual expenditures (for all household on-perimeter plots)			
Total agricultural expenditures (FCFA)	321,000	306,000	322,000
Irrigation expenditures (FCFA)	18,000	19,000	18,000
Fertilizer expenditures (FCFA)	76,000	64,000	77,000
Seed expenditures (FCFA)	70,000	55,000	71,000
Labor expenditures (FCFA)	87,000	110,000	86,000
Preparation and processing expenditures (FCFA)	24,000	20,000	24,000
Household sample size	*781*	*120*	*661*
Annual per hectare costs (for all household on-perimeter plots)			
Annual irrigation cost per hectare, dry and rainy seasons (FCFA/ha)	21,000	23,000	21,000

[9] Conversions between FCFA and USD are based on a historical average exchange rate of 0.0017 FCFA per USD for the period October 2018 to September 2019, which covers the past dry and rainy season we asked about in our household survey (Exchange Rates UK 2020a, 2020b).

Indicator	Full sample	Female PAPs	Male PAPs
Annual fertilizer cost per hectare, dry and rainy seasons (FCFA/ha)	95,000	77,000	95,000
Annual seed cost per hectare, dry and rainy seasons (FCFA/ha)	84,000	65,000	85,000
Annual labor cost per hectare, dry and rainy seasons (FCFA/ha)	116,000	164,000	113,000
Annual preparation and processing cost per hectare, dry and rainy seasons (FCFA/t)	6,000	12,000	6,000
Household sample size	*781*	*120*	*661*

Notes: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. All FCFA values have been rounded to the nearest thousand.

C.6. Perimeter-level agricultural productivity and profitability

To justify the IMAP investment in the perimeter, the value of production on the perimeter has to increase. This can be achieved by cultivating a larger area of land, shifting to more profitable crops, increasing agricultural productivity, or achieving higher prices and thus incomes from crop sales. Previous sections have presented information on area cultivated and crop choice; in this section, we describe baseline levels for yields and incomes from crop sales to establish a reference for the pre-post analysis.

Table II.9 presents perimeter-level yields (t/ha) and per hectare income (FCFA/ha) for the focus crops that are most commonly grown in each season. Corn, sorghum, and tomatoes are grown in both seasons; anise, cabbage, onions, and wheat are common in the dry season; and cowpeas, millet, and groundnuts are common in the rainy season. Income was calculated as revenue from crop sales plus the estimated value of own consumption net of agricultural expenditures. Income was then divided by total area cultivated to calculate income per hectare.

Tomatoes in both seasons and onions, cabbage, and anise in the dry season earned the highest income per hectare. This pattern is in line with the CBA model, which projects a shift in crop choice toward crops that are more profitable per hectare when irrigation is available (Turiansky et al. 2018). Higher-value per hectare crops, including onions, tomatoes, and anise (as well as squash and rice), are expected to take the place of less profitable crops like sorghum and millet.

In the dry season, perimeter yields and income per hectare for anise were higher among female-only PAP households relative to male PAP households. Female-only PAP households had a higher yield and income for cabbage and onions relative to male PAP households. In the rainy season, yields and income per hectare for all crops (except for sorghum yield) were higher for male PAP households relative to female-only PAP households. Subgroup analysis is not available for all crops because some crops were grown by a very small number of female-only PAP households. Where sample sizes were below 20, subgroup analysis was omitted.

There are also differences between documented and undocumented plots for perimeter yields and income per hectare (**Appendix C, Table C.6**). In the dry season, documented plots had notably higher yields and income per hectare for cabbage, whereas for undocumented plots, yields and income per hectare were higher for tomatoes. In the rainy season, documented plots had higher yields and income per hectare for tomatoes and groundnuts, whereas income per hectare was higher for cowpeas on undocumented plots.

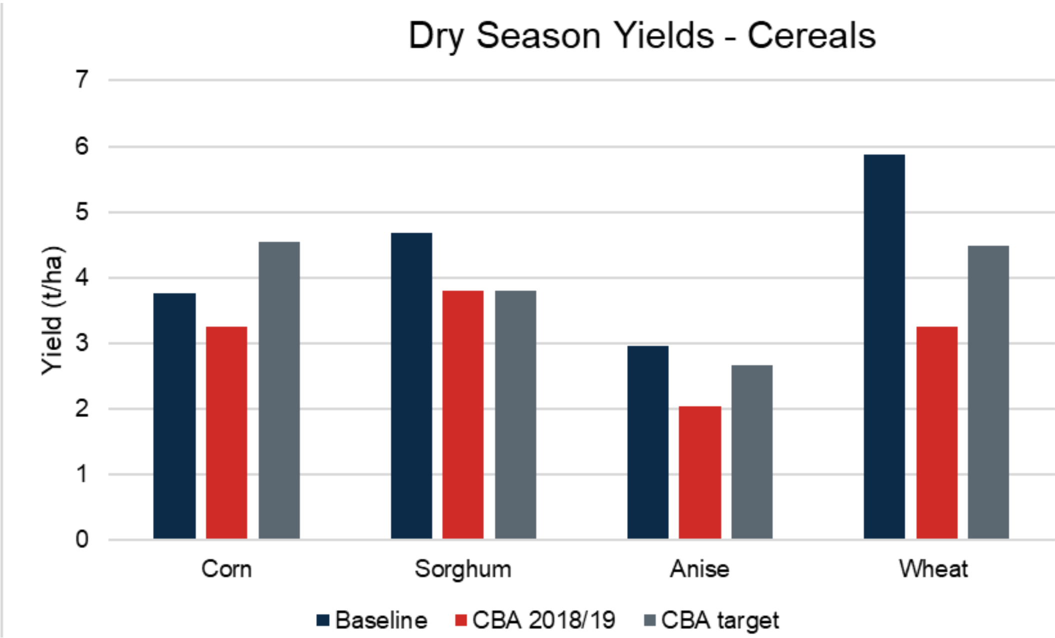
Table II.9. Perimeter-level crop yield, income, and income per hectare

Indicator	Full sample	Female PAPs	Male PAPs
Yield in dry season (t/ha)			
Corn	3.77	4.51	3.73
Sorghum	4.68	N/A	N/A
Tomatoes	18.52	N/A	N/A
Anise	2.96	3.49	2.92
Cabbage	33.53	52.59	32.86
Onions	19.75	23.88	19.63
Wheat	5.88	N/A	N/A
Income per hectare in dry season (FCFA/ha)			
Corn	469,000	658,000	458,000
Sorghum	588,000	NA	NA
Tomatoes	1,436,000	NA	NA
Anise	1,769,000	7,065,000	1,409,000
Cabbage	2,272,000	2,796,000	2,254,000
Onions	4,015,000	4,139,000	4,012,000
Wheat	1,057,000	NA	NA
Yield in rainy season (t/ha)			
Corn	5.25	3.62	5.48
Sorghum	3.49	3.67	3.48
Tomatoes	31.68	NA	NA
Cowpeas	2.48	2.08	2.50
Groundnuts	3.45	NA	NA
Millet	4.82	5.00	4.82
Income per hectare in rainy season (FCFA/ha)			
Corn	790,000	399,000	843,000
Sorghum	424,000	328,000	428,000
Tomatoes	4,120,000	NA	NA
Cowpeas	817,000	208,000	846,000
Groundnuts	655,000	NA	NA
Millet	819,000	675,000	826,000

Notes: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. Some subgroup values have been omitted due to small sample sizes. All FCFA values have been rounded to the nearest thousand. NA = not available.

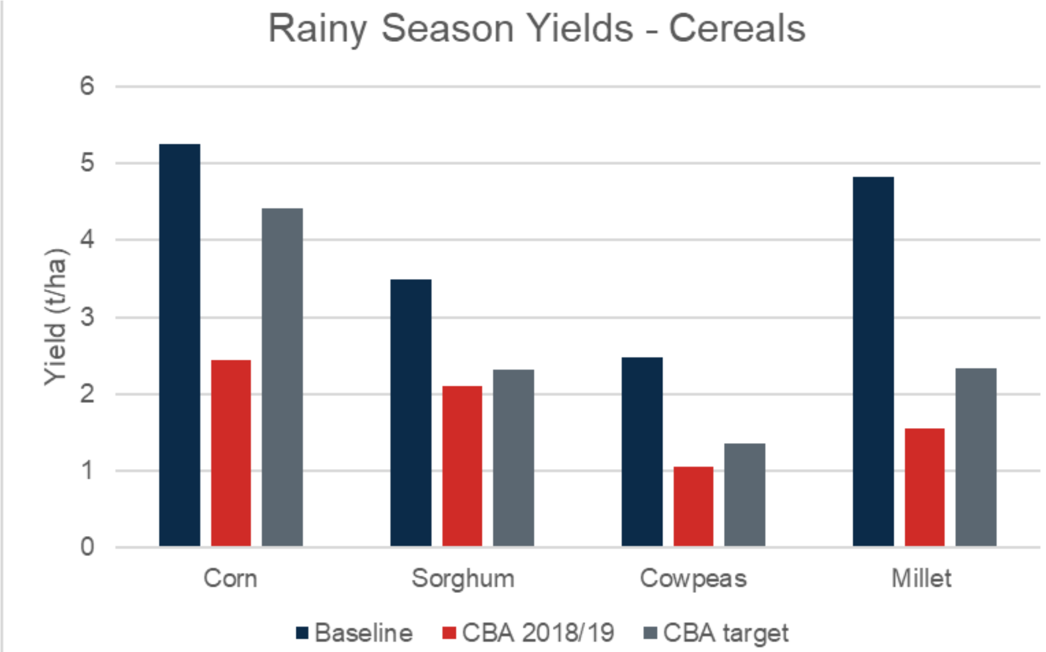
Figures II.3, II.4, and **II.5** compare the perimeter-level yields presented in **Table II.9** to the estimates for 2018–2019 dry and rainy seasons and the target crop yields from MCC's Cost Benefit Analysis model (Turiansky et al. 2018). In general, the baseline cereal yields in the dry season and all yields in the rainy season used in the MCC CBA model are lower than the yields we calculated from the household survey data. For the dry season vegetable yields, the opposite is true—yields for cabbage and onions estimated from our baseline survey are lower than baseline CBA model values. This is relevant to potential benefit streams associated with the provision of irrigation that underlie the ERR projections. Even though there are some differences between the estimated yields from our baseline and the baseline used in the CBA model, both data agree that the primary room for improvement in agricultural productivity relative to the targets can be found in the dry season vegetable production. The most important benefit streams in the CBA model, however, do come from increasing the area cultivated and shifting to higher-value production.

Figure II.3 Cereal yields in dry season yields: baseline survey and CBA model



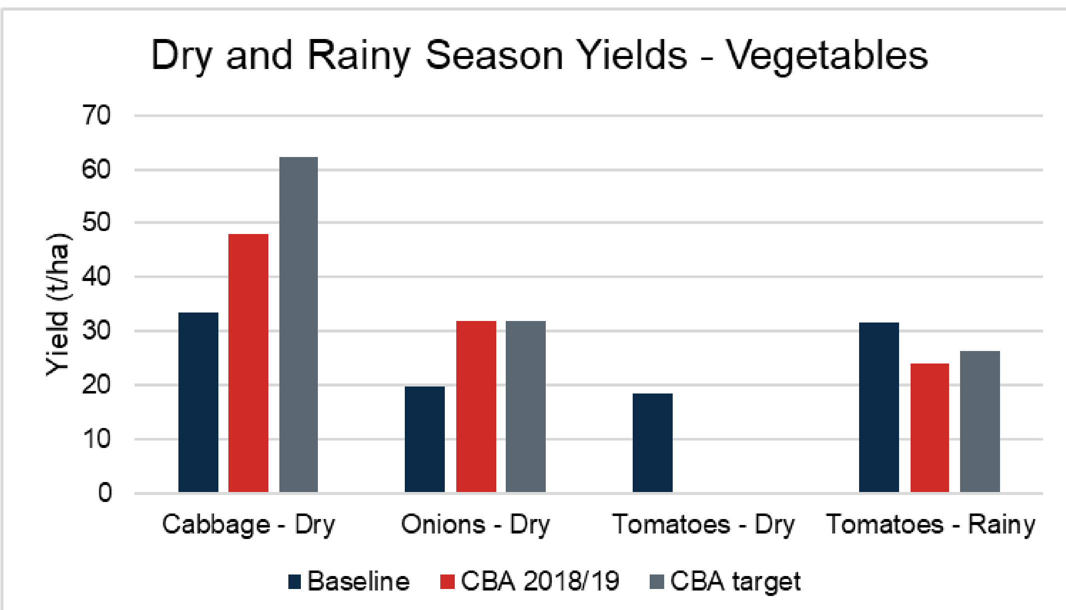
Notes: CBA refers to the cost-benefit analysis model that underlies the calculation of the economic rate of return. CBA 2018/2019 values are the estimated baseline yields in 2018 and 2019 before the project is implemented. CBA target is the projected yields starting with MCC's completed investment. Crop yields are measured in tons per hectare (t/ha).

Figure II.4. Cereal yields in rainy season: baseline survey and CBA model



Notes: CBA refers to the cost-benefit analysis model that underlies the calculation of the economic rate of return. CBA 2018/2019 values are the estimated baseline yields in 2018 and 2019 before the project is implemented. CBA target is the projected yields starting with MCC's completed investment. Crop yields are measured in tons per hectare (t/ha).

Figure II.5. Vegetable yields in dry and rainy seasons: baseline survey and CBA model



Notes: CBA refers to the cost-benefit analysis model that underlies the calculation of the economic rate of return model. CBA 2018/2019 values are the estimated baseline yields in 2018 and 2019 before the project is implemented. CBA target is the projected yields starting with MCC's completed investment. CBA values for tomatoes in the dry season are not available. Crop yields are measured in tons per hectare (t/ha).

C.7. Household income, sales, and profits

The ultimate objective of MCC's investments is to increase household incomes and food security through increases in agricultural productivity and sales. In this section, we describe baseline levels of agricultural sales, agricultural profits, and household income; and put baseline household income into perspective by contrasting it with national and international poverty lines. We also provide some suggestive evidence on the importance of access to irrigation on household incomes.

Table II.10 shows the breakdown of income and profit across sources, including different types of crops and non-agricultural sources, as well as how crop sales vary by season.

Although the average household income per person in Konni remains below the global poverty line of $3.10 USD per person per day, it is still better than many areas of Niger, where poverty remains widespread. Total average annual household income from agricultural and non-agricultural sources (including the estimated value of own consumption) was 2,294,000 FCFA (approximately $3,900 USD), which translates to 628 FCFA ($1.07 USD) per person per day for the average household size of 10 members in our household data. The 2014/2015 consumption-based poverty line for rural Tahoua Niger (the region in which Konni is located) was 434 FCFA ($0.74 USD) per person per day (Schneider 2019). This translates to a poverty line of approximately 1,584,100 FCFA ($2,693 USD) per household per year for the average household on the Konni perimeter. Therefore, average household income on the Konni perimeter is approximately 1.45 times the rural poverty line in Tahoua.

When converted in terms of purchasing power parity (PPP) to compare to global poverty lines, average household income per person per day in Konni—628 FCFA—is equal to approximately $2.14 USD PPP per person per day.[10] The average household income on the Konni perimeter is 13 percent above the global extreme poverty line of $1.90 USD PPP per person per day, but remains below the (less extreme) global poverty line of $3.10 USD PPP (World Bank 2017a). The average household on the Konni perimeter is therefore likely better off than many Nigeriens, but also remains quite poor and vulnerable on a global scale.

The majority of agricultural income, about 63 percent, comes from on-perimeter land. Cash crop sales account for the largest share of annual agricultural revenue (585,000 FCFA, $995 USD), followed by dual-purpose crops (98,000 FCFA, $167 USD). Traditional crops (millet and sorghum) are the least profitable (23,000 FCFA, $39 USD annual sales). Traditional crop sales are not presented for the dry season because only four households grew sorghum or millet in the dry season.

Non-agricultural income through employment and self-employment activities is also an important source of household income. Averaging 902,000 FCFA ($1,533 USD) annually, it accounts for roughly 35 percent of total household income. Thirty percent of households engaged in non-agricultural employment and 72 percent of households engaged in self-employment during the past year.

Crop sales from the dry season, when cash crops are predominantly cultivated, generate more than 1.5 times as much revenue as crop sales from the rainy season, when primarily traditional crops are cultivated, highlighting the importance of dry season cultivation for total household income. Dry season

[10] Daily per person income is converted to 2011 USD PPP in two steps: (1) we convert 2018 FCFA to 2018 USD PPP units based on the FCFA to USD PPP exchange rate in 2017 and (2) we adjust 2018 USD PPP to 2011 USD PPP, the standard global poverty unit, to account for inflation (World Bank 2020).

cash crop sales, in particular, dwarf rainy season cash crop sales, 424,000 FCFA ($720 USD) compared to 21,000 FCFA ($36 USD).

Total income was 49,000 FCFA larger ($83 USD), or about 2 percent higher, in female-only PAP households compared to male PAP households. However, in female-only PAP households, income from agriculture is lower and income from non-agricultural employment and self-employment is higher relative to male PAP households.

Total income was 265,000 FCFA larger ($451 USD), or about 12 percent, higher, in households with undocumented plot(s) compared to households with at least one documented plot (**Table C.7**). This difference is due entirely to higher non-agricultural income in households with undocumented plots (440,000 FCFA, or $748 USD higher). Agricultural income, however, is 213,000 FCFA ($362) higher in households with documented plot(s). This could suggest that households with less land security hedge against this insecurity by earning more income from other non-agricultural sources, or that households with higher non-agricultural earnings have rented or bought a plot on the perimeter without formal documentation. These differences are larger than differences between female-only PAP households and male PAP households.

Table II.10. Household income, revenue, and sales

Indicator	Full sample	Female PAPs	Male PAPs
Annual			
Total agricultural and non-agricultural income, including own consumption (FCFA)	2,294,000	2,340,000	2,291,000
Agricultural income, including own consumption (FCFA)	1,349,000	1,275,000	1,353,000
Agricultural on-perimeter income, including own consumption (FCFA)	853,000	773,000	857,000
Agricultural off-perimeter income, including own consumption (FCFA)	469,000	454,000	469,000
Agricultural revenue (FCFA)	1,015,000	940,000	1,019,000
Agricultural on-perimeter revenue (FCFA)	718,000	680,000	720,000
Agricultural off-perimeter revenue (FCFA)	329,000	319,000	330,000
Crop sales on-perimeter (FCFA)	727,000	708,000	728,000
Cash crop sales on-perimeter (FCFA)	585,000	483,000	590,000
Traditional crop sales on-perimeter (FCFA)	23,000	25,000	23,000
Dual purpose crop sales on-perimeter (FCFA)	98,000	159,000	95,000
Non-agricultural income (FCFA)	902,000	952,000	899,000
Employment income (FCFA)	253,000	290,000	251,000
Self-employment income (FCFA)	658,000	662,000	658,000
Dry season on-perimeter			
Crop sales (FCFA)	447,000	401,000	450,000
Cash crop sales (FCFA)	424,000	351,000	428,000
Traditional crop sales (FCFA)	NA	NA	NA
Dual purpose crop sales (FCFA)	22,000	47,000	20,000
Rainy season on-perimeter			
Crop sales (FCFA)	265,000	307,000	263,000
Cash crop sales (FCFA)	21,000	23,000	21,000
Traditional crop sales (FCFA)	160,000	152,000	160,000
Dual purpose crop sales (FCFA)	69,000	105,000	68,000
Household sample size	*782*	*120*	*662*

Notes: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. All FCFA values have been rounded to the nearest thousand. Cash crops are anise, cabbage, onion, okra, groundnuts, tomatoes, and wheat. Traditional crops are millet and sorghum. All other crops are dual crops.

NA = not available.

Households with access to irrigation have higher incomes than those without. As such, the baseline household survey suggests that the ultimate project goal of increasing incomes remains salient and that increasing access to dry season irrigation is an appropriate means to that end.

Table II.11 presents the difference in household income for households with access to irrigation in the dry season (households with at least one plot that was cultivated and used irrigation in the dry season) compared to households without access to irrigation in the dry season (households that either did not cultivate in the dry season or cultivated but did not use irrigation).

Households with dry season irrigation (34 percent of households) had, on average, total annual household income that was 1,123,000 FCFA larger ($1,909 USD) or 58 percent higher than households without dry season irrigation. Average annual crops sales among households with dry season irrigation were more than six times that of households without dry season irrigation. Cash crop sales account for the majority of this difference.

For households with dry season irrigation access, total annual household income (including the value of own consumption[11]) was 3,055,000 CFA ($5,194 USD), which translates to 837 CFA per person per day ($1.42 USD and $2.85 USD PPP), placing these households well above the poverty line for Tahoua Niger (434 FCFA, $0.74 USD) and the global extreme poverty line ($1.90 USD PPP) but still below the less extreme global poverty line ($3.10 USD PPP).

In contrast, households without dry season irrigation access are only slightly above the global extreme poverty line. These households had an annual household income of 1,932,000 FCFA ($3,284 USD), which translates to 529 FCFA per person per day ($0.90 USD and $1.80 USD PPP). Although still above the Tahoua Niger and global extreme poverty lines, these households fall just below the global extreme poverty line ($1.90 USD PPP), illustrating that dry season irrigation access is an important factor in household poverty.

Both types of households have relatively similar levels of income from off-perimeter land and similarly sized landholdings off-perimeter, which may suggest that households without dry season irrigation have limited opportunities to earn agricultural income. They appear to compensate for this with marginally more non-agricultural employment and self-employment; income from non-agricultural sources was 56,000 FCFA ($95 USD) or 6 percent higher, on average, for households without dry season irrigation.

Table II.11. Household income, revenue, and sales by access to dry season irrigation

Indicator	Full sample	Access to dry season irrigation	No access to dry season irrigation
Annual			
Total agricultural and non-agricultural income, including own consumption (FCFA)	2,294,000	3,055,000	1,932,000
Agricultural income, including own consumption (FCFA)	1,349,000	2,138,000	975,000
Agricultural on-perimeter income, including own consumption (FCFA)	853,000	1,594,000	500,000
Agricultural off-perimeter income, including own consumption (FCFA)	469,000	532,000	438,000
Agricultural revenue (FCFA)	1,015,000	1,924,000	584,000
Agricultural on-perimeter revenue (FCFA)	718,000	1,669,000	265,000
Agricultural off-perimeter revenue (FCFA)	329,000	388,000	302,000
Crop sales on-perimeter (FCFA)	727,000	1,698,000	265,000
Cash crop sales on-perimeter (FCFA)	585,000	1,441,000	178,000
Traditional crop sales on-perimeter (FCFA)	23,000	22,000	23,000
Dual crop sales on-perimeter (FCFA)	98,000	190,000	54,000
Non-agricultural income (FCFA)	902,000	864,000	920,000

[11] The value of own consumption is computed as the total value of production less the value of sales and losses.

Indicator	Full sample	Access to dry season irrigation	No access to dry season irrigation
Employment income (FCFA)	253,000	118,000	318,000
Self-employment income (FCFA)	658,000	740,000	619,000
Household sample size	*782*	*262*	*520*

Notes: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. All FCFA values have been rounded to the nearest thousand. Cash crops are anise, cabbage, onion, okra, groundnuts, tomatoes, and wheat. Traditional crops are millet and sorghum. All other crops are dual crops.

C.8. Household food security, poverty, and women's empowerment

IMAP's program logic also anticipates improved outcomes for several other socioeconomic indicators, including increased women's empowerment and assets, as well as improvements in terms of food security—the second goal of the program logic.

Table II.12 indicates the frequency with which households experience food insecurity and household poverty. All food insecurity measures are derived from survey questions about the previous month; given the timing of the baseline survey March 8–21, 2020, the food insecurity questions approximately correspond to the period from early to late February 2020. As such, the food insecurity measures are unlikely to reflect the severity of food insecurity that may be experienced in the lean season prior to harvests in the rainy season.

Food insecurity is relatively uncommon among households, but slightly more common in female-only PAP households relative to male PAP households. Among those experiencing some degree of food inadequacy, hunger, or extreme hunger, the majority rarely experienced food insecurity (defined as 1–2 times in the past month). Only 1 to 3 percent of households experienced food inadequacy, hunger, or extreme hunger more than 10 times in the past month.

The results from the analysis of asset-based poverty scores confirm that households on the Konni perimeter are better off than households within Niger at large. As shown in **Table II.12**, the average poverty score among households on the Konni perimeter is 45.35, which represents a 13.5 percent likelihood of households falling below the 2011 national poverty line and a 4.3 percent likelihood of falling in the bottom poorest half of Nigeriens. Households with only female PAPs are less poor than households with male PAPs. The poverty score of 46.96 for female-only PAP households represents a 7.7 percent likelihood of falling below the national poverty line, whereas the poverty score of 45.27 for households with at least one male PAP represents a likelihood of 13.5 percent (Schreiner 2018). (A higher poverty score indicates a lower likelihood of being poor).

In **Table II.12,** we also highlight some components of the poverty score. Thirty percent of households have an improved toilet (defined as an improved latrine or a flush toilet). Most households (61 percent) do not have electricity, but 53 percent have a motorcycle or private vehicle, although this number is substantially lower for households with only female PAPs (39 percent). A larger share of female-only PAP households have improved roof materials, an improved toilet, and electricity relative to male PAP households, which contribute to their lower predicted likelihood of being poor.

Food insecurity is low and does not meaningfully differ between households with documented versus undocumented plots (**Table C.8**). The average poverty score for households with documented plots is slightly higher (46.19) relative to households with undocumented plots (44.64). Households with documented plots have, on average, a 7.7 percent likelihood of falling below the national poverty line, whereas the likelihood is 13.5 percent for households with undocumented plots. This difference is similar in magnitude to the difference between female-only and male PAP households.

Table II.12. Household food security and poverty

Indicator	Full sample	Female PAPs	Male PAPs
Food insecurity			
Food inadequacy (0/1)	0.18	0.27	0.18
Rare food inadequacy (1–2 times in past month)	0.10	0.19	0.10
Sometimes food inadequacy (3–10 times in past month)	0.06	0.07	0.06
Often food inadequacy (more than 10 times in past month)	0.03	0.01	0.03
Hunger (0/1)	0.13	0.16	0.12
Rare hunger (1–2 times in past month)	0.06	0.12	0.06
Sometimes hunger (3–10 times in past month)	0.04	0.01	0.04
Often hunger (more than 10 times in past month)	0.02	0.02	0.02
Extreme hunger (0/1)	0.06	0.07	0.06
Rare extreme hunger (1–2 times in past month)	0.03	0.06	0.02
Sometimes extreme hunger (3–10 times in past month)	0.02	0.00	0.02
Often extreme hunger (more than 10 times in past month)	0.01	0.01	0.01
Poverty			
Poverty score	45.35	46.96	45.27
Improved roof materials (0/1)	0.56	0.69	0.55
Number of rooms	3.53	3.73	3.51
Improved toilet (0/1)	0.30	0.45	0.30
Electricity (0/1)	0.39	0.49	0.39
Number of cellphones	2.41	2.53	2.41
Owns motorized transportation (0/1)	0.53	0.39	0.54
Household sample size	*782*	*120*	*662*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

Increasing women's economic empowerment is an anticipated long-term outcome of IMAP's logic model. During the design and questionnaire development phases of the evaluation, MCC also highlighted an interest in understanding changes in women's empowerment more broadly beyond economic empowerment. To explore this, we adapted a commonly used tool to measure empowerment, the Women's Empowerment in Agriculture Index (WEAI). The WEAI methodology conceptualizes empowerment as agency and autonomy over critical parts of life, including production, resources, income, and leadership, and develops a set of questions that allow for the construction of a quantitative empowerment score. Given that the cumulative respondent burden of administering the WEAI in conjunction with the modules designed to collect information on agricultural outcomes would have been too onerous, we shortened and adapted the WEIA modules.

Relative to a standard WEAI index, our empowerment score includes four out of five WEAI domains (production, resources, income, and leadership) but excludes time use. Because we only ask a female member of the household about empowerment, we cannot construct a gender parity measure. In addition, we've selected questions in the productive income, control over household income, resources, and leadership domains that are most relevant to the IMAP context and have adapted them to the local context as well.

Following the WEAI methodology (IFPRI 2012; Alkire et al. 2013), empowerment is defined as a weighted adequacy score of 80 percent or higher, indicating that women have achieved a weighted adequacy in at least 80 percent of a possible 100 percent of input indicators across the production, resources, income, and leadership domains. Domains are weighted so that they contribute equally (in our adaptation with four domains at 25 percent each) to the total adequacy score. Similarly, within each domain, input indicators are weighted so they contribute equally to the domain. These weights vary within each domain depending on the number of input indicators.

The vast majority of women on the Konni perimeter remain unempowered. We characterize women's empowerment in **Table II.13**, disaggregating important components of the empowerment score. As shown in **Table II.1** as well, women on the Konni perimeter have an empowerment score of 64 percent (out of a potential 100 percent).[12] This score reflects that 21 percent of women are empowered across the four domains in the modified index (input into productive income, control over household income, resources, and leadership), 79 percent are unempowered, and unempowered women have an average adequacy score of 54 percent. Women in households with only female PAPs are more empowered (79 percent) than those in households with one or more male PAPs (61 percent). Women's empowerment does not differ significantly for women in households with documented plots compared to women in households with plots lacking documentation (**Table C.9**).

Fifty-eight percent of women report having input into productive decisions, 71 percent report control over household income, 52 percent report adequacy with respect to resources (with only 11 percent making decisions about purchases, sales or transfers of assets), and 43 percent report leadership adequacy (with only 15 percent reporting community group membership). These values suggest a strong opportunity for the IMAP to increase women's empowerment as a result of planned project activities.

We find slightly higher levels of empowerment and adequacy among women in households on the Konni perimeter relative to what Wouterse (2019) finds in surrounding areas. This could be due to several factors. First it is possible that the women in households with land on the Konni perimeter are more peri-urban given the proximity to Konni, which may be correlated with higher empowerment scores. An alternative explanation may be related to the construction of our index, which relies on a subset of the WEAI dimensions. In particular, it might not be surprising that we find slightly higher levels of empowerment and adequacy given the omission of time use and gender parity components, which are likely to reflect the lack of agency regarding time use and the relative disempowerment of women compared to their male counterparts.[13]

[12] The sample of 755 women comprises one woman each from distinct households.
[13] Because Wouterse (2019) does not present an empowerment measure excluding time use or gender parity, it is not possible to directly compare the two measures of women's empowerment.

Table II.13. Women's empowerment in agriculture

Indicator	Women	Women in HHs with only female PAPs	Women in HHs with 1+ male PAPs
Women's empowerment score (%)	0.64	0.79	0.61
Empowered (%)	0.21	0.31	0.20
Unempowered (%)	0.79	0.69	0.80
Adequacy score (0/1)	0.57	0.74	0.56
Adequacy score among unempowered (0/1)	0.54	0.69	0.51
Input into productive decisions (0/1)	0.58	0.95	0.56
Control over household income (0/1)	0.71	0.97	0.70
Resource domain adequacy (0/1)	0.52	0.58	0.52
Ownership of assets (0/1)	0.74	0.79	0.74
Makes decisions about purchase, sale, or transfer of assets (0/1)	0.11	0.19	0.10
Makes decisions about borrowing or using credit (0/1)	0.72	0.78	0.72
Leadership domain adequacy (0/1)	0.43	0.47	0.43
Community group membership (0/1)	0.15	0.25	0.15
Comfortable speaking in groups or in public (0/1)	0.70	0.69	0.70
Household sample size	*755*	*119*	*636*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

III. Evaluation administration

A. Summary of IRB requirements and clearances

Mathematica is committed to protecting the rights and welfare of human subjects. We have ensured that the study meets all U.S. and Niger research standards for ethical clearance. Mathematica used Health Media Lab as our IRB because of our positive experience with it on other MCC projects. IRB approval required three sets of documents: (1) a research protocol that described the purpose and design of the research and provided information about our plans for protecting study participants and their confidentiality and human rights, including how we acquired consent for their participation; (2) copies of all data collection instruments and consent forms used for the evaluation; and (3) a completed IRB questionnaire that provided information about the research protocol, how we will securely collect and store our data, our plans for protecting participants' rights, and any possible drawbacks for participants that might result from any breach of data confidentiality. We also collaborated with our data collection firm, Société de Développement International (SDI), to obtain approval for conducting fieldwork from the National Statistics Institute in Niger.

Evidence of IRB approval was provided to MCC. IRB approval is valid for one year; we will submit annual renewals for subsequent approvals as data collection proceeds through follow-up collection processes. We expect the annual renewals to require only minimal updates to the core application materials because we will collect similar data from year to year. If data collection instruments change substantially from those approved by the IRB, we will reapply for review; small changes to the instruments (such as rewording or reordering of questions, or editing changes) do not require reapplication. We will submit the final instruments to the IRB for documentation.

B. Preparing data files for access, privacy, and documentation

All data collected for this evaluation are securely transferred from the data collection firm to Mathematica, stored on Mathematica's secure server, and accessible only to project team members who use the data. After producing and finalizing each of the final evaluation reports, including this baseline report, we will prepare corresponding de-identified data files, user manuals, and codebooks based on the quantitative survey data. We understand that these files could be made available to the public; therefore, the data files, user manuals, and codebooks will be de-identified according to MCC's most recent guidelines. Public use data files will be free of personal or geographic identifiers that would permit unassisted identification of individual respondents or their households. In addition, we will remove or adjust variables that introduce a reasonable risk of deductive disclosure of the identity of individual participants.

For internal control and audit purposes, the local data collection firm will retain the data files, both in paper and electronic form, for the entire duration of the project, including the base contract and the subsequent option contracts. All the collected data and databases are the property of Mathematica and will be delivered to us at the end of the contract. We will also recode unique and rare data by using top and bottom coding or replacing affected 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

Due to ongoing COVID-19-related travel restrictions, the Mathematica team will present evaluation findings remotely at both MCC and MCA-N headquarters. We will also participate in any other MCC-financed dissemination and training events related to the findings from the baseline, interim, and final reports. 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 within the agriculture sector, especially for policymakers and practitioners. After acceptance of the interim and final evaluation reports, the team will develop a policy brief with findings and analysis relevant to MCC and Government of Niger decision makers. We expect the broader research community to have a strong interest in the evaluation findings. To facilitate wider dissemination of findings and lessons, we will collaborate with MCC and other stakeholders to identify additional forums—conferences, workshops, and publications—for disseminating the results.

D. Evaluation team: Roles and responsibilities

Evaluation team members	Role	Responsibility
Mr. Matt Sloan	Program manager	Overseeing the project team, providing quality assurance
Dr. Christopher Ksoll	Project director/primary point of contact for MCC	Leading the evaluation design and data analyses, overseeing the execution of the quantitative components of the design and data collection, managing quantitative data analysis. Communicating with client, coordinating with key stakeholders in the Niger agriculture sector, overseeing evaluation budget, overseeing data collection, managing evaluation team staffing and priorities, primarily responsible for delivering high quality products that meet MCC's and other stakeholders' needs
Dr. Anthony D'Agostino	Senior analyst	Working on the design of the performance analysis and the analysis. Conducting data quality checks and overseeing the programming
Ms. Patricia Costa	Senior analyst	Working on data collection instrument development and the qualitative aspects of the evaluation, coordinating data collection subcontractors
Dr. Esteban Quinones	Analyst	Working on the quantitative data analysis and creating the outline for the baseline report
Ms. Margo Berends	Analyst	Supporting the analysis and data collection and drafting of the baseline report, coordinating data collection and subcontractors
Mr. Evan Fantozzi	Research assistant	Supporting data analysis
Ms. Sara Bryk	Research assistant	Supporting data analysis
Mr. Saidou Amadou	In-country coordinator	Overseeing data collection fieldwork, monitor data quality, coordinate site visits, assist in communications with MCA-N
Ms. Poorva Upadhyaya	Project manager	Managing the project internally, invoicing, communication with MCC

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Appendix A:

Research questions, evaluation methods, and data sources

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Appendix Table A.1. Evaluation methods, research questions, data sources, and key outcomes for evaluation of Konni Irrigation Perimeter Development Activity

Evaluation method	Research questions	Data sources	Key outcomes
Infrastructure assessment	RQ9. Were the expected outputs produced by the activity? RQ10. Is the new/improved infrastructure functioning properly in terms of water flow?	• Perimeter visits • KIIs	• Irrigation water flow rates • Percentage of irrigation structures functioning
Quantitative descriptive analysis	RQ11a. Is water for irrigation in farmers' plots available as expected from the irrigation system?	• Surveys of households • Monitoring data • Satellite/drone imagery	• Irrigation availability • Irrigation timing • Frequency of flooding
Pre-post analysis	RQ3. Did PAP households experience changes in their household incomes, volumes, and value of agricultural products sold and traded, food and nutritional security, and production of cash crops? RQ7. What is the post-Compact ERR of the project (except for the Roads for Market Access Activity)? RQ12a. Did irrigated land increase as expected? RQ13a. Did the cost of irrigation water change?	• Surveys of households • Administrative data • Satellite/drone imagery	• Agricultural and non-agricultural income • Agricultural outcomes • Cropping pattern • Food and nutritional security • Irrigation access, costs, and usage
Qualitative outcomes analysis	RQ11b. If water for irrigation in farmers' plots is not available as expected, why not? RQ12b. If irrigated land did not increase as expected, why not? RQ13b. If the cost of irrigation water did not change, why not?	• KIIs • FGDs	• Factors affecting irrigation expansion, accessibility to households, and cost
Qualitative sustainability analysis	RQ5. If the project produced results, are they expected to be sustained? If the project did not meet its expected results, why not?	• KIIs	• Perceptions of sustainability

Notes: ERR = economic rate of return; FGD = focus group discussion; KII = key informant interview; PAP = project affected person. Research questions in table are abbreviated versions of full-text questions in **Appendix Table A.2**. Perimeter visits were not possible at baseline due to COVID-19 restrictions.

Appendix Table A.2. Evaluation design overview

Activity		Question group	Evaluation method	Data source and type
Overarching questions				
All	***RQ1***	*Did the project components interact as envisioned during project design to reach a common objective? If yes, what facilitated the interaction and if not, why not?*	• Implementation analysis	• KIIs with program implementers and key stakeholders • FGDs with beneficiaries
	RQ1a	*Was there close coordination and planning among the different contractors designing and implementing the activity (land allocation, infrastructure, IWUA, and agricultural services)? Did UNOPS in the role of project management consultant* *facilitate the rollout and coordination of activities?*	• Implementation analysis	• KIIs with program implementers and key stakeholders • FGDs with beneficiaries
	RQ2	*To what extent did the project interact with the grant facility of the Climate-Resilient Communities Project? What facilitated the interaction and what didn't?*	• Implementation analysis	• KIIs with program implementers and key stakeholders • FGDs with beneficiaries • Project documentation
	RQ3	Did PAP households experience changes in their household incomes, volumes, and value of agricultural products sold and traded, food and nutritional security, and production of cash crops?	• Pre-post analysis • Qualitative outcomes analysis	• Surveys of households • Mobile price data collection • FGDs with beneficiaries • Monitoring data
	RQ4	*Do stakeholders believe the project was well designed to achieve the project objective? What changes occurred and why?*	• Qualitative outcomes analysis	• KIIs with stakeholders
	RQ5	*If the project produced results, are they expected to be sustained? If the project did not meet its expected results, why not?*	• Sustainability analysis	• KIIs with stakeholders • Budget outlays
	RQ6	*What lessons can be drawn to inform future projects?*	• Synthesis of evaluation analyses	• Mathematica evaluation analyses • Compact closeout documents • KIIs
	RQ7	*What is the post-Compact ERR of the project (except for the Roads for Market Access Activity)?*	• Quantitative descriptive analysis • Pre-post analysis	• Surveys of households • Mobile price data collection • Project documentation • Cost information

Activity		Question group	Evaluation method	Data source and type
Irrigation Perimeter Development Activity				
All	***RQ8***	*Were project activities implemented as planned? If not, what changes occurred?*	• Implementation analysis	• Project documents • KIIs and FGDs
	RQ9	*Were the expected outputs produced by the activity?*	• Qualitative outcomes analysis • Infrastructure assessment	• KIIs and FGDs • Perimeter visits • Project documentation
	RQ10	*Is the new/improved infrastructure functioning properly in terms of water flow?*	• Infrastructure assessment	• Perimeter visits • KIIs
	RQ11	*Is water for irrigation in farmers' plots available as expected from the irrigation system, including frequency, timing, and amount as per planned irrigation schedules? If not, why not?*	• Quantitative descriptive analysis • Qualitative outcomes analysis	• Surveys of households • ONAHA water user surveys • Project documentation • Monitoring data • KIIs and FGDs
	RQ12	Did irrigated land increase as expected (as a whole and per family)? If not, why not?	• Pre-post analysis • Qualitative outcomes analysis	• Surveys of households • ONAHA water user surveys • Administrative data • KIIs • Project documentation
	RQ13	Did the cost of irrigation water change? If not, why not?	• Pre-post analysis • Qualitative outcomes analysis	• Surveys of households • KIIs and FGDs
Management Services and Market Facilitation Activity				
All	***RQ14***	*Were project activities implemented as planned? If not, what changes occurred?*	• Implementation analysis	• KIIs and FGDs • Project documentation
	RQ15	*Were the expected outputs produced by the activity?*	• Qualitative outcomes analysis	• KIIs and FGDs • Monitoring data • Project documentation
SISM Sub-Activity	***RQ16***	*Were IWUAs set up? How many were set up?*	• Quantitative descriptive analysis	• Monitoring data • Project documentation
	RQ17	*What was the profile of the participants (total number of participants disaggregated by sex and age)?*	• Quantitative descriptive analysis	• Monitoring data

Activity	Question group		Evaluation method	Data source and type
	RQ18	*What percentage of IWUA leadership committee members at the end of the Compact were women?*	• Quantitative descriptive analysis	• Administrative data
	RQ19	*Are IWUAs functioning as expected? Is the irrigation infrastructure being maintained properly?*	• Qualitative outcomes analysis • Infrastructure assessment	• Administrative data • FGDs and KIIs • Site visit • IWUA annual reports •
LTS Sub-Activity	***RQ20***	*Is a land tenure registry functioning according to plan? Is the land registry used as a tool by local authorities to continually record changes in land holdings? Do land holders have access to the correct documentation (contrats d'occupation or long-term leases for farmers, publicly held property titles of overall perimeters) according to the project plan? Were land use plans at the commune level successfully completed?*	• Implementation analysis • Qualitative outcomes analysis • Quantitative descriptive analysis	• KIIs • Project documentation • Site visits • Surveys of households
	RQ21	*Are the local land commissions in the project zone better equipped to ensure sustainable management of land rights in/around the perimeter?*	• Sustainability analysis	• Project documentation • Budget outlays • KIIs
	RQ22	Was the level and risk of land conflict reduced? Did land tenure security increase?	• Pre-post analysis	• Surveys of households • Conflict monitoring system/land administrative data
SAA Sub-Activity	***RQ23***	*Did participants perceive that they learned new skills/knowledge? Did this vary by subgroup? If they didn't perceive learning/acquire new knowledge, why or why not?*	• Quantitative descriptive analysis • Qualitative outcomes analysis	• Surveys of households • Administrative data collected by SAA consultant • Monitoring data • FGDs
	RQ24	*What percentage of participants of adult functional literacy and numeracy trainings report improvement in their skills (basic reading and writing) after the training? What percentage of them indicate improved knowledge of nutrition and hygiene, and budgeting and record keeping (inasmuch as these concepts were introduced as part of the literacy and numeracy training)?*	• Quantitative descriptive analysis • Qualitative outcomes analysis	• Surveys of households • Monitoring data • FGDs
	RQ25	*What percentage of participants' self-report increased knowledge of sustainable land and water resources management?*	• Quantitative descriptive analysis	• Surveys of households

Activity		Question group	Evaluation method	Data source and type
	RQ26	*What percentage of participants can name and explain at least two or three new or improved agricultural practices that they did not know before the training?*	• Quantitative descriptive analysis	• Surveys of households
	RQ27	*What percentage of members of comités de gestion within the cooperatives indicate improved knowledge of cooperative management?*	• Quantitative descriptive analysis	• Surveys of households
	RQ28	*Have participants applied new practices and technologies? Was this different for women/men or youth/non-youth participants? If knowledge was not applied, why not?*	• Qualitative outcomes analysis • Quantitative descriptive analysis	• Survey of households • Monitoring data • FGDs
	RQ29	*Were savings and loans groups created and fostered by the project? Based on their participation, have group participants indicated they have improved access to credit?*	• Implementation analysis • Qualitative outcomes analysis	• Monitoring data • Project documentation • FGDs
	RQ30	*How are cooperatives applying knowledge?*	• Qualitative outcomes analysis	• Monitoring data • FGDs
Policy Reform Activity				
All	***RQ31***	Did the Fertilizer Reform Sub-Activity produce the expected outputs? What changes occurred to the original design? Did the sub-activity lead to increased private sector participation in the fertilizer sector? If not, why not? Have reform activities made fertilizer more affordable and accessible?	• Implementation analysis • Pre-post analysis • Qualitative outcomes analysis	• Surveys of households • Mobile price data collection • KIIs • Monitoring data
	RQ32	*Did the National Statistical Capacity Sub-Activity produce the expected outputs? What changes occurred to the original design? Have reform activities improved GoN's statistical capacities in data collection, analysis, and reporting?*	• Implementation analysis • Qualitative outcomes analysis	• KIIs • FGDs

Notes: IPD = Irrigation Perimeter Development Activity; MSMF = Management Services and Market Facilitation Activity; PR = Policy Reform Activity; MCA-N = Millennium Challenge Account-Niger; UNOPS = United Nations Office for Project Services; GoN = Government of Niger; ONAHA = *l'Office National des Aménagements Hydroagricoles*; CAIMA = *Centrale d'Approvisionnement en Intrants et Matériels Agricoles*; PAP = project affected person; FGD = focus group discussion; KII = key informant interview; SAA = Agricultural Support Services Sub-Activity; SISM = Sustainable irrigation System Management; LTS = Land Tenure Security

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Appendix B:

Sampling tables and secondary outcome indicators

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Appendix Table B.1. Sampling probabilities and response rates by PAP type

Type	Sampling probability	Response rate
Individuals		
Female PAP (0/1)	0.67	1.00
Male PAP (0/1)	0.15	0.99
PAP owns 1 plot or fewer (0/1)	0.17	1.00
PAP owns 2 plots or more (0/1)	0.28	0.97
Strata		
Female PAP (0/1)	0.67	1.00
Male PAP owns less than 0.25 ha (0/1)	0.25	0.99
Male PAP owns 0.25 to less than 1.5 ha (0/1)	0.14	0.99
Male PAP owns 1.5 ha or more (0/1)	1.00	0.97
PAP used improved irrigation on 1+ plots	0.17	0.99
PAP used unimproved irrigation on 1+ plots	0.28	1.00
PAP acquired 1+ plots through purchase, government, or cooperative	0.16	0.99
PAP acquired 1+ plots through gift or inheritance	0.19	0.99

Appendix Table B.2. Balance between sampled and non-sampled PAPs

Indicator	Non-sampled (1)	Sampled (2)	Difference [1-2] (3)	Interviewed (4)	Difference [1-4] (5)
Individuals	3,605	830	-	784	-
Age	42.6	43.0	-0.4	43.1	-0.6
Strata					
Female PAP (0/1)	0.02	0.19	-0.17	0.19	-0.17
Male PAP owns less than 0.25 ha (0/1)	0.07	0.11	-0.04	0.11	-0.04
Male PAP owns 0.25 to less than 1.5 ha (0/1)	0.91	0.66	0.25	0.66	0.24
Male PAP owns 1.5 ha or more (0/1)	0.00	0.04	-0.04	0.04	-0.04
Number of plots on perimeter	1.05	1.11	-0.06	1.09	-0.04
Total land area on perimeter (ha)	0.55	0.57	-0.02	0.56	-0.01
Individuals with at least one plot with any irrigation (0/1)	0.66	0.64	0.02	0.65	0.01
Individuals with at least one plot with improved irrigation (0/1)	0.63	0.61	0.02	0.61	0.02
Individuals with at least one plot acquired through inheritance (0/1)	0.52	0.55	-0.04	0.56	-0.04
Individuals with at least one plot acquired through purchase (0/1)	0.11	0.12	-0.01	0.11	-0.00
Individuals with at least one plot acquired through gift/donation (0/1)	0.14	0.16	-0.03	0.16	-0.03
Individuals with at least one plot acquired from govt. or coop. (0/1)	0.25	0.19	0.06	0.19	0.06
Individuals with at least one plot acquired through other means (0/1)	0.00	0.00	0.00	0.00	0.00
Individuals with at least one plot with rainy season cultivation (0/1)	0.98	0.98	0.00	0.98	-0.00
Individuals with at least one plot with dry season cultivation (0/1)	0.70	0.70	0.00	0.71	-0.00
Individuals with at least one plot with dry or rainy season cultivation (0/1)	1.00	1.00	0.00	1.00	0.00

Indicator	Non-sampled (1)	Sampled (2)	Difference [1-2] (3)	Interviewed (4)	Difference [1-4] (5)
Total plot area with rainy season cultivation (ha)	0.54	0.56	-0.02	0.55	-0.01
Total plot area with dry season cultivation (ha)	0.24	0.23	0.01	0.23	0.01
Individuals with at least one plot with sorghum in rainy season (0/1)	0.83	0.84	-0.01	0.85	-0.02
Individuals with at least one plot with cowpea in rainy season (0/1)	0.39	0.40	-0.01	0.40	-0.01
Individuals with at least one plot with onion in dry season (0/1)	0.14	0.14	0.00	0.15	-0.01
Individuals with at least one plot with cabbage in dry season (0/1)	0.21	0.23	-0.02	0.24	-0.02
Individuals with at least one plot with 2+ crops in rainy season (0/1)	0.71	0.73	-0.02	0.73	-0.02
Individuals with at least one plot with 2+ crops in dry season (0/1)	0.44	0.45	-0.01	0.46	-0.02
Individuals with at least one plot with 2+ crops in dry or rainy season (0/1)	0.84	0.85	-0.01	0.85	-0.01

Joint orthogonality test	Sampled		Interviewed	
	f-statistic	p-value	f-statistic	p-value
All variables	1.05	0.39	1.11	0.33

Appendix Table B.3. Secondary outcome indicators for pre-post analysis

Key indicator	Data source	Definition
Land security and use (plot and perimeter levels)		
Cropping patterns	• Surveys of households	Seasonal indicators of plots with mono- or multi-crop cultivation
Irrigation (plot level)		
Irrigation available when needed	• Surveys of households	Seasonal indicators of irrigation availability when needed most
Fertilizer (plot and perimeter levels)		
Fertilizer application area	• Surveys of households	Seasonal share of perimeter area where fertilizer was applied
Type of fertilizer used	• Survey of households	Seasonal indicators of fertilizer use and quantities for chemical and organic fertilizer
Agricultural inputs (plot and household level)		
Type of seeds	• Survey of households	Seasonal indicators of purchased and/or improved seeds and the associated share of plot area sown
Seed expenditures	• Surveys of households	Annual household expenditures on seeds and cost of seeds per hectare
Improved inputs or practices	• Surveys of households	Indicators for use of improved inputs or practices including improved water and soil management techniques
Credit and expenditures (household and plot level)		
Credit access	• Survey of households	Indicators of access to credit or taking out a loan in the past year and the associated value of loans
Plot collateral	• Survey of households	Indicators of using or considering using plot as collateral for credit
Agricultural expenditures	• Survey of households	Annual household agricultural expenditures
Labor expenditures	• Surveys of households	Annual household expenditures on labor and cost of labor per hectare
Preparation and processing expenditures	• Surveys of households	Annual household expenditures on preparing and processing crops for sale and cost per tonne
Income (household level)		
Agricultural revenue	• Surveys of households	Annual value of revenue from crop sales and rent
Crop sales	• Surveys of households	Seasonal and annual values of revenue from crop sales including cash crops, traditional crops, and dual purpose crops
Non-agricultural income	• Surveys of households	Annual value of employment and self-employment income
Food insecurity (household level)		
Extreme hunger	• Surveys of households	Indicator of households where at least 1 member did not eat for an entire day in the previous month
Food insecurity frequency	• Surveys of households	Number of times in the past month that household experienced food inadequacy, hunger, or extreme hunger
Poverty (household level)		
Poverty score	• Survey of households	Scorocs Simple Poverty Scorecard for Niger based on nine poverty indicators to estimate consumption-based poverty rates

Key indicator	Data source	Definition
Poverty indicators	• Survey of households	Select indicators related to the poverty score: improved roof materials, number of rooms, improved toilet, electricity, number of cellphones, and motorized transport
Women's Empowerment in Agriculture Index (WEAI) (household level)		
Percent empowered	• Surveys of households	Share of women who are empowered (at or above 80 percent adequacy) based on production, resources, income, and leadership domains
Percent unempowered	• Surveys of households	Share of women who are unempowered (below 80 percent adequacy) based on production, resources, income, and leadership domains
Adequacy score	• Surveys of households	Weighted measure of adequacy (the extent of empowerment)
Adequacy score among the unempowered	• Surveys of households	Weighted measure of adequacy (the extent of empowerment) among unempowered women

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Appendix C:

Outcomes disaggregated by land tenure documentation

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Appendix Table C.1. Land tenure security, holdings, and use on the perimeter

Indicator	Full sample	Documented Plot	Undocumented Plot
Plot tenure security			
Formalized land rights for plot (0/1)	0.41	1.00	0.00
Experienced land dispute in last year over plot (0/1)	0.01	0.00	0.02
Perceived risk of involuntary loss of plot in next 5 years (0/1)	0.02	0.02	0.02
Plot holdings and land use			
Size of plot (ha)	0.53	0.50	0.56
Dry season			
Plot was cultivated based on self-report (0/1)	0.70	0.76	0.66
Plot area cultivated based on self-report (ha)	0.34	0.36	0.32
Plot was cultivated triangulated (0/1)	0.40	0.44	0.36
Plot area cultivated triangulated (ha)	0.18	0.19	0.16
Cash crop cultivated on plot (0/1)	0.37	0.40	0.33
Plot area cultivated with cash crops	0.13	0.14	0.12
Traditional crop cultivated on plot (0/1)	0.03	0.05	0.02
Plot area cultivated with traditional crops	0.01	0.01	0.01
Dual purpose crop cultivated on plot (0/1)	0.14	0.13	0.15
Plot area cultivated with dual purpose crops	0.03	0.03	0.04
Plot was mono-cropped (0/1)	0.15	0.18	0.12
Plot was multi-cropped (0/1)	0.25	0.26	0.25
Rainy season			
Plot was cultivated (0/1)	0.97	0.98	0.97
Plot area cultivated (ha)	0.49	0.46	0.51
Cash crop cultivated on plot (0/1)	0.33	0.36	0.32
Plot area cultivated with cash crops	0.07	0.07	0.06
Traditional crop cultivated on plot (0/1)	0.88	0.87	0.89
Plot area cultivated with traditional crops	0.30	0.27	0.33
Dual purpose crop cultivated on plot (0/1)	0.60	0.58	0.60
Plot area cultivated with dual purpose crops	0.12	0.12	0.12
Plot was mono-cropped (0/1)	0.19	0.21	0.18
Plot was multi-cropped (0/1)	0.78	0.77	0.79
Plot sample size	*874*	*385*	*472*
Perimeter			
Share of perimeter area under land dispute (%)	0.01	0.00	0.01
Share of perimeter area with a perceived risk of involuntary loss of land (%)	0.02	0.01	0.02
Dry season			
Total perimeter area cultivated (ha)	808	347	421
Share of perimeter area cultivated (%)	0.33	0.14	0.17
Rainy season			
Total perimeter area cultivated (ha)	2,242	892	1,287
Share of perimeter area cultivated (%)	0.92	0.37	0.53

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. Cash crops are anise, cabbage, onion, okra, groundnuts, tomatoes, and wheat. Traditional crops are millet and sorghum. All other crops are dual purpose crops.

Appendix Table C.2. Use and perceived quality of irrigation

Indicator	Full sample	Documented Plot	Undocumented Plot
Plots			
Dry season			
Used irrigation, conditional on cultivation (0/1)	0.80	0.84	0.79
Irrigation always available when needed, conditional on using irrigation (0/1)	0.88	0.85	0.91
Plot sample size	*357*	*171*	*175*
Rainy season			
Used irrigation, conditional on cultivation (0/1)	0.13	0.18	0.10
Irrigation always available when needed, conditional on using irrigation (0/1)	0.83	0.79	0.88
Plot sample size	*854*	*378*	*460*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

Appendix Table C.3. Fertilizer

Indicator	Full sample	Documented Plot	Undocumented Plot
Plots			
Dry season			
Organic and/or inorganic fertilizer applied, conditional on cultivation (0/1)	0.98	0.98	0.99
Inorganic fertilizer applied (0/1)	0.96	0.97	0.96
Quantity of inorganic fertilizer applied (0/1)	0.14	0.15	0.12
Organic fertilizer applied (0/1)	0.64	0.56	0.70
Quantity of organic fertilizer applied (t)	1.72	1.71	1.71
Plot sample size	*821*	*368*	*436*
Rainy season			
Organic and/or inorganic fertilizer applied, conditional on cultivation (0/1)	0.96	0.95	0.99
Inorganic fertilizer applied (0/1)	0.83	0.83	0.86
Quantity of inorganic fertilizer applied (0/1)	0.14	0.11	0.15
Organic fertilizer applied (0/1)	0.81	0.73	0.87
Quantity of organic fertilizer applied (0/1)	5.04	4.62	5.39
Plot sample size	*789*	*349*	*423*
Perimeter			
Dry season			
Share of perimeter area with fertilizer applied, conditional on cultivation (%)	0.90	0.40	0.48
Share of perimeter area with inorganic fertilizer applied, conditional on cultivation (%)	0.88	0.39	0.46
Share of perimeter area with organic fertilizer applied, conditional on cultivation (%)	0.56	0.22	0.32
Inorganic fertilizer per hectare (t/ha)	0.38	0.40	0.35
Organic fertilizer per hectare (t/ha)	4.75	4.51	4.91
Rainy season			
Share of perimeter area with fertilizer applied, conditional on cultivation (%)	0.88	0.34	0.52
Share of perimeter area with inorganic fertilizer applied, conditional on cultivation (%)	0.76	0.29	0.46
Share of perimeter area with organic fertilizer applied, conditional on cultivation (%)	0.74	0.27	0.45
Inorganic fertilizer per hectare (t/ha)	0.25	0.22	0.26
Organic fertilizer per hectare (t/ha)	9.17	8.78	9.49

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

Appendix Table C.4. Seeds and improved agricultural practices

Indicator	Full sample	Documented Plot	Undocumented Plot
Plots			
Dry season			
Sowed purchased seeds, conditional on cultivation (0/1)	0.93	0.96	0.90
Share of plot area with purchased seeds (%)	0.92	0.95	0.90
Sowed improved seeds (0/1)	0.47	0.50	0.47
Plot sample size	*616*	*288*	*315*
Rainy season			
Sowed purchased seeds (0/1)	0.81	0.86	0.79
Share of plot area with purchased seeds (%)	0.74	0.79	0.70
Sowed improved seeds (0/1)	0.32	0.40	0.27
Plot sample size	*853*	*378*	*459*
Annual			
Applied improved water and soil management techniques (0/1)	0.77	0.74	0.79
Applied improved inputs or practices (0/1)	1.00	1.00	0.99
Number of improved inputs or practices (out of 9)	4.45	4.49	4.42
Plot sample size	*859*	*382*	*461*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. Improved inputs or practices are: zero tillage land preparation, planting seeds in rows, improved seeds, improved water and soil management techniques, using mechanized equipment, applying inorganic fertilizer, applying pesticides or herbicides, processing crops after harvest, storing crops in hermetic bags.

Appendix Table C.5. Credit and expenditures

Indicator	Full sample	Documented Plot	Undocumented Plot
Credit (household)			
Household can access credit (0/1)	0.25	0.30	0.22
Loan taken out in the last year (0/1)	0.25	0.30	0.22
Total value of loan(s) taken out in the last year, not conditional on borrowing (FCFA)	32,000	45,000	25,000
Household sample size (credit)	*782*	*344*	*425*
Collateral (plots)			
Used plot as collateral for credit in past dry or rainy season (0/1)	0.05	0.07	0.04
Would consider using plot as collateral (0/1)	0.02	0.05	0.00
Plot sample size	*872*	*385*	*471*
Annual expenditures (for all household on-perimeter plots)			
Total agricultural expenditures (FCFA)	321,000	351,000	297,000
Irrigation expenditures (FCFA)	18,000	19,000	18,000
Fertilizer expenditures (FCFA)	76,000	89,000	66,000
Seed expenditures (FCFA)	70,000	77,000	63,000
Labor expenditures (FCFA)	87,000	82,000	90,000
Preparation and processing expenditures (FCFA)	24,000	32,000	18,000
Annual per hectare costs (for all household on-perimeter plots)			
Annual irrigation cost per hectare, dry and rainy seasons (FCFA/ha)	21,000	22,000	20,000
Annual fertilizer cost per hectare, dry and rainy seasons (FCFA/ha)	95,000	112,000	83,000
Annual seed cost per hectare, dry and rainy seasons (FCFA/ha)	84,000	95,000	74,000
Annual labor cost per hectare, dry and rainy seasons (FCFA/ha)	116,000	113,000	118,000
Annual preparation and processing cost per hectare, dry and rainy seasons (FCFA/t)	6,000	7,000	6,000
Household sample size (expenses and costs)	*781*	*344*	*425*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. All FCFA values have been rounded to the nearest thousand.

Appendix Table C.6. Perimeter-level crop yield, profit, and unit profit

Indicator	Full sample	Documented Plot	Undocumented Plot
Yield in dry season (t/ha)			
Corn	3.77	3.57	3.95
Sorghum	4.68	N/A	N/A
Tomatoes	18.52	13.22	23.06
Anise	2.96	3.14	3.01
Cabbage	33.53	40.00	28.88
Onions	19.75	20.85	20.47
Wheat	5.88	5.83	5.92
Income per hectare in dry season (FCFA/ha)			
Corn	469,000	386,000	517,000
Sorghum	588,000	N/A	N/A
Tomatoes	1,436,000	905,000	1,915,000
Anise	1,769,000	2,553,000	1,292,000
Cabbage	2,272,000	2,953,000	1,755,000
Onions	4,015,000	4,352,000	4,144,000
Wheat	1,057,000	1,169,000	951,000
Yield in rainy season (t/ha)			
Corn	5.25	5.81	4.93
Sorghum	3.49	3.87	3.28
Tomatoes	31.68	35.89	24.77
Cowpeas	2.48	2.76	2.29
Groundnuts	3.45	4.46	2.86
Millet	4.82	4.84	4.76
Income per hectare in rainy season (FCFA/ha)			
Corn	790,000	933,000	732,000
Sorghum	424,000	468,000	399,000
Tomatoes	4,120,000	4,686,000	3,103,000
Cowpeas	817,000	564,000	1,003,000
Groundnuts	655,000	1,048,000	419,000
Millet	819,000	786,000	830,000

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. Some subgroup values have been omitted due to small sample sizes. All FCFA values have been rounded to the nearest thousand.

N/A = not available.

Appendix Table C.7. Household income, sales, and profits

Indicator	Full sample	Documented Plot	Undocumented Plot
Annual			
Total agricultural and non-agricultural income, including own consumption (FCFA)	2,294,000	2,134,000	2,399,000
Agricultural income, including own consumption (FCFA)	1,349,000	1,472,000	1,259,000
Agricultural on-perimeter income, including own consumption (FCFA)	853,000	954,000	762,000
Agricultural off-perimeter income, including own consumption (FCFA)	469,000	499,000	460,000
Agricultural revenue (FCFA)	1,015,000	1,159,000	916,000
Agricultural on-perimeter revenue (FCFA)	718,000	892,000	587,000
Agricultural off-perimeter revenue (FCFA)	329,000	363,000	312,000
Crop sales on-perimeter (FCFA)	727,000	914,000	588,000
Cash crop sales on-perimeter (FCFA)	585,000	721,000	480,000
Traditional crop sales on-perimeter (FCFA)	23,000	36,000	15,000
Dual crop sales on-perimeter (FCFA)	98,000	128,000	77,000
Non-agricultural income (FCFA)	902,000	640,000	1,080,000
Employment income (FCFA)	253,000	162,000	317,000
Self-employment income (FCFA)	658,000	488,000	773,000
Dry season on-perimeter			
Crop sales (FCFA)	447,000	506,000	402,000
Cash crop sales (FCFA)	424,000	482,000	380,000
Traditional crop sales (FCFA)	N/A	N/A	N/A
Dual crop sales (FCFA)	22,000	14,000	27,000
Rainy season on-perimeter			
Crop sales (FCFA)	265,000	384,000	177,000
Cash crop sales (FCFA)	160,000	241,000	98,000
Traditional crop sales (FCFA)	21,000	33,000	13,000
Dual crop sales (FCFA)	69,000	97,000	50,000
Household sample size	*782*	*344*	*425*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values. All FCFA values have been rounded to the nearest thousand. Cash crops are anise, cabbage, onion, okra, groundnuts, tomatoes, and wheat. Traditional crops are millet and sorghum. All other crops are dual crops.

N/A = not available.

Appendix Table C.8. Household food security and poverty

Indicator	Full sample	Documented Plot	Undocumented Plot
Food insecurity			
Food inadequacy (0/1)	0.18	0.18	0.19
Rare food inadequacy (1-2 times in past month)	0.10	0.10	0.11
Sometimes food inadequacy (3-10 times in past month)	0.06	0.07	0.05
Often food inadequacy (more than 10 times in past month)	0.03	0.02	0.03
Hunger (0/1)	0.13	0.10	0.13
Rare hunger (1-2 times in past month)	0.06	0.05	0.07
Sometimes hunger (3-10 times in past month)	0.04	0.04	0.04
Often hunger (more than 10 times in past month)	0.02	0.01	0.02
Extreme hunger (0/1)	0.06	0.06	0.05
Rare extreme hunger (1-2 times in past month)	0.03	0.03	0.02
Sometimes extreme hunger (3-10 times in past month)	0.02	0.02	0.02
Often extreme hunger (more than 10 times in past month)	0.01	0.01	0.00
Poverty			
Poverty index	45.35	46.19	44.64
Improved roof materials (0/1)	0.56	0.51	0.60
Number of rooms	3.53	3.51	3.52
Improved toilet (0/1)	0.30	0.41	0.22
Electricity (0/1)	0.39	0.34	0.44
Number of cellphones	2.41	2.59	2.31
Owns motorized transportation (0/1)	0.53	0.51	0.55
Household sample size	*782*	*344*	*425*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

Appendix Table C.9. Women's empowerment in agriculture

Indicator	Women	Women in HHs with documented plot	Women in HHs with undocumented plot
WEAI 4D empowerment subindex score (%)	0.64	0.61	0.66
Percent empowered (%)	0.21	0.22	0.22
Percent unempowered (%)	0.79	0.78	0.78
Adequacy score (0/1)	0.57	0.54	0.59
Adequacy score among unempowered (0/1)	0.54	0.50	0.57
Input into productive decisions (0/1)	0.58	0.55	0.59
Control over household income (0/1)	0.71	0.64	0.76
Resource domain adequacy (0/1)	0.52	0.51	0.53
Ownership of assets (0/1)	0.74	0.69	0.77
Makes decisions about purchase, sale, or transfer of assets (0/1)	0.11	0.15	0.08
Makes decisions about borrowing or using credit (0/1)	0.72	0.70	0.74
Leadership domain adequacy (0/1)	0.43	0.46	0.41
Community group membership (0/1)	0.15	0.24	0.09
Comfortable speaking in groups or in public (0/1)	0.70	0.67	0.71
Household sample size	*755*	*336*	*406*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

Appendix D:

Analysis of discrepancies in area cultivated between survey data and remote-sensing analysis

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Because the area cultivated estimated from the survey data diverged from information provided by ONAHA, we investigated the source of this discrepancy. Using remote-sensing data to triangulate our survey data, we found a number of instances in which the NDVI values from satellite imagery indicated that a plot was not cultivated during the dry season, yet the PAP reported that the majority or all of the plot was cultivated. After conducting follow-up interviews with PAPs and the presidents of several GMPs to investigate this discrepancy, we have determined that there are two primary explanations for this pattern we observe:

1. The primary reason reported by key informants for the discrepancy is that PAPs planted most or all of their plot, but their crop failed due to lack of access to or availability of water throughout the dry season as the reservoir was insufficient for total water needs. As a result, while they did plant the plot area that they reported, farmers were not able to cultivate to term, and thus, they did not have any crop growth or harvest. Our household survey only asked PAPs to report the area cultivated, so we are unable to verify the area harvested based on survey data. In many cases, respondents report a quantity harvested of zero, or close to zero.
2. When probed, farmers and presidents of cooperatives suggested that there may have been other instances in which a PAP misreported the area cultivated and quantity harvested because they incorrectly assumed that they needed to present themselves to the survey team as a larger producer to gain access to water or other resources or benefits. In these cases, the PAP did not plant anything, as indicated by satellite imagery, and therefore would not have had any crop growth or harvest. However, in many cases, the PAP then provided an internally consistent misrepresentation by reporting non-zero quantity harvested.

To conservatively correct for this observed discrepancy in the baseline data, we identify plots for which the difference between the percentage of plot area cultivated based on survey data and remote-sensing data is greater than or equal to 75 percentage points. In cases where respondents reported full cultivation while remote sensing indicated no cultivation, the difference would be 100 percentage points. This is a clear case of the divergence in results being so wide that survey responses should be overwritten. Similarly, if a respondent reported cultivating 90 percent of her plot, but our remote sensing approach predicts that 40 percent of the plot was cultivated, the difference between the two is 50 percentage points. As the difference between survey response and remotely sensed predictions of cultivated area decreases, the case for overriding survey responses diminishes. We believe that setting a threshold minimum of 75 percentage points is a sufficient level of disagreement between survey response and remotely sensed prediction, that assigning these plots an "unharvested" status is empirically justified. To determine the plot area cultivated in the 2019 dry season based on remote-sensing data, we calculate the area-weighted share of a parcel based on pixels with a pre-harvest dry-season maximum NDVI of greater than 0.42.[14,15]

[14] Since we do not have high-quality, historical ground truth data on dry season cultivation, we are not able to identify a normalized difference vegetation index (NDVI) value that distinguishes cultivated plots from uncultivated plots. Instead, we use ONAHA dry season cultivated area statistics for both Konni 1 and Konni 2 spanning 2016 through 2020 to identify the NDVI value of 0.42, which minimizes the root mean squared error (RMSE) of NDVI-derived predictions over those five years. For each year, we select the pixel-wise maximum value over the January 1–February 28 window. We also considered an alternative pixel-wise approach that differences the median NDVI value over November 15–December 31 with the median NDVI value from January 1–February 28 to identify what increase in NDVI is most associated with ONAHA cultivation statistics, also using an RMSE approach. While this approach produced a slightly lower RMSE than our maximum NDVI method using the 0.42 value, is it less straightforward to communicate.

[15] This analysis was done at the pixel-level, and then the average pre-harvest dry season NDVI maxima were averaged up to the plot-level.

For example, if 50 percent of the pixels comprising a plot had a maximum NDVI value of 0.5, and the other 50 percent maximum values of 0.3, then we would conclude that half of the parcel was cultivated. Our approach ensures we are only correcting the most egregious cases—cases in which we are certain that the PAPs did not have any vegetation growth or harvest from the area they reported cultivating. For these identified plots (206 in total, or 30 percent), we recode the dry season area cultivated to zero and recode their dry season output/harvest, sales, and post-harvest expenses to missing, as these modules of the survey should have been skipped for plots without cultivation. We do, however, retain their self-reported dry season input practices and costs because the first (and reportedly primary) case for the discrepancy specifies that they did apply inputs and incur these costs before irrigation water became unavailable and their crop failed. For the identified plots, the final outcomes data after these corrections are made reflect that the plot was not cultivated in the dry season, had no yield, and the PAP had a negative dry season profit for that plot (incurred expenses but did not earn any income).

Differences in cultivated area measurements are one potential factor for observed differences in estimated crop yields, which themselves will vary when different data collection methods are applied. In the context of comparing our survey reported yields and the CBA 2018/2019 values, a review of how yields can be estimated is instructive. Aside from asking farmers to self-report yields, yield estimates can also come from sub-plot crop cuts and from full-plot crop cuts. In a sub-plot crop cut, one or more measurement squares are laid on a field, typically encompassing between 5 meters to 8 meters each side. At the end of the season, the crops inside the square are dried and weighed by trained staff, with the yield estimate derived as the ratio of the output weight to the measurement square's area. A full-plot crop cut extends this procedure to the entirety of a plot, using GPS readings to calculate plot area and adopting the same output weighing procedure to arrive at a plot-level yield. While the full-plot crop cut is considered the "gold standard" for computing yields, they are expensive and more labor-demanding than the sub-plot crop cuts.

ONAHA's approach to estimate yields is crop specific. As one example, ONAHA conducts sub-plot crop cuts to measure rice production, by placing approximately one measurement square for each 5 hectares of production area (ONAHA 2020). Measurement squares are placed on randomly selected plots with the goal of obtaining a representative view across the range of productivity levels found throughout a perimeter. Measurement square dimensions also vary, from 1 meters each side to 5 meters. For portions of the perimeter where sub-plot crop cuts were not conducted, ONAHA relies on farmers' self-reported yield estimates.

Several papers find survey reports exceeding yields calculated from sub-plot crop cuts, while other papers find the opposite relationship. Gourlay, Kilic and Lobell (2019) show that survey reported yields, especially for small-holder plots, are often larger on average than yields from crop cuts. Paliwal and Jain (2020) and Wahab (2020) on the other hand find crop cut yields exceeding self-reported yields. Paliwal and Jain (2020) find that survey yields in their setting are 40% lower than crop cut yields and conclude that self-reported yields cannot be used to train remote sensing algorithms. Wahab (2020) finds crop cut yields that are more than three times larger than self-reported yields. Which data source is more reliable then becomes a natural follow-up question. Several papers suggest that crop cuts outperform survey responses in measuring yields (for example Carletto et al. 2015), but there are several strands of evidence that suggest this determination is not as straightforward. According to Wahab (2020), farmers adapt the area cultivated over the course of the season which reduces the effective area under cultivation as the season progresses. However, the area on which the measurement square is placed is less likely to be abandoned. Desiere and Joliffe (2018) note that crop cuts might be measuring potential yields, while the information on production contained in the surveys might measure actual harvests across a wider area.

Furthermore, yield values also may refer to distinct quantities. Whereas yields derived from full-plot or sub-plot cuts are based on the area harvested, self-reported yields may be calculated using planting area or harvested area. Since harvested area is de facto less than or equal to planted area, using planted area as the denominator in yield calculations will lead to lower yield values than if calculated using harvested area. Wahab (2020) notes that "conventionally, yield measurement is based on farmer-reported estimations of cropped area", but observes among a sample of survey plots in Ghana that cropped area is smaller than planted area by 15-30%, with obvious implications for yield estimates.

If yield estimate differences across data sources arise in interim and endline data rounds, we will investigate potential causes and explanations including conducting interviews with government officials to determine the extent of methodological differences between ONAHA's data collection and our own.

To ensure that comparisons over time are not driven by methodological differences, the methodology we used to apply adjustments to baseline survey responses based on remote sensing data will also be applied to interim and endline survey responses.

Appendix E:

Historical precipitation totals for Konni perimeter

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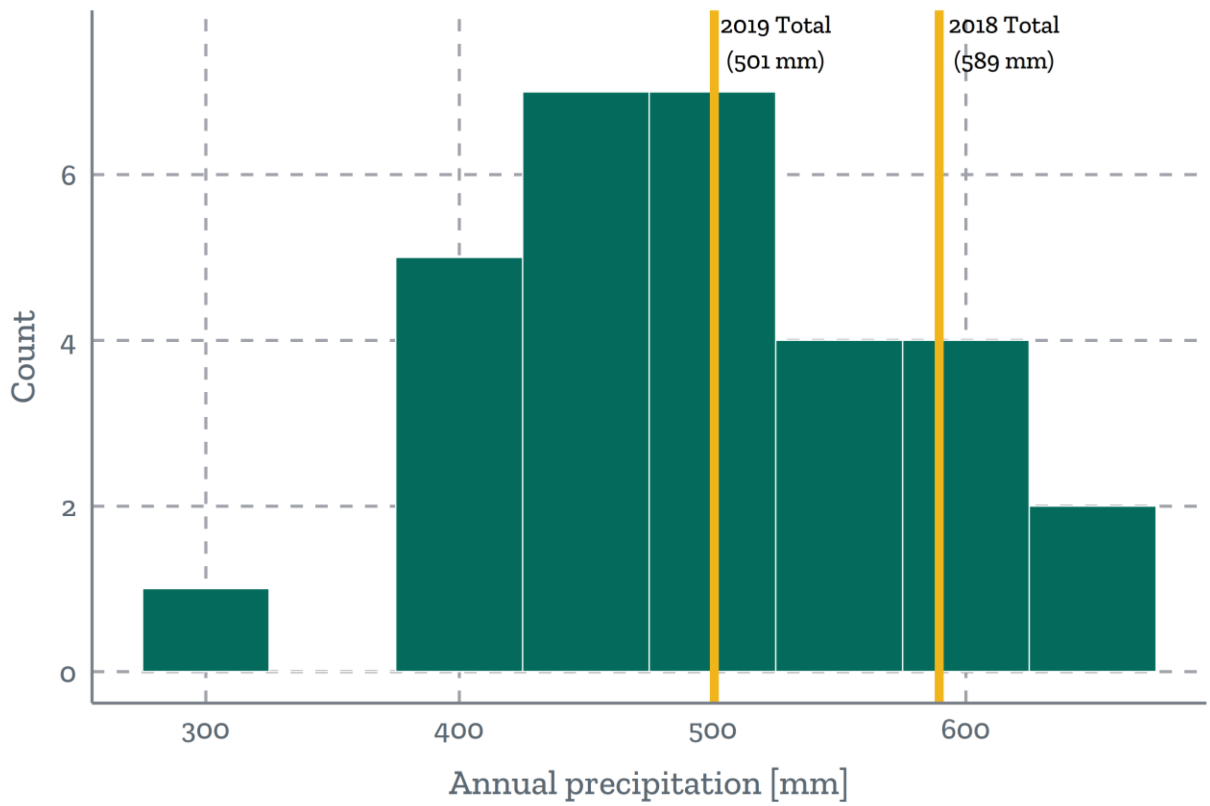
In this appendix, we examine historical rainfall records to determine if yield data collected for the dry and rainy seasons of the 2018–2019 agricultural campaign may be attributable to anomalous rainfall totals. We compute monthly rainfall from 1990 through 2019 as the spatial average over the Konni perimeter, using data from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) (Funk et al. 2014).

An average amount of rainfall fell in 2019 (501 millimeters) relative to the distribution of annual totals for the 39 years of data presented in Figure E.1, and this amount is only slightly higher than the mean of 494 mm over the same period. It is, therefore, unlikely that rainfall would be a contributor to any deviations in crop yields from their interannual mean. Similarly, dry season crop yields would be partly influenced by rain accumulated in the preceding rainy season. While the 589 mm of rainfall accrued in 2018 was above average, it would have affected rainy season crop yields for 2018 (before the period covered in the baseline survey) more than dry season yields for 2018–2019.

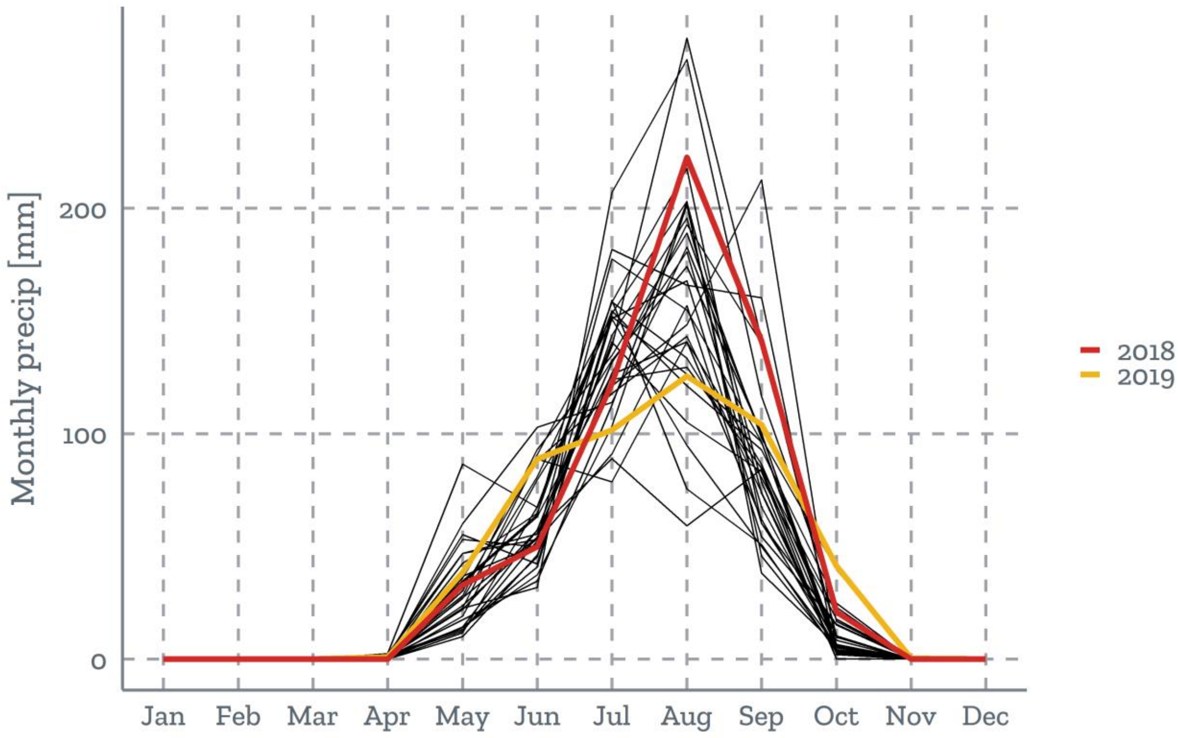
Appendix Figure E.1. Histogram of annual precipitation for the Konni perimeter, 1981–2019



Source: Mathematica calculations using CHIRPS data (Funk et al. 2014).

We also find no evidence that the temporal distribution of rainfall in either 2018 or 2019 was particularly remarkable, which rules out the possibility of unevenly distributed rainfall as a key influence on crop yield deviations from their long-term mean. In both years, monthly totals are within a usual range for the 1981–2019 period (Figure E.2). Although rainfall was low in July and August 2019 compared to other years, it was above average in June, September, and October 2019.

Appendix Figure E.2. Monthly precipitation for the Konni perimeter by year, 1981–2019



Source: Mathematica calculations using CHIRPS data (Funk et al. 2014).

Appendix F:

Food security disaggregated by access to irrigation

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Appendix Table F.1. Household food security and poverty, by access to dry season irrigation

Indicator	Full sample	Access to dry season irrigation	No access to dry season irrigation
Food insecurity			
Food inadequacy (0/1)	0.18	0.17	0.19
Rare food inadequacy (1–2 times in past month)	0.10	0.09	0.11
Sometimes food inadequacy (3–10 times in past month)	0.06	0.04	0.07
Often food inadequacy (more than 10 times in past month)	0.03	0.04	0.02
Hunger (0/1)	0.13	0.09	0.14
Rare hunger (1–2 times in past month)	0.06	0.03	0.08
Sometimes hunger (3–10 times in past month)	0.04	0.02	0.05
Often hunger (more than 10 times in past month)	0.02	0.03	0.01
Extreme hunger (0/1)	0.06	0.05	0.06
Rare extreme hunger (1–2 times in past month)	0.03	0.02	0.03
Sometimes extreme hunger (3–10 times in past month)	0.02	0.01	0.03
Often extreme hunger (more than 10 times in past month)	0.01	0.02	0.00
Poverty			
Poverty score	45.35	43.42	46.27
Improved roof materials (0/1)	0.56	0.54	0.57
Number of rooms	3.53	3.41	3.58
Improved toilet (0/1)	0.30	0.25	0.34
Electricity (0/1)	0.39	0.38	0.40
Number of cellphones	2.41	2.52	2.36
Owns motorized transportation (0/1)	0.53	0.51	0.54
Household sample size	*782*	*262*	*520*

Note: Sample sizes shown are for the largest sample, but some variables may have smaller sample sizes due to missing values.

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Appendix G:

Stakeholder comments

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Appendix Table G.1. Stakeholder comments

#	Page	Section	Reviewer Sector	Comments & Questions	Suggestions	Mathematica Response
Comments received in writing						
1	*8*	*D. Findings*	Ag	The estimate for dry season production at 70%/1,632 hectares for the SS 18/19 is (according to MCA & ONAHA) grossly overestimated. Confirming the number with those sources but the number likely did not surpass 300 hectares. For SS19/20 there were only 107 hectares under production (53 in Konni 1 and 54 for Konni 2).	Cross reference this finding with other sources to determine the disparity of this large of a magnitude. This rate of cultivation would far outpace even what our expected rehabilitation effort would provide during the dry seasons.	We've used remote sensing indicators of land cultivated, information from ONAHA on area cultivated, and interviews with key informants and farmers to triangulate the survey data. Key informants indicate two primary sources of discrepancy, which are (a) that farmers started cultivation but were unable to cultivate to term due to a lack of data, and (b) that some farmers may have overreported that they cultivated in order to present themselves as more deserving of water access. We have been able to use satellite imagery to confirm whether or not a plot was cultivated, and to correct farmer-reported information (e.g., if a farmer reports cultivating the entire plot but the area estimated by remote sensing is below 10 percent).
2	*9*	*Table 1.2*	Ag	The lower experienced yields are quite striking compared to estimates used for ERR, particularly on the key crop of onion but also cabbage. Could the evaluator offer any additional information in this baseline that would either explain the significant overestimation in the model or experience low yields from HHs?		Limiting the calculation of yields to those plots for which the remote sensing confirms cultivation reduces the gap between the ERR baseline yields and the survey reported yields for onions and cabbage somewhat. The yields and amounts produced are very consistent with the amounts households reported selling.
3	*9*	*Footnote*	Ag	I believe pimento is more accurately captured as fresh or green pepper. I'd also point out that the recorded yields are actually higher than the theoretical yield at INRAN and far surpass the reference yield: https://reca-niger.org/IMG/pdf/Fiche_technico-economique_piment_vert_Dosso_Juin2017.pdf	While pepper jumped out to me (and was highlighted for low sample size), I think some of the reported yields should at least be crosschecked against some of the reference yields and exceptional numbers should be mentioned.	We've changed pimento to green pepper throughout. In terms of the yields, the technical document you listed suggests satisfactory yields for smallholder farmers are 8 t/ha on average, while good yields are 12t. The document does not have upper limits on the possible yields, but the survey results of 14t/ha we found in the draft version are indeed high. Given that this average is based on a small number of households, we set the value to NA in the table, highlighting the low reliability of an average based on a small sample size.

#	Page	Section	Reviewer Sector	Comments & Questions	Suggestions	Mathematica Response
4	*9*		Ag	Particularly concerning the rainy season, the seasonal variability makes a big difference for yields. I think additional context is needed to put these numbers into perspective with historical highs and lows.		Since the total rainfall received in 2019 (501 mm) approximated the region's long-term mean (494 mm), we do not see evidence for precipitation patterns being a source of any observed anomalies in crop yields against their typical values.
5	*15*	*Footnote to Table*	Ag	In my read, the image presented in Figure 1.4 seems to show that satellite data was used so this footnote seems contradictory but to the major issue I have with reported production numbers, I wouldn't think that this aligns with the actual production figures.		Notes under Figures I.4, Table II.2, and Figure II.2 have been updated to ensure clarity. The footnote to Table II.2 now reads accordingly: "While we do analyze remotely sensed Sentinel-2 imagery, sub-meter resolution satellite and drone imagery from NASA and RTI is not yet available at the time of the baseline report."
6	*28*	*Ag income*	Ag	Just a reminder that the ERR takes into account HH consumption as a benefit so the HH food basket would have to be quantified. I see this in Table 10 but am unclear of the process for how this was arrived at		The following footnote has been added to explain how the household food basket is quantified: "The value of own consumption is computed as the total value of production less the value of sales and losses."
7		*HH food security*	Ag	I don't see anything in the narrative that describes how this timing fits in with typical lean seasons for Niger. Given that the questions only ask about the past month, is this a reliable way to predict overall food security or nutritional outcomes?		We have added the following text to address your comment: "It should be noted that all food insecurity measures are derived from survey questions about the previous month; given the timing of the baseline survey March 8–21, 2020, the food insecurity questions approximately correspond to the period from early to late February 2000. As such, the food insecurity measures are unlikely to reflect the severity of food insecurity that may be experienced in the lean season prior to harvests in the rainy season." To answer your question: No, this is not the optimal may to identify overall food security or nutritional outcomes. That would require a more comprehensive set of questions spanning timeframes, including the dry season, that was not feasible for the baseline survey. Moving forward, questions on food insecurity during the dry season and at the time of the survey will be added to provide a more comprehensive snapshot.

#	Page	Section	Reviewer Sector	Comments & Questions	Suggestions	Mathematica Response
7	*11*	*II. Konni baseline analysis, A.1. Definition of sample and response rates*	Kent, land	Use of the RAP census as the sampling frame omits pertinent context. A significant parcel consolidation ("remembrement") exercise was conducted in late-2019 that reconfigured or even relocated the parcels of significant numbers of PAPs. Reconsolidation of parcels was necessary following a ONAHA decree specifying a minimum parcel size of 0.25h and a maximum holding by a single farmer of 1.5 ha. The report needs to provide this context and account for the parcel reconsolidation in the study methodology. How will the study account for the differences between the two databases (i.e., pre- and post-remembrement databases). For example, the report states that a small number of PAPs possess more than 1.5 ha (which was the case prior to remembrement), but following application of the ONAHA decree there should be no farmers possessing more than 1.5 ha. Also, the reported average size of HH landholdings (0.71 ha; p.12) and of plots (0.66 ha; p. 16) have likely changed following the parcel consolidation exercise.	Recommend that the EDR acknowledge and account for the changes in parcel sizes and location following the "remembrement" exercise.	We have added the following passage to address this comment: "Sampling was performed on land holding records from the RAP census collected prior to a remembrement (parcel consolidation) process in late-2019 that redistributed land from individuals holding more than 1.5 hectares and stipulated a 0.25-hectare minimum parcel size. As a result, land holdings reported in the baseline survey differ from the holdings listed in the RAP census data at the time of sampling. The parcel consolidation exercise in itself does not affect our analysis. The probability of being sampled and the associated sample weights are unchanged and all forthcoming analyses will be based on the outcomes observed for the fixed group of sampled individuals over time. That being said, the absence of PAPs with more than 1.5 hectares of perimeter land moving forward implies that results for strata 4 will be representative of large land holders whose land was redistributed (as opposed to individuals with more than 1.5 hectares of perimeter land)."

#	Page	Section	Reviewer Sector	Comments & Questions	Suggestions	Mathematica Response
8	*16*	*II. Konni baseline analysis, C.1. Land security, land holdings, and land use on the perimeter*	Land	I find it surprising that 41 percent of on-perimeters plots are said to have formalized land rights.	Please specify precisely what is meant by “formalized land rights.” What document(s) are being referred to? Were documentation options provided during PAP interviews? That is, were terms such as “contrat d’occupation” or “contrat d’exploitation” specifically mentioned and discussed? Did PAPs actually produce documentation? Or (as is more likely), is this finding based on oral responses that may or may not have identified specific options for land rights documentation. If the actual documentation was not produced there is significant risk that the questioner and the respondent had different understandings regarding the question of what constitutes formal documentation of land rights.	We did not ask PAPs to provide any documentation. We have added the following text in a footnote to make this clear: "Plots were considered to have formal documentation if the PAP stated that they have a contract to occupy, a contract to cultivate, a rental contract, or a sales receipt. We did not ask survey respondents to produce documentation." This categorization is based solely on oral responses to the question: "What type of documentation do you have for your plot?" The options provided in the survey were: rental contract/document de location, contract to occupy/contrat d'occupation, contract to cultivate/contrat d'exploitation, none, or other. A small number of PAPs stated that they had a water receipt or sales receipt as "other" documentation, but we did not consider a water receipt as formal documentation. Therefore, this 41 percent of on-perimeter plots is based on plots for which the PAP stated that they have a document de location, contract d'occupation, contrat d'exploitation, or recu de vente. But we agree that this could be overstated since we did not confirm that PAPs indeed have these documents.
9		*WEAI*	MCC-GSI	Table 11.1 (Characteristics of Konni PAPs and households at baseline) lists 1 observation for the Women’s empowerment score.	I realize this is for %, and 0.64 is the mean score. However, what number (n) of people actually took the WEAI? Is it 755? Thank you.	Yes, that is correct. We have added the following text to the note below Table II.1 to make this clearer: "The women’s empowerment score is based on responses from 755 women, each in a distinct household."
10	*13*	*Overview of Sampling*	M&E- EL	What does it mean that women are unempowered? How is that measured?	Add a footnote on WEAI	The following footnote has been added to make this clear: "Unempowered is defined as a lack of agency and autonomy over critical parts of life, including production, resources, income, and leadership. This is measured with a composite index adapted from the WEAI approach. For more information, refer to section C.8. Household food security, poverty, and women’s empowerment."
11	*18*		M&E EL	Typo – “there may be considerable room for improved access to irrigation in the dry season.:		Thanks, this has been corrected.

#	Page	Section	Reviewer Sector	Comments & Questions	Suggestions	Mathematica Response
12	*22*	*Credit and expenditures*	M&E EL	Is there evidence that the prices for expenditures are (labor, fertilizer, seed) are distorted?		Yes, background documents from the Chambre Regional d'Agriculture de Tahoua and the Government of Niger's plan to reform the fertilizer sector provide evidence of a distorted market typified by price distortions. There is no evidence of such distortions for seeds and labor. Regarding fertilizer, this may be reflected by the combination of low or less than universal levels of input use and high levels of expenditures reflected in the baseline report.
13	*31*	*C.8. Household food security, poverty, and women's empowerment*	M&E	Poverty Score: given the relatively low representation of female-only PAPs, is it safe to compare and conclude that female PAPs have a better poverty score than male PAPs?		The difference in poverty scores between households that only have female PAPs vs. those that have a mix of females and males or all males is not statistically significant. This suggests that households that only have female PAPs are not better off in terms of poverty scores.
14	*13*	*A.2. Description of Konni PAPs and households at baseline*	M&E	Household sizes: this is quite interesting. I would want to see what the value is for Sia-Kouanza. We used a much lower value in the development documents		Thanks, we are also interested to see if the households in the Dosso-Gaya are comparable or differ from those in Konni in terms of household size, once baseline data are available for the Dosso-Gaya area.
15	*18*	*C.2. Irrigation*	M&E	Reliance on irrigation water in dry season: 76% of PAPs. Does that include off-perimeter farms?		No, this only refers to plots on the perimeter.
15	*18*	*C.2. Irrigation*	M&E	"consistent with the ERR, there may considerable room for improved access to irrigation in the dry season." This sentence seems to be missing a verb ("BE").		Thanks, this has been corrected.
16	*29*	*Table II.9. Household income, revenue, and sales*	M&E	It would be interesting to show the standard deviation values of these indicators – that can help better see the spread of revenues and ag expenditures	If those values are available outside of the report, I would be interested in seeing them	We are sending the corresponding tables that include the standard deviations as a separate Word document for the reviewer's reference.

#	Page	Section	Reviewer Sector	Comments & Questions	Suggestions	Mathematica Response
17	*30*	*Table II.10. Household income, revenue, and sales by access to dry season irrigation*	M&E	Same as above		
18	*22*	*C.5. Credit and Expenditures*	M&E	The average annual expenditure of $546: does the average significantly change on the basis of sex or on whether it's on-perimeter vs. off-perimeter cultivation?		Total average annual agricultural expenditures of approximately 546 USD corresponds to 321,000 FCFA in Table II.7 for all households. Although this does vary somewhat, the difference is not considerable between households that only include females PAPs (306,000 FCFA) and households that include female and/or male PAPS (322,000 FCFA). Comprehensive expenditure information is only available for plots on the perimeter, so it is not possibly to credibly address the latter part of your question.
19	*22*	*C.5. Credit and Expenditures*	M&E	"Expenditures are dominated by labor, fertilizer, and seeds; expenses for irrigation are relatively low in comparison." I would be interested in seeing whether this assertion holds come endline studies, and after the fertilizer reform activities are fully implemented		The interim and final evaluations will assess changes in composition of expenditures and access to credit.
20	*22*	*C.5. Credit and Expenditures*	M&E	Same comment as above – this time on credit access. I'm curious to see whether our VSL program will lead to a significant change on this come endline.		
Comments from the presentation to MCA						

#	Page	Section	Reviewer Sector	Comments & Questions	Suggestions	Mathematica Response
21		*Fertilizer use*	Ibrahim Moussa	Could we link the fertilizer use to yields? Wants to understand why the amount of chemical fertilizer applied is low when 88% of the people had access.		Assessing determinants of low baseline fertilizer use is outside of the scope of this evaluation. The evaluation will assess changes in fertilizer use between baseline and the interim and final evaluations. To do so, we will rely on qualitative and quantitative data collection.
22		*Dry season irrigation*	Moussa Said	Would like to see the disaggregation of the 46% who did not have access to irrigation in dry season.		Table II.10 disaggregates the results on income, revenue, and sales by access to irrigation in the dry season.
23		*Access to water*	Hamilton, Djafarou	Would like to know the split in types of water access at household level. Understand the underground water resources. Spoke about the test wells MCA dug to follow the water table and the variation in areas around Niger river		In the revised analysis, in the rainy season, irrigation use is reported on fewer than 15 percent of plots. The most common types of irrigation reported in the rainy season are pumps, on approximately 7 percent of plots, followed by hand watering applications, such as using water cans or hoses, on roughly 3.5 percent of plots. In the dry season, irrigation use is reported on more than 75 percent of plots. The most common types of irrigation reported in the dry season are pumps, on approximately 27 percent of plots, canals/gates/ditches on roughly 24 percent of plots, hand watering applications on approximately 13 percent of plots, and a permanent hose on roughly 9 percent of plots. The report provides this information at the plot as opposed to the household level.
24		*Dry season irrigation*	Ag	Would like to see the share of cultivation in the dry season, 70% of the perimeter being cultivated is really high. IS willing to facilitate scheduling meetings with the right people		We've used remote sensing information on cultivation status to triangulate the self-reports from the survey, and to correct mis-reporting. Please see the responses to comment #1 above.
25		*Off farm activities*	Myrlene, Philippe Chabot	Any disaggregation in food security in farmers using irrigation vs. not cultivating in dry season?		Please see the table in the appendix disaggregating household food security and poverty by dry season irrigation, where we observe higher levels of food inadequacy and hunger among households without irrigation in the dry season.

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