MATHEMATICA Policy Research

REPORT

FINAL REPORT

Impact Evaluation of the Irrigation Infrastructure Activity in Armenia

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All of the above organizations and individuals have contributed tremendously to this report and to the project more generally, but any remaining errors are the fault of the authors alone.

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DISCLOSURE STATEMENT

None of the authors of this report stands to gain financially from the findings in this report. We note that two AVAG staff who were involved in data collection and reporting were also involved in the formative work of the Millennium Challenge Corporation's Compact with Armenia. Melik Gasparyan, who was the team leader for collection of the water user association administrative data, worked with the Millennium Challenge Corporation to help develop the Compact before it entered into force. Sergey Balasanyan, who was responsible for collecting much of those same data on behalf of AVAG, was previously employed by the Millennium Challenge Account for Armenia for approximately one year early in the life of the Compact. Mr. Balasanyan worked with the Monitoring and Evaluation team to help oversee data collection. Lastly, AVAG was involved in developing irrigation policy recommendations that were part of the Institutional Strengthening Subactivity of the Water-to-Market initiative (but are not the subject of this report). We do not believe any of these prior positions compromise AVAG's objectivity in collecting and reporting on the water user association administrative data.

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TABLES

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FIGURES

LIST OF ACRONYMS

ACDI/VOCA	American company that implemented Water-to-Market training in partnership with VISTAA
AREG	Armenian non-governmental organization that, in partnership with Jen Consult, is responsible for household-level data collection
AVAG	Armenian company that is responsible for collection of administrative data from water user associations
HVA	High-Value Agriculture
ISSA	Institutional Strengthening Subactivity
MCC	Millennium Challenge Corporation
MCA	Millennium Challenge Account (for Armenia)
OFWM	On-Farm Water Management
VISTAA	Armenian company that implemented Water-to-Market training in partnership with ACDI/VOCA and the Institutional Strengthening Subactivity in partnership with Mott MacDonald
WtM	Water-to-Market
WSA	Water Supply Agency
WUA	Water User Association

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EXECUTIVE SUMMARY

The aim of the Millennium Challenge Corporation's Compact with Armenia ("the Compact"), a five-year agreement signed in March 2006, was to increase household income and reduce poverty in rural Armenia through improved performance of the country's agricultural sector. The Compact, managed by the Millennium Challenge Account with Armenia (MCA-Armenia), was originally designed to include two projects: (1) the Rehabilitation of Rural Roads Project and (2) the Irrigated Agriculture Project.[1] The Irrigated Agriculture Project comprised two complementary activities, the rehabilitation of irrigation infrastructure ("the Irrigation Infrastructure Activity," hereafter, Infrastructure Activity) and the provision of training, technical assistance, and access to credit for farms and agribusiness ("the Water-to-Market Activity").

The Millennium Challenge Corporation (MCC) has commissioned rigorous impact evaluations to examine each of the three main activities of the MCA-Armenia program. This report focuses on the evaluation plans for the Infrastructure Activity. The Infrastructure Activity was completed near the end of the Compact in 2011 and is the final of the three evaluations MCC commissioned. The Rehabilitation of Rural Roads Project and the Water-to-Market Activity of the Compact were evaluated previously (Fortson et al. 2015; Fortson et al. 2013). The data used in the Infrastructure Activity evaluation cover the 2013 agricultural season, so the evaluation will examine effects two to three years after completion of the infrastructure work.

In addition to evaluating the Infrastructure Activity itself, we will also present a simple check on the potential for complementarities between the irrigation infrastructure rehabilitation and select components of the Water-to-Market Activity that were evaluated before the rehabilitation had been completed. We focus on two components of the Water-to-Market Activity that were designed to have particularly strong complementarities with the rehabilitated infrastructure, the Institutional Strengthening Subactivity and Water-to-Market training.

A. Overview of the Infrastructure and Water-to-Market Activities

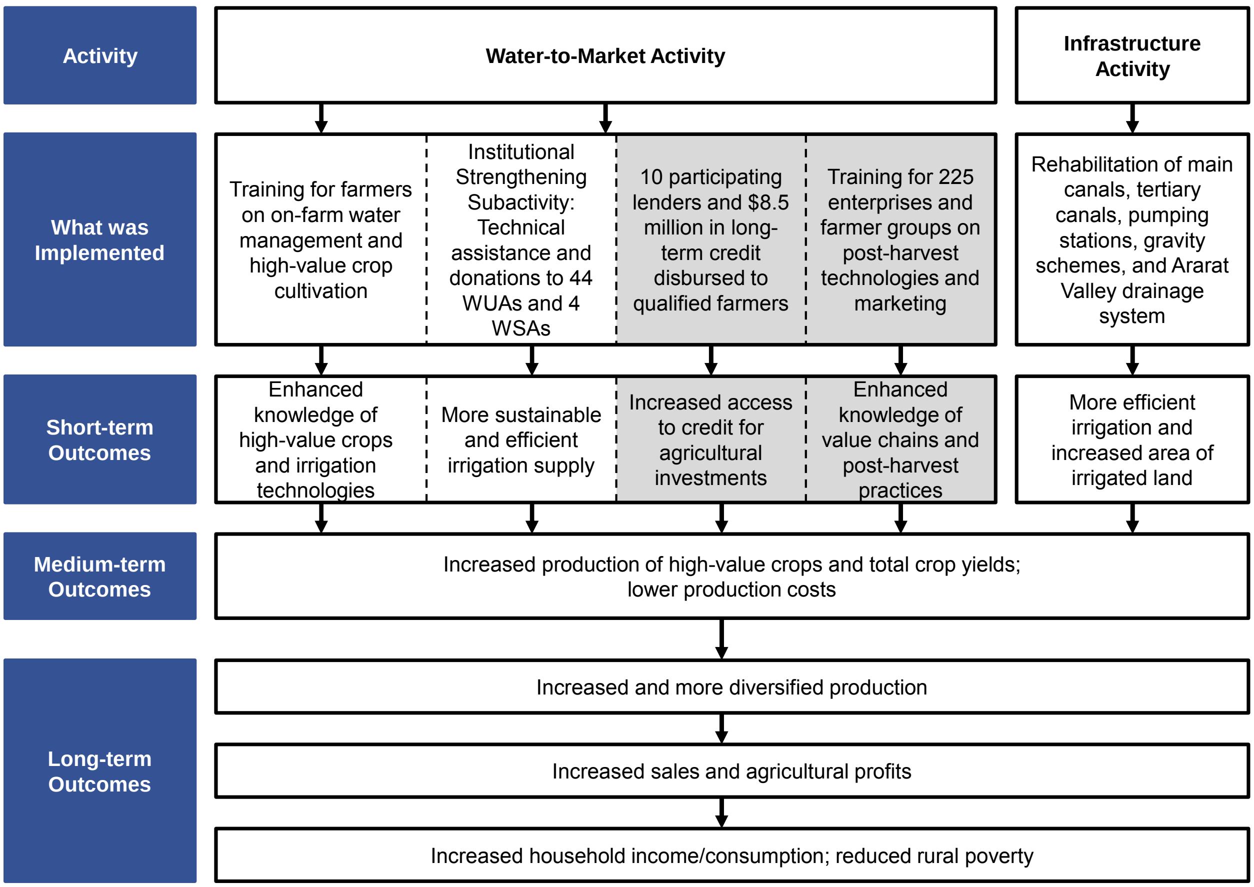
Prior to rehabilitation, water user associations, the regional organizations that manage the distribution of and payment for irrigation water in Armenia, estimated that only 25 to 40 percent of irrigation water actually reached the fields in most of the affected villages. The lost water would instead drain into the land surrounding the canals. The Compact provided $121 million of funding to rehabilitate several different types of irrigation infrastructure serving 298 communities throughout rural Armenia from 2008 to 2011. MCA-Armenia rehabilitated 220 kilometers of tertiary canals, 43 kilometers of main canals, 1 drainage system, 17 pumping stations, and 5 gravity schemes.

The short-term goals of the Infrastructure Activity were to improve the efficiency of irrigation and to increase the area of irrigated land (Figure 1)—both by expanding irrigation to

[1] At the June 2009 Millennium Challenge Corporation board meeting, the decision was made not to continue funding any further road construction and rehabilitation under the $236 million Compact because of concerns about democratic governance. Approximately 25 km of pilot roads had been completed prior to this decision. Many of the road projects designed with funding from MCC were ultimately financed by the World Bank and the Republic of Armenia.

areas that were not irrigated before the project, and to prevent decreases in irrigated area in the absence of the project as unrehabilitated irrigation equipment deteriorated further. With access to a more consistent supply of irrigation water, farmers could increase their agricultural production. In conjunction with the Water-to-Market Activity, the Infrastructure Activity was designed to shift crop production toward higher-value crops, increase sales, and increase agricultural profits for beneficiary farmers. Fortson et al. (2013) describe the Water-to-Market Activity more extensively, but we focus below on summarizing the specific Water-to-Market components that were intended to strongly complement the Infrastructure Activity.

Figure 1. Logic model of the Infrastructure and Water-to-Market activities



Note: The Water-to-Market Activity comprises four components, two of which were designed to have particularly strong complementarities with the Irrigation Infrastructure Activity (Water-to-Market farmer training and the Institutional Strengthening Subactivity). The other two components are grayed in the figure. All components of the Water-to-Market Activity are discussed in Fortson et al. (2013).

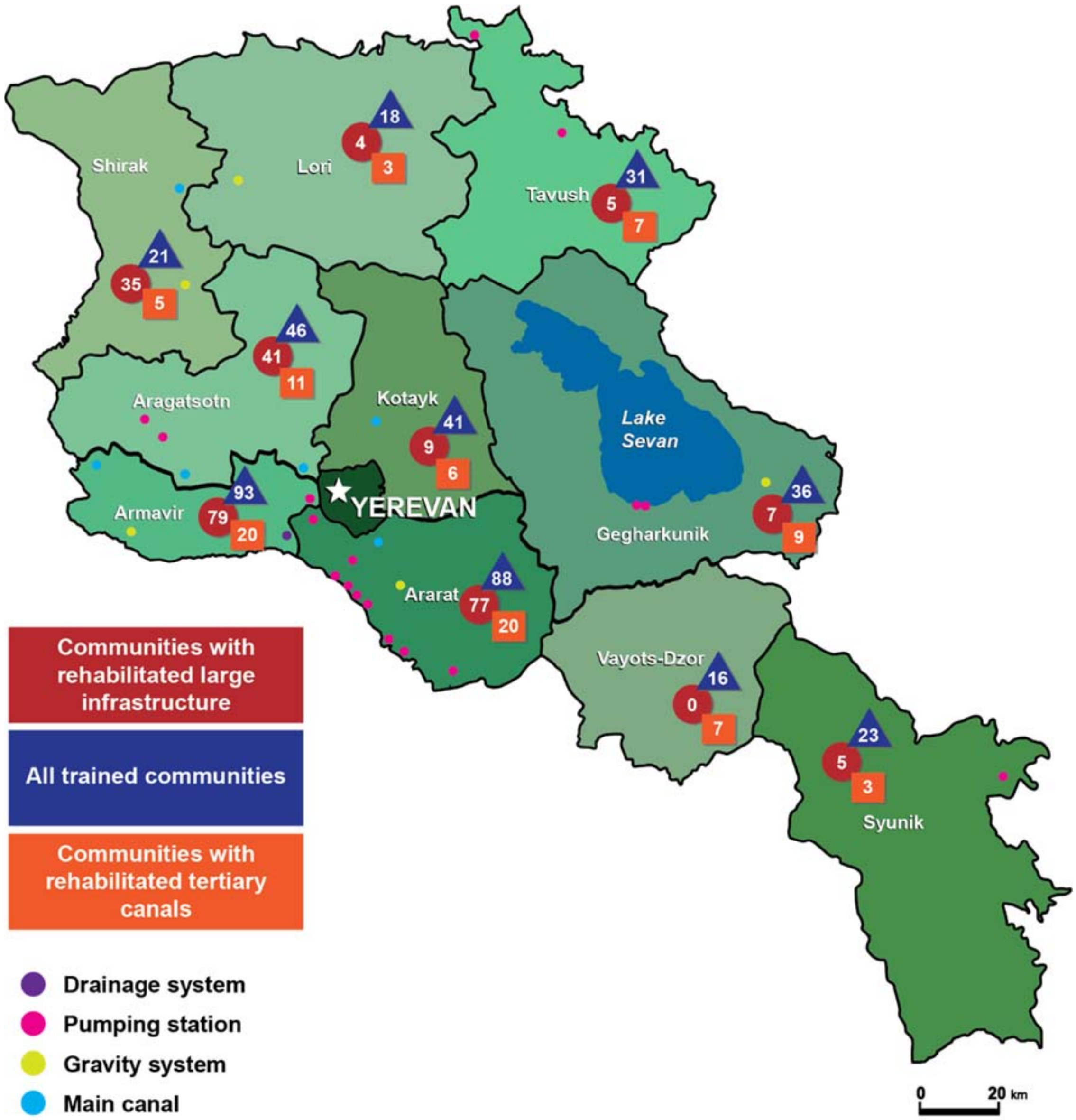
WUA = water users associations; WSA = water supply agencies.

The Institutional Strengthening Subactivity component of the Water-to-Market Activity provided general technical support to water user associations. The Institutional Strengthening Subactivity also provided assistance to three water supply agencies that operate and maintain irrigation dams and pumping stations. The general aim of the Institutional Strengthening Subactivity was to strengthen water user associations' and water supply agencies' managerial, technical, structural, and financial capacity and self-sufficiency. The intent of these improvements was to create more efficient and consistent irrigation supply for water user association members. The Institutional Strengthening Subactivity also included an irrigation policy reform component, in which a reform strategy was developed through a participatory process with stakeholders. Altogether, the Institutional Strengthening Subactivity cost $4.9 million.

Water-to-Market farmer training included two types of training conducted from 2007 to 2011. The first type of training covered on-farm water management techniques aimed at helping farmers learn to use improved irrigation technologies such as modifying furrow spacing. As part of this component, demonstration plots were also established to demonstrate the irrigation technologies in practice. In total, 45,000 farmers were scheduled to be trained in on-farm water management practices from 2007 to 2010. The goal of this training was for farmers to adopt new and more efficient irrigation techniques, which would lead to increased and more cost-effective agricultural production and higher sales. The second type of training was high-value agriculture training, which consisted of establishing demonstration plots and conducting training sessions for farmers on high-value crop substitution and cropping intensity. In total, 36,000 farmers who received on-farm water management training were also scheduled to be trained by ACDI in high-value agriculture from 2007 to 2011. The goal of high-value agriculture training was for farmers to adopt new cropping techniques and high-value crops, which would lead to increased and more diverse agricultural production as well as increased sales.

Water-to-Market farmer training in on-farm water management and high-value agriculture was expected to be especially beneficial for farmers who had reliable access to irrigation. Some farmers who participated in Water-to-Market training already had reliable irrigation, but some communities whose irrigation supply was inadequate were provided training with the expectation that the Infrastructure Activity would soon improve their water supply. Figure 2 illustrates the overlap between the different types of infrastructure rehabilitation and Water-to-Market training.

Figure 2. Distribution of tertiary canals and large infrastructure that was selected for rehabilitation and trained communities, by marz



Source: Millennium Challenge Corporation program data.

The last two components of the Water-to-Market Activity focused on increasing access to agricultural loans for farmers and training agribusinesses in post-harvest technologies and marketing. These components are shaded in gray in Figure 1 to indicate that they will not be reexamined in this study because they do not have the direct linkages to the Infrastructure Activity that Water-to-Market farmer training and the Institutional Strengthening Subactivity have, nor were there reasons to expect that their effects may have substantially increased over time.

B. Research questions

The overarching research questions guiding the evaluation of the Infrastructure Activity were designed to parallel the program logic in Figure 1. Different components of the evaluation focus on different subsets of these research questions. The evaluation of the Infrastructure Activity separately examines impacts of rehabilitating tertiary canals and other, larger types of irrigation infrastructure, as discussed in more detail in the next section, but both (sub-) evaluations focus on the same subset of research questions. The specific research questions that are addressed in the present report are:

1. **Did the program affect the quantity and reliability of irrigation water provided to Armenian farmers?** This is a key short-term outcome assessed in the evaluations of rehabilitating infrastructure. Our analysis controls for the provision of Water-to-Market training, so these estimates are focused on the influence of the Infrastructure Activity.
2. **Did farmers adopt new agricultural practices as a result of the program?** Further, is there evidence that farmers who received Water-to-Market training postponed adopting new agricultural practices until after the irrigation infrastructure had been rehabilitated? We assess whether there is evidence for longer-term effects of Water-to-Market training by examining adoption rates in communities that received both infrastructure rehabilitation and training.
3. **Did the program affect agricultural productivity?** This is the key medium-term outcome assessed in the evaluations of rehabilitating infrastructure.
4. **Did the program improve household well-being for farmers served by the rehabilitated infrastructure, especially income and poverty?** This is the key long-term outcome assessed in the evaluations of rehabilitating infrastructure. MCC had expected that household well-being would be improved almost immediately, and that benefits would continue to accrue afterwards. In answering this research question, we consider both the evidence of whether any income impacts have materialized thus far (two to three years after the rehabilitation) as well as evidence of medium-term impacts that might suggest larger impacts on income in the future.
5. **Is there evidence that the infrastructure investments will be sustained after rehabilitation was complete?** Are the water user associations themselves financially sustainable? This is the key outcome considered in reassessing the longer-term effects of the Institutional Strengthening Subactivity.
6. **Were the program effects large enough to justify its costs?** We answer this question by reassessing the benefits and costs of the activity. In 2008, MCC estimated the economic rate of return for the Infrastructure Activity to be 24.4 percent over a 20-year time horizon. This estimate is calculated based on the total social costs and benefits. The costs for the rehabilitation projects include investment, contingency, maintenance, design, supervision, and other construction costs, as well as overhead costs. The benefits are measured as the estimated incremental agricultural income generated from the improved infrastructure.

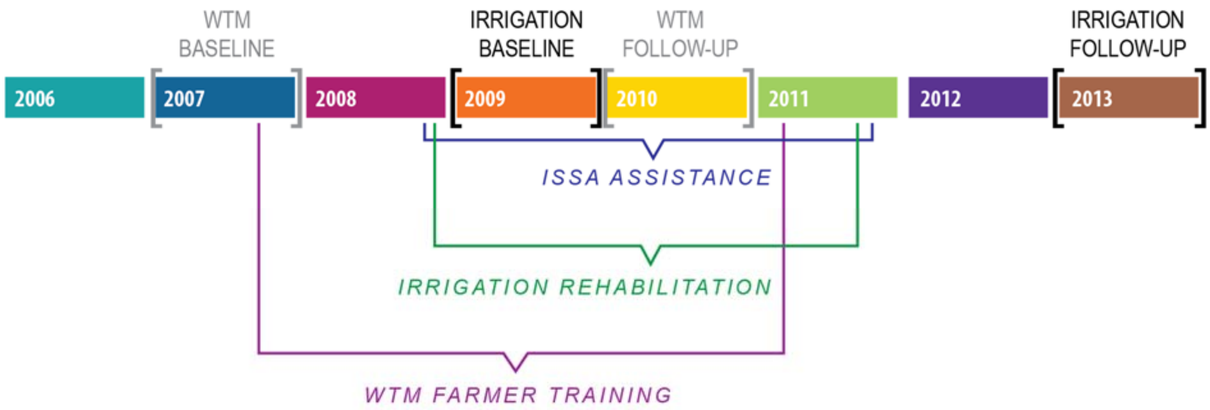
C. Evaluation approaches

MCA-Armenia’s irrigation rehabilitation efforts covered several different types of irrigation infrastructure, including tertiary canals, main canals, the Ararat Valley drainage system, pumping stations, and gravity schemes. However, for most of these types of infrastructure, only a handful of projects was implemented, too few to support a rigorous evaluation, and there were no other hypothetical projects that could serve as a comparison group. Hence, MCC and Mathematica originally agreed to focus the evaluation effort on the tertiary canal rehabilitation efforts because the prospective research design was rigorous and precise enough to yield informative impact estimates on an important intervention.

The evaluation of rehabilitated tertiary canals remains as the most rigorous of the subevaluations in this report, but MCC subsequently asked Mathematica to expand the evaluation to examine other project components as well. In particular, we developed an evaluation design to estimate, as best we can, the impacts of rehabilitating the other, larger irrigation infrastructure using existing data. The Tertiary Canal Survey sample included at least one community that was affected by almost every piece of large infrastructure that had been rehabilitated; the exceptions were five pumping stations and two gravity schemes. The five excluded pumping stations represent about 17 percent of the cost of all pumping stations that were rehabilitated, and the two excluded gravity schemes represent about 45 percent of the costs for rehabilitating gravity schemes under the Compact. We also developed plans to conduct longer-term assessments of the Institutional Strengthening Subactivity and Water-to-Market training, two of the components of the Water-to-Market Activity that were evaluated previously (Fortson et al. 2013) but thought to have complementarities with the Infrastructure Activity that may not have been fully realized at the time of the Water-to-Market evaluation. Because the evaluation of rehabilitated tertiary canals is the most rigorous, we present those findings first in the present report.

The tertiary canal subevaluation uses a matched comparison group design and controls for rehabilitation of large infrastructure. Under this approach, communities with tertiary canals for which rehabilitation was implemented (treatment group) were matched to other communities sharing similar geography, pre-rehabilitation conditions, and types of crops cultivated. Examining how outcomes change for farmers in the comparison group, whose canals were not rehabilitated, informs us about how farmers in the treatment group might have fared in the absence of the rehabilitation efforts. We estimate the impacts of the program by comparing the post-rehabilitation outcomes for these two sets of communities, controlling for pre-rehabilitation outcomes, the rehabilitation of large infrastructure, and Water-to-Market training. We primarily use data from the Tertiary Canal Survey, a survey of households in the two sets of communities that was designed and administered specifically for this evaluation. The survey covers the 2013 calendar year and agricultural season, which is approximately two years after completion of the Infrastructure Activity, two to three years after rehabilitation was completed in sample communities, and four years after the baseline Tertiary Canal Survey (Figure 3).

Figure 3. Timeline of Irrigation Infrastructure Activity, Water-to-Market initiatives, and associated data collection



WTM = Water-to-Market; ISSA = Institutional Strengthening Subactivity.

The design for estimating impacts of rehabilitating large infrastructure shares many features with the tertiary canal evaluation described. Most prominently, we use data from the Tertiary Canal Survey, which was originally designed exclusively for the tertiary canal evaluation. We also use a matched comparison group evaluation design, comparing communities served by any large project to other communities whose large infrastructure was not rehabilitated. The analysis controlled for the rehabilitation of tertiary canals and Water-to-Market training. The analytic sample included communities influenced by the rehabilitation of a main canal, the Ararat Valley drainage system, 10 pumping stations (of 17 total that were rehabilitated by MCC), or 3 gravity schemes (of 5 total that were rehabilitated by MCC).

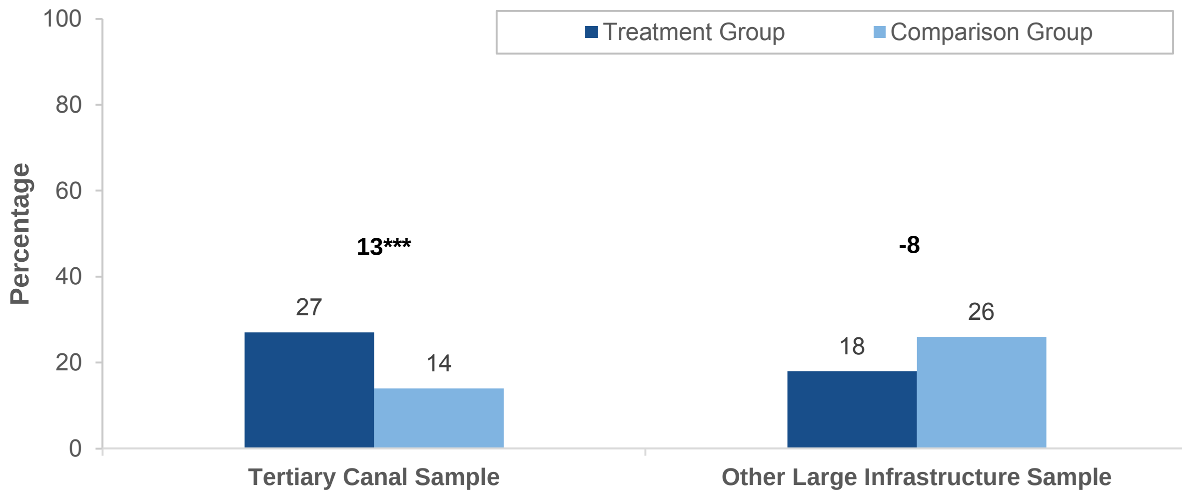
The reassessment of Water-to-Market training mainly uses simple descriptive analyses to examine longer-term rates of adoption of the technologies taught as part of the training sessions. We also examine crop cultivation. The Tertiary Canal Survey is the data source for this analysis as well. As shown in Figure 2, the Water-to-Market training evaluation used data as of the 2010 calendar year, a period over which few irrigation projects had been completed. The present analysis extends this by three additional years, the latter two of which are after irrigation rehabilitation was completed.

In reassessing the Institutional Strengthening Subactivity we rely mainly on descriptive analyses of water user association administrative data. These data were collected directly from water user associations and supplemented by survey data that cover more subjective topics. The survey was already administered and analyzed for the years 2008 through 2010, which were covered in the Water-to-Market evaluation. Our reassessment adds three new years of data but otherwise employs the same methodology of comparing outcomes before and after the Institutional Strengthening Subactivity. There is no comparison group for the water user associations who were assisted by the Institutional Strengthening Subactivity.

D. Summary of findings

Rehabilitating tertiary canals increased farmers' perceptions of the condition of their irrigation systems, but rehabilitating other infrastructure did not. The farmers were asked to assess the condition of the irrigation system in their community on a 5-item scale, ranging from "very bad" to "very good." For the tertiary canal analysis, farmers in the treatment group were 13 percentage points more likely to report the condition of the system to be good or very good (27 percent) than were farmers in the comparison group (14 percent). For the analysis of large infrastructure, farmers in the treatment group were less likely to rate their systems as good or very good (18 percent) than were farmers in the comparison group (26 percent), but this difference was not statistically significant (Figure 4).

Figure 4. Impacts on percent of farmers who rate their irrigation systems as very good or good



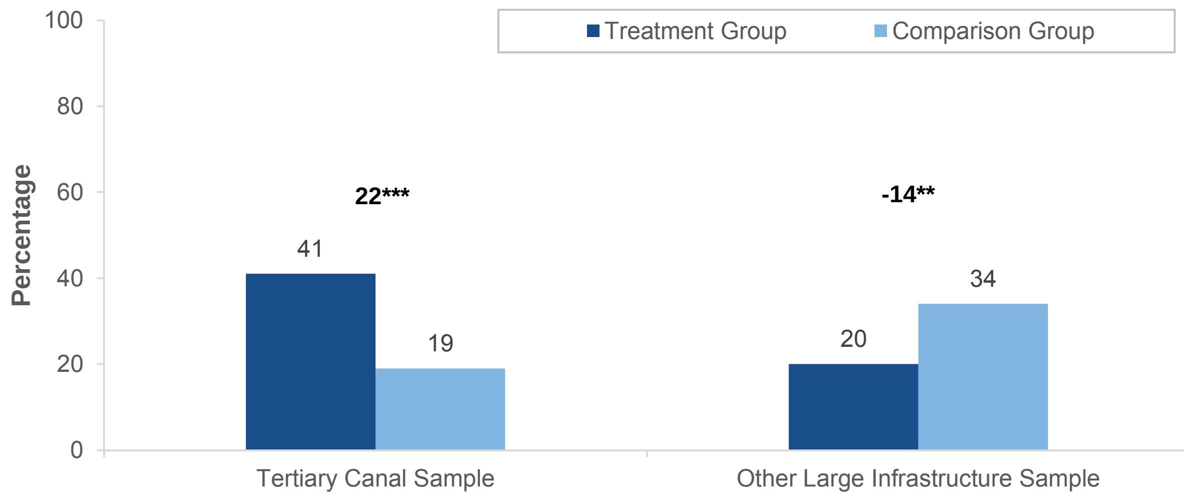
Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Farmers whose tertiary canals were rehabilitated also reported timeliness and quantity of irrigation water had improved, but farmers whose large infrastructure was rehabilitated did not. Forty-one percent of farmers in the tertiary canal treatment group reported that timeliness or quantity of irrigation water had improved over the past five years compared with 19 percent of the tertiary canal comparison group (Figure 5). Tertiary canal farmers were also significantly less likely to report that the timeliness and quantity had become worse. In contrast, for the large infrastructure, the treatment group was actually significantly less likely to report that timeliness or quantity of irrigation water had improved.

Figure 5. Impacts on percent of farmers who report that timeliness and quantity improved since 5 years ago



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

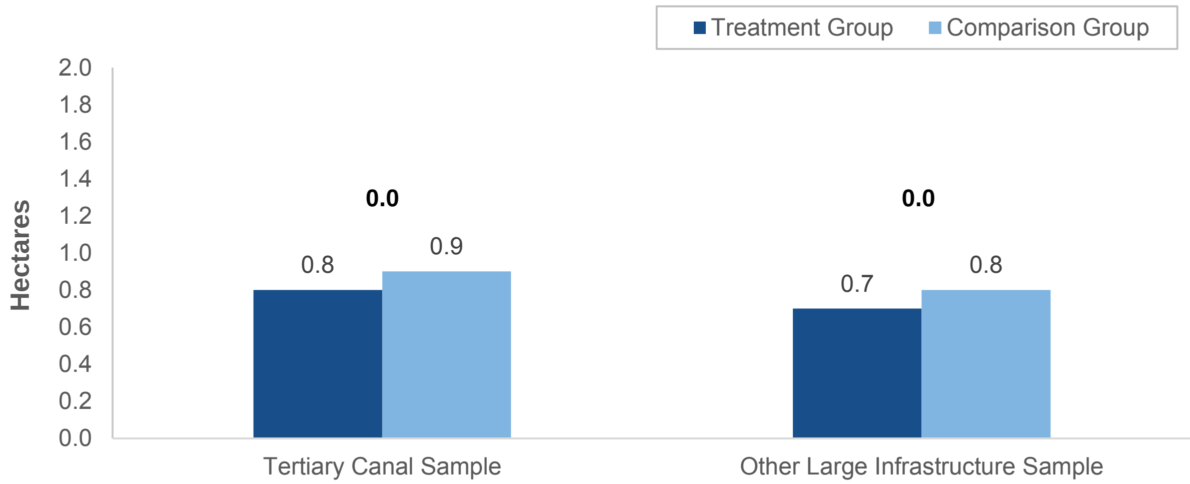
Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Rehabilitating irrigation infrastructure did not increase the amount of land that was irrigated. There were no impacts of rehabilitating tertiary canals or large infrastructure on the hectares of land that were irrigated (Figure 6). There were also no meaningful impacts when we disaggregated the impacts by type of land (arable land, orchards, vineyards, kitchen plots, other). We similarly did not find substantial increases over time in total water deliveries or total irrigated land area using aggregate data from water user associations. The aggregate data included farms that are not covered by the survey sample (not shown; see Section VII of report).

There were modest impacts on irrigation intensity for some types of land, but no consistent pattern. To assess whether the rehabilitated infrastructure allowed farmers to use more network irrigation water, we measured impacts on the frequency and duration of irrigation in a week, by type of land (Tables 1 and 2). Water gauges were not installed on tertiary canals to track how much network irrigation water was used before and after the rehabilitation. Instead, households were asked for the number of times their land was irrigated in a week and the total hours their land was irrigated in a week. Neither tertiary canal rehabilitation nor rehabilitation of large infrastructure had a meaningful impact on the number of times arable land, orchards, vineyards, or kitchen plots were irrigated. There were positive impacts of tertiary canal rehabilitation on the hours per week that arable land was irrigated (impact of 4.6 hours per week) and kitchen plots were irrigated (impact of 2.4 hours per week), both of which are statistically significant at the 10 percent level (Table 1). There was also a significant impact of 3.2 hours per week for large infrastructure rehabilitation (Table 2). However, given the inconsistency of these patterns, and that there is not a reason to expect those types of land to be uniquely affected, we believe these statistically significant estimates may be due to sampling variability rather than true impacts of the Infrastructure Activity.

Figure 6. Impacts on land that is cultivated and irrigated (hectares)



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group averages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Table 1. Impacts of rehabilitated tertiary canals on frequency and duration of irrigation

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Arable land				
Number of times land was irrigated	2.1	1.9	0.2	0.44
Total hours of irrigation	19.0	14.3	4.6*	0.05
Orchards				
Number of times land was irrigated	0.7	0.9	-0.1	0.34
Total hours of irrigation	4.8	5.5	-0.7	0.47
Vineyards				
Number of times land was irrigated	0.7	0.7	0.0	0.93
Total hours of irrigation	5.5	5.3	0.2	0.85
Kitchen plot				
Number of times land was irrigated	5.0	4.4	0.7	0.15
Total hours of irrigation	13.3	10.9	2.4*	0.09
Other				
Number of times land was irrigated	0.1	0.1	0.0	0.44
Total hours of irrigation	0.5	0.3	0.2	0.40
Sample size	882	879		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Table 2. Impacts of rehabilitated large infrastructure on frequency and duration of irrigation

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Arable land				
Number of times land was irrigated	1.7	2.0	-0.3	0.47
Total hours of irrigation	16.0	12.8	3.2	0.26
Orchards				
Number of times land was irrigated	0.7	0.7	0.0	0.97
Total hours of irrigation	4.1	4.0	0.2	0.87
Vineyards				
Number of times land was irrigated	0.5	0.4	0.1	0.18
Total hours of irrigation	5.0	1.8	3.2**	0.02
Kitchen plot				
Number of times land was irrigated	4.5	4.8	-0.3	0.70
Total hours of irrigation	11.4	12.2	-0.8	0.67
Other				
Number of times land was irrigated	0.1	0.0	0.1**	0.03
Total hours of irrigation	0.5	0.0	0.5**	0.04
Sample size	809	509		

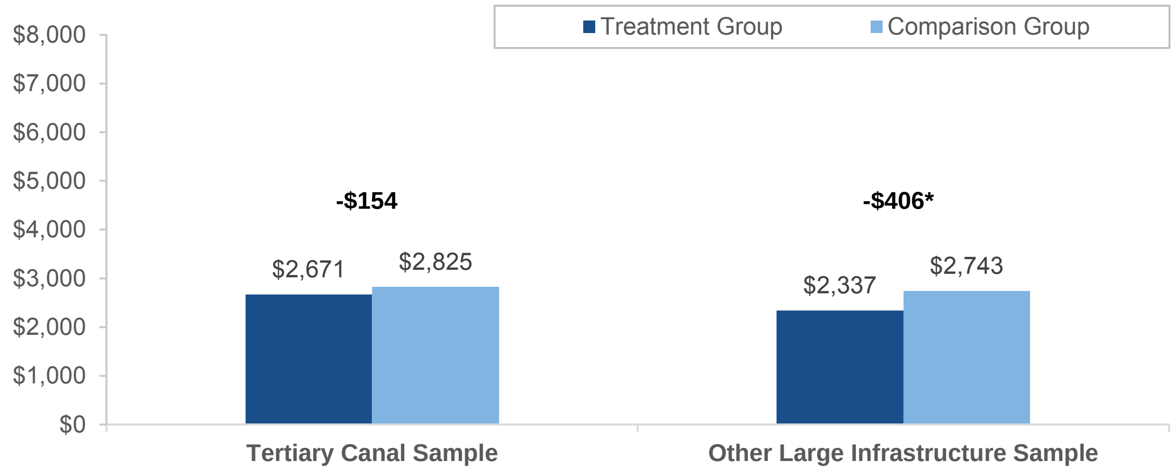
Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Rehabilitating irrigation infrastructure did not lead to increased production. The average annual market value of production was similar for the tertiary canal treatment and comparison group, and for the large infrastructure analysis the estimate was actually negative (Figure 7). The finding is similar when we instead consider total tonnage of production. This was true overall, for high-value crops and non-high-value crops separately, and for major categories of high-value and non-high-value crops. We also measured impacts for individual crops (not shown) and did not find other evidence of systematic changes in production.

Figure 7. Impacts on market value of harvest



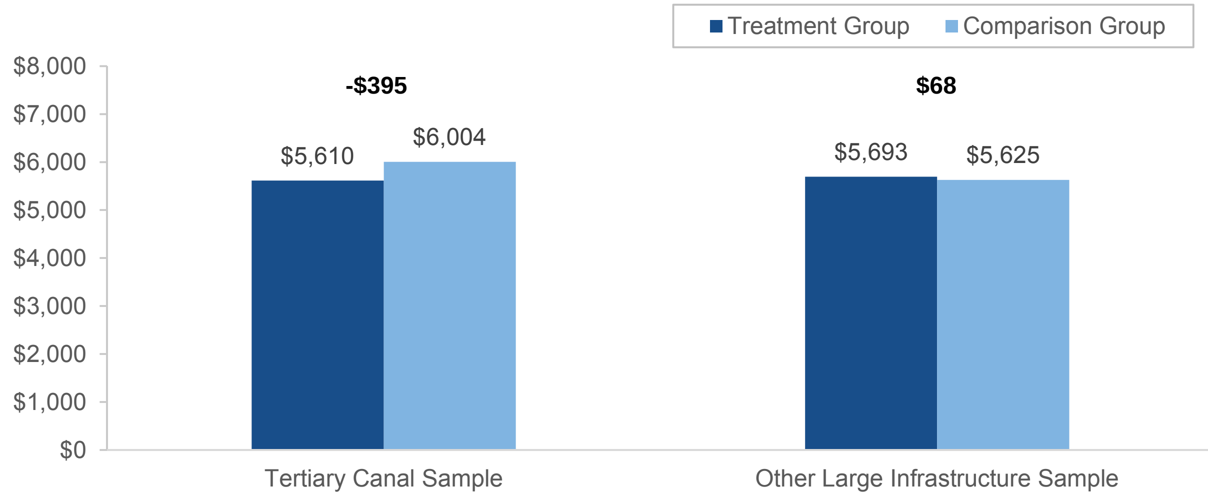
Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group averages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Rehabilitating irrigation infrastructure did not increase farmers' household income. As shown in Figure 8, we do not observe any impacts for total household income, nor did we find positive impacts of tertiary canals on nonagricultural income or agricultural profit. For large infrastructure rehabilitation, we found limited evidence that the rehabilitated large infrastructure led to decreases in agricultural profits that might have been offset by increases in nonagricultural income; overall, there was no impact on total economic income.

Figure 8. Impacts on annual household income



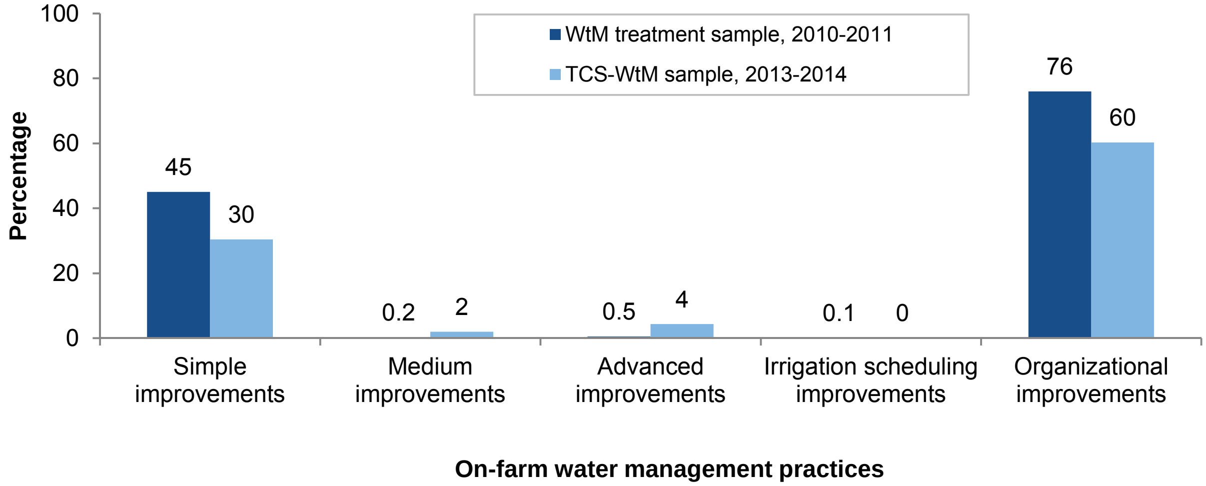
Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group averages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

For communities that had received Water-to-Market training in 2008, we did not observe that adoption of on-farm water management practices was substantially higher for farmers in 2013 than it was in 2010. In fact, fewer farmers in the TCS-WtM sample used in the present report used simple improvements compared to farmers in the Water-to-Market treatment group from 2010 (Figure 9). Adoption of medium improvements (such as gated pipes) or advanced improvements (such as drip irrigation) was still low for both groups, although slightly higher in the TCS-WtM sample. Organizational improvements, such as the preparation of irrigated land or having a copy of the farm's water user association water contract, were used by more than half of farmers in the TCS-WtM sample and more than three-quarters in the Water-to-Market treatment group.

Figure 9. Adoption of on-farm water management practices for Water-to-Market communities (percentages)



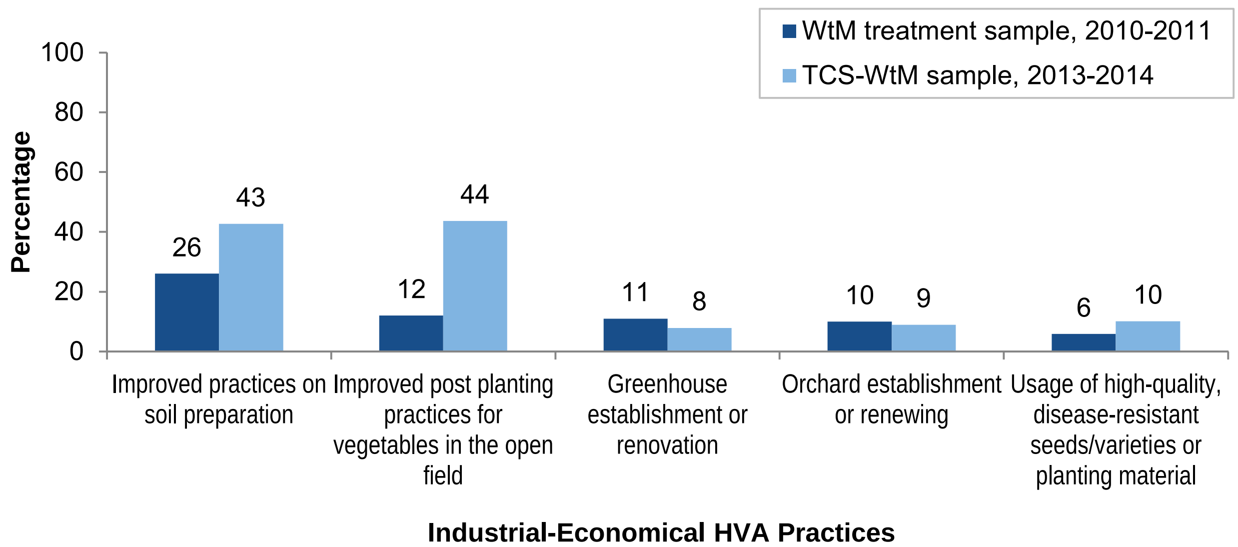
Sources: 2013–2014 Tertiary Canal Surveys and 2010–2011 Farming Practices Surveys.

Note: Reported means are from different research samples and presented for descriptive purposes only. We did not test for statistical differences between the two groups.

OFWM = on-farm water management; WtM = Water-to-Market

We found evidence of increased adoption of improved soil preparation and improved post-planting procedures for communities that had received Water-to-Market training. More than 40 percent of farmers in the TCS-WtM sample reported implementing these practices. Other industrial-economical practices were much less common, with prevalence of 10 percent or less (Figure 10). We also found that the TCS-WtM sample was much more likely than was the Water-to-Market sample to exclusively use pesticides allowed in Armenia, but this was the exception among social-environmental practices (Figure 11). All other social-environmental practices had comparable rates of adoption between the two samples, or higher rates of adoption by the Water-to-Market treatment group than the TCS-WtM sample, suggesting that adoption rates were not increasing over time.

Figure 10. Adoption of industrial-economical HVA practices for Water-to-Market communities (percentages)

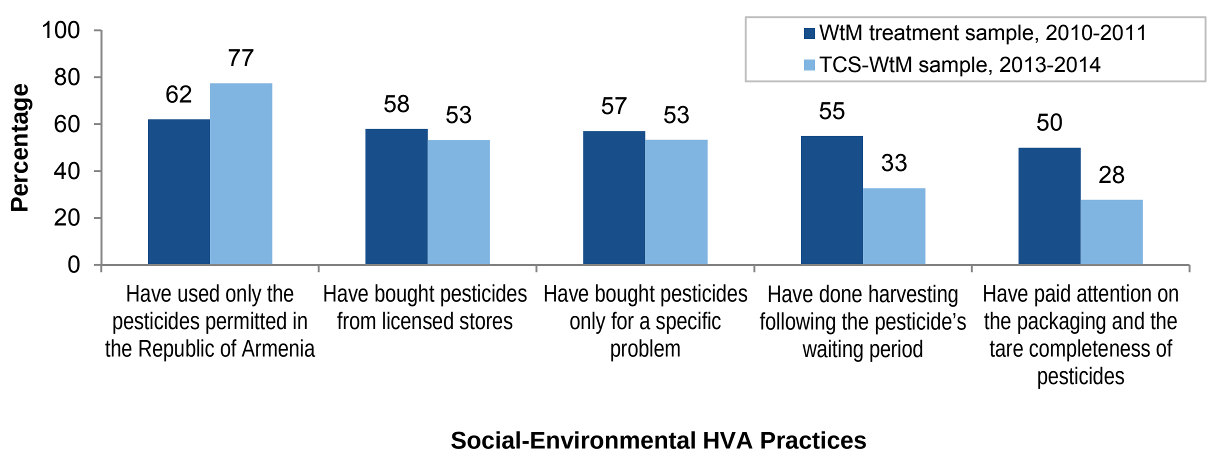


Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys and 2007–2008 and 2010–2011 Farming Practices Surveys.

Note: Reported means are from different research samples and presented for descriptive purposes only. We did not test for statistical differences between the two groups.

HVA = high-value agriculture; WtM = Water-to-Market.

Figure 11. Adoption of social-environmental HVA practices for Water-to-Market communities (percentages)



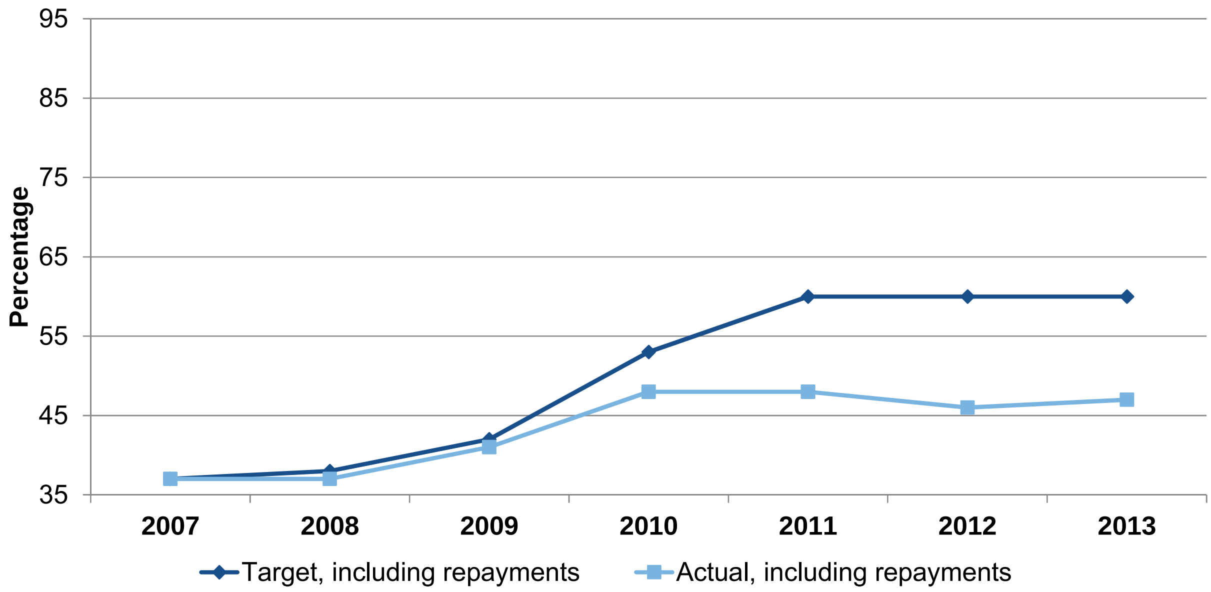
Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys and 2007–2008 and 2010–2011 Farming Practices Surveys.

Note: Reported means are from different research samples and presented for descriptive purposes only. We did not test for statistical differences between the two groups.

HVA = high-value agriculture; WtM = Water-to-Market.

Water user associations' financial statuses have leveled off since 2010, with little further progress toward financial self-sustainability. The Water-to-Market evaluation found that water user associations improved their financial standings from 2007 to 2010. Water user associations reduced expenditures on water payments, improved their membership fee collection, and improved their cost recovery rates. However, large annual deficits persisted, and water user associations did not appear to be approaching financial solvency in the near-term. The present evaluation updates those estimates for 2011 to 2013, but the water user associations' cash expenditures, revenues, and net revenues have changed little over this period (Figure 12).

Figure 12. Cost recovery rate over all WUAs, 2007-2013 (percentages)

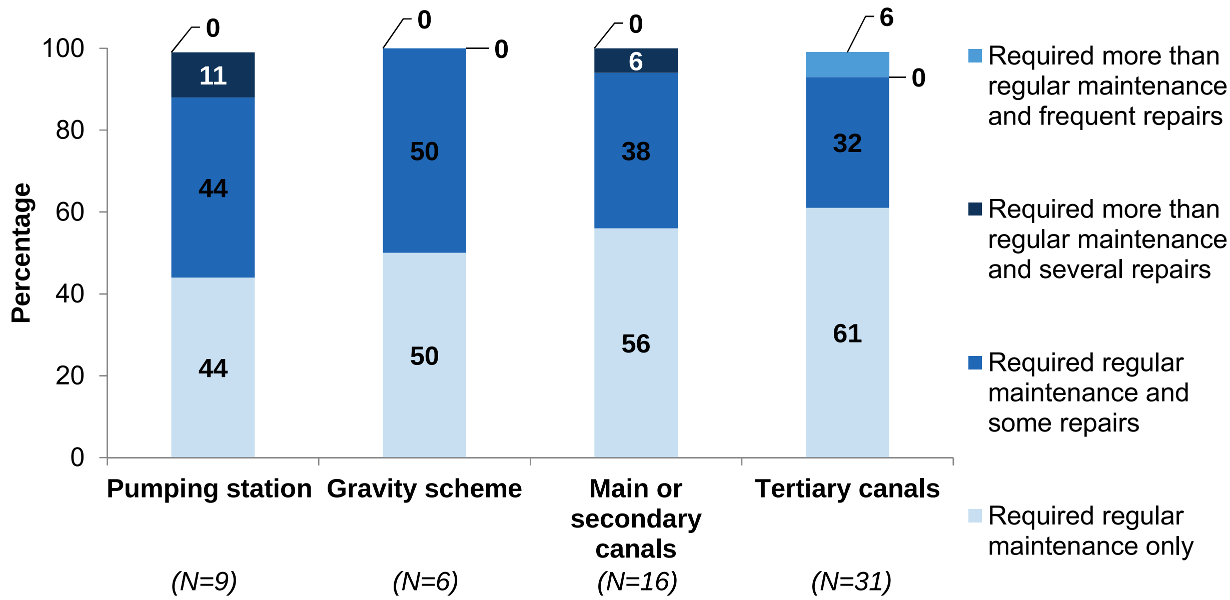


Sources: 2011, 2012, 2013 WUA administrative data, Water-to-Market evaluation report, and Armenia post-Compact Monitoring and Evaluation Plan (Jan. 2013).

Notes: Estimates for each year are based on 44 WUAs except in 2013, when two pairs of WUAs merged. In 2013, we summed the measures over all WUAs and divided by 44 to impute averages as if the WUAs had remained separate. A constant target of 60 percent was assumed from 2011 through 2013.

Water user associations report that the irrigation infrastructure rehabilitated under the Compact has mostly operated as planned, requiring little more than regular maintenance. In addition to the financial conditions of water user associations, the sustainability of MCA-Armenia's infrastructure investments depends on the challenges faced by water user associations to perform regular maintenance and any additional repairs. Nearly all water user associations reported that their rehabilitated infrastructure either required regular maintenance only or with some repairs (Figure 13).

Figure 13. Perceived functionality of rehabilitated pumping stations, gravity schemes, main or secondary canals, and tertiary canals (percentages)



Source: 2014 WUA survey.

Notes: Estimates are conditional on the WUA reporting that they had each type of rehabilitated infrastructure.

E. Implications for benefit-cost analysis of the Infrastructure Activity

MCC estimated benefits and costs at the outset of the Compact to help determine whether the projected benefits of rehabilitating irrigation infrastructure were sufficiently large to justify the costs. Its estimates projected the benefits and costs expected for the activity over the 20-year time horizon that is standard for economic rates of return in MCC Compacts, beginning with the first year of the Compact and ending 15 years after Compact close. MCC found that the *ex ante* estimated economic rate of return was 24 percent, meaning that the projected benefits substantially outweighed the projected costs. MCC generally seeks to invest in projects that meet a threshold of 10 percent.

Most of the costs contained in the model are for the construction work that was part of the project and were incurred in the second through fifth years of the Compact. They also factor in the costs of the Institutional Strengthening Subactivity that was designed to support the sustainability of the irrigation infrastructure investments.

The primary component of the benefits in MCC's *ex ante* model is households' increased agricultural income, with energy savings for some types of rehabilitated infrastructure (such as gravity schemes) playing a small role. MCC projected immediate impacts of the irrigation rehabilitation on households' agricultural income due to greater access to and reliability of irrigation water for land already under cultivation. MCC projected that the impacts on households' agricultural income would grow over time as farmers adapted further to the improved water supply by expanding the area under cultivation and having increased production on cultivated areas. The exact projected benefits vary somewhat for different types of irrigation infrastructure, but the broad pattern of benefits is shared across all types of irrigation infrastructure—immediate impacts after rehabilitation, with benefits doubling by six years after rehabilitation and tripling by the 10th year after rehabilitation.

We revisited the assumptions of the *ex ante* benefits and costs in light of the impact estimates from the present report. The estimates reported herein are as of the 2013 agricultural season, which is two to three years after all construction was completed and seven years into the 20-year time horizon MCC considered. Unfortunately, the estimated impacts on household income for neither the rehabilitation of tertiary canals nor the rehabilitation of large infrastructure were significantly different from zero. Thus, the early impacts that were expected have not materialized thus far.

Although MCC's projections predict that the earnings impacts are expected to grow beyond our evaluation time frame, the *ex ante* benefit-cost model is predicated on having already witnessed substantial increases in irrigated land, a result not found in the impact estimates. The evidence from the other intermediate impacts examined in this report does not give great hope that large effects are near on the horizon—there is only evidence of modest changes in water use behavior, no significant evidence of adoption of new agricultural practices, and no significant evidence of adoption of new crops whose benefits could be seen in future years. Consequently, we do not expect that the economic rate of return will be as large as the *ex ante* prediction of 24 percent.

F. Limitations

The analyses of tertiary canals and large infrastructure both use nonrandom comparison groups to establish a benchmark counterfactual against which beneficiary farmers' outcomes are measured. A crucial assumption in our methods is that our models account for all variables that could lead the treatment and comparison groups to have different outcomes in the absence of the rehabilitation. Our methods establish that the treatment and comparison groups are similar on key outcome measures at baseline and many other characteristics, but some of the follow-up differences indicate the two groups may still have had a few underlying differences for which we cannot fully account. For instance, in the evaluation of rehabilitated large infrastructure, the treatment group was significantly more likely to report experiencing a natural disaster than the comparison group, which would bias our estimates toward understating positive effects. These weather patterns could bias the impact estimates for production and income-related outcomes in the negative direction and could possibly explain our null and negative estimates for some outcomes. However, they are unlikely to affect the irrigation and agricultural practices chosen before the harvest, so those estimated impacts should not be biased by differences in actual disasters experienced.

Our survey sample also focused on smaller-scale farmers, most of whom cultivated 1 to 2 hectares of land, and nearly all of whom cultivated fewer than 10 hectares. Nationally, about 6 percent of farms cultivate more than 10 hectares (National Statistical Service 2015a). Smaller-scale farmers were intended to benefit from irrigation rehabilitation, but it could be that it was only larger-scale farms who benefitted. If so, then our analysis with the survey sample would understate the full impacts of the program because it omits the effects for large farms. However, this would still be a disappointing finding in that a much smaller subset of people were directly benefitting, and we found no evidence that any unmeasured benefits for large farms were spilling over onto small farms in the form of increased employment opportunities that increased households' total income. Further, WUAs' total water deliveries and land area irrigated (including large-scale farms) did not increase noticeably after infrastructure rehabilitation was completed, suggesting that any irrigation benefits that accrued only to larger-scale farms would be small.

We also note that the program logic assumes the infrastructure was in need of repair, but especially for tertiary canals, we do not have tangible evidence of the status of the canals before rehabilitation. It is conceivable that the repairs had more of a cosmetic effect without affecting the canals' capacity for water delivery.

A final limitation that we note for the analyses of infrastructure rehabilitation is that the follow-up data were collected only two years after construction was completed for the communities where rehabilitation occurred last. We did not expect impacts to fully manifest for longer-term outcomes such as household income and poverty rates within two years. However, as we discussed relating to the estimated benefits and costs, MCC's *ex ante* estimated benefit-cost analysis projected sizable impacts on earnings immediately after rehabilitation was complete, and we also expected farmers to have begun changing the crops they grow, the areas they irrigate, and the practices they use. We did not find significant changes for these short- and medium-term outcomes that might suggest longer-term impacts.

The reanalyses of Water-to-Market training and the Institutional Strengthening Subactivity were both descriptive. Neither was expected to provide conclusive answers to their respective research questions because they only compare estimates from 2013 to earlier years. We do not have compelling estimates for their counterfactuals in the form of a randomly-selected control group or a nonrandom comparison group. The findings for those two components are instructive as they suggest what the effects likely were, but the specific estimated changes over time should be interpreted with caution.

G. Summary of key findings

To summarize the lessons learned from the evaluation, we first revisited the program logic model for the infrastructure evaluation (Figure 1) and assessed the strength of the evidence for the expected outcomes. Table 3 provides an overview of the findings for the evaluations of rehabilitated tertiary canals and large infrastructure, focusing on the expected outcomes for households in the intervention groups relative to households in the comparison groups. Households in the tertiary canal treatment group perceived improvements to the irrigation water supply although households in the large infrastructure treatment group did not. However, there was limited evidence of changes in irrigation practices for households in both of the treatment groups, and no evidence of improvements in agricultural production and household well-being, findings that were similar for the analyses of tertiary canals as well as large infrastructure.

Based on these findings, our takeaway is that the rehabilitation of the irrigation infrastructure for these communities did not improve household well-being two to three years after the rehabilitation was completed. However, we do not anticipate large positive impacts on agricultural income in future years because there is no evidence of systematic positive impacts on intermediate outcomes such as irrigation behavior, adoption of agricultural practices, or crop cultivation.

Table 3. Summary of evidence for the logic model of the Infrastructure activity

Expected outcomes in logic model	Evidence for communities with rehabilitated tertiary canals	Evidence for communities with rehabilitated large infrastructure
Immediate		
Improvements in irrigation infrastructure	Strong evidence: farmers perceived improvements in the timeliness and reliability of irrigation water.	Weak evidence: farmers were more likely to report dissatisfaction with the timeliness and quantity of irrigation water, but WUAs reported the infrastructure was generally functioning well as planned. The expected (but modest) energy savings for gravity schemes did not materialize.
Short-term		
More efficient irrigation	Limited evidence that may be anomalous: farmers did not systematically adopt improved irrigation technologies or increase the adoption of higher-value but more irrigation-intensive crops.	
Increased area of irrigated land	Limited evidence that may be anomalous: farmers did not irrigate more of their land or more frequently overall, but farmers increased the total hours of irrigation on some portions of their land.	
Medium-term		
Increased production of high-value crops and total crop yields	No evidence of increases.	
Lower production costs	No evidence of decreases.	
Long-term		
Increased and more diversified production	No evidence of increases.	
Increased sales and agricultural profits	No evidence of increases.	
Increased household income/consumption	No evidence of increases.	
Reduced rural poverty	No evidence of decreases.	

H. Possible explanations for the null impact estimates

Farmers have behavioral inertia. Many of these farmers only farm part-time and possibly only for household consumption. Even among farmers who cultivate crops to sell, many are also employed or migrate to Russia parts of the year for work. On average, farming households earn about 40 percent more from nonagricultural work compared to the value of their harvests. They earn more than twice as much from nonagricultural work compared to agricultural net profits after subtracting agricultural costs. Those farmers are less likely to be attentive to opportunities to increase profits, and changing crops or investing in new technologies is also a bigger behavioral change because it entails deciding to place greater emphasis on farming as a main activity. The growing behavioral economics literature hypothesizes that there could be non-rational or even subconscious reasons people do not change behavior. For example, even in the absence of other constraints, farmers might not have changed their behaviors because they stick to what they are comfortable with or it takes mental effort and time to reassess the benefits and costs of change, and this is especially salient if farming is one of two or three sources of income for the household.

Farmers lacked funds to invest in new crops or new agricultural technologies. Farmers may have lacked personal funds or access to affordable agricultural credit to pay for irrigation water that would have been needed to expand cultivation or change crops. Alternatively, farmers may have lacked funds and credit to purchase inputs that would be complementary to irrigation water such as supplies needed for new crops or equipment for new agricultural practices. Although our evidence on these is limited, what we have observed did not support this hypothesis. For the subset of farmers who were asked, few farmers reported that agricultural inputs were not affordable. Most reported that they still did not perceive irrigation water as reliable or were not interested in expanding their cultivation.

Farmers viewed investments in new crops or new agricultural technologies as too risky. Most of the higher-value crops as well as new agricultural technologies entail higher upfront costs but much higher profit margins. Farmers may have been reluctant to make these investments because they did not know what markets would buy their produce, feared price volatility, or feared the risk of a failed harvest.

System functionality was not as good as was expected. Rehabilitation might not have repaired the targeted problems as well as was hoped for farmers. Alternatively, rehabilitation may have targeted the wrong issues with the irrigation systems or an incomplete set of issues—for example, perhaps a main canal was rehabilitated, but many of the tertiary canals that deliver water to the fields are still in poor repair. There unfortunately are not reliable, independent measures of the functionality of infrastructure. Farmers report in the Tertiary Canal Survey that irrigation functionality remains a constraint for them, but they may not have the expertise to assess functionality accurately, so we do not know if their reports are accurate. One way to measure the impact of complete rehabilitation would be to compare communities that were influenced by rehabilitation of tertiary canals and at least one large type of infrastructure to communities that were not influenced by any infrastructure rehabilitation. Unfortunately, we cannot conduct this comparison because of sample size limitations; only 30 treatment communities and 17 comparison communities would be in the sample if we did the bare minimum of matching.

Other less likely explanations. The follow-up period of two to three years after rehabilitation was too short. The impact evaluation is based on survey data collected approximately two to three years after irrigation rehabilitation was complete. Impacts on some outcomes, such as agricultural production and household income, may not be fully realized in three years. However, there are not impacts on intermediate outcomes that could foretell future impacts, such as substantially increasing irrigation use, cultivating higher-value crops, or adopting new agricultural practices, so we are skeptical that future impacts are likely. But it could be that farmers were slow to realize that their irrigation systems had been rehabilitated, in which case even these intermediate impacts could be delayed. Another possibility is that farmers were slow to respond to improvements in their irrigation systems because of reasons related to the global financial crisis in 2008, such as having difficulty accessing agricultural credit or weakened markets for agricultural production. The global economic conditions would affect post-harvest outcomes similarly for the two groups, but we cannot definitively say whether treatment and comparison farmers would have reacted differently without the recession. The impacts of the program could have been different in the absence of the financial crisis if it suppressed farmers' willingness to take advantage of the newly rehabilitated infrastructure with increased production.

Many of the above explanations focus on smaller-scale farmers, and conceivably, larger-scale farm operations could have been better poised to change their operations. The survey on which the impact evaluation was based included smaller-scale farm operations—nearly all survey respondents cultivated 15 hectares or less at baseline (and few even cultivated more than 10). Consequently, the household-level impact estimates do not reflect impacts that accrued to larger-scale farms, which might have had more resources to adopt new agricultural practices and grow high-value crops. However, the WUA administrative data cover both small and large-scale farms, and we do not find evidence that total water deliveries increase after the rehabilitation was completed.

I. Suggestions for future irrigation evaluations

Well-executed random assignment could be used to learn about different types of irrigation infrastructure and different groups of beneficiaries. A crucial assumption in our empirical methods is that our models account for all variables that could lead the treatment and comparison groups to have different outcomes in the absence of the rehabilitation. Our methods establish that the treatment and comparison groups are similar on key outcome measures at baseline and many other characteristics, but we cannot prove that the groups are equivalent for factors that cannot be measured. Future programs could use a well-executed randomized controlled trial to generate intervention and control groups that are equivalent on average, and randomization can be structured so that impacts can be rigorously estimated for subgroups of beneficiaries that receive different types of infrastructure rehabilitation. We note instances where there are many units that are considered for rehabilitation, and a significant subset actually are rehabilitated, such as with tertiary canals, would be especially conducive to a randomized-controlled trial.

Engineering experts could inspect irrigation functionality. Although other data sources have measures of irrigation functionality, having an irrigation expert assess functionality would be a more reliable way to explore this possible explanation. It could be that the systems are actually functioning well but farmers do not yet realize it and/or use perceived irrigation limitations to justify behavioral inertia. The key question for the engineer would be whether irrigation water is flowing as it is supposed to, particularly downstream (in the tertiary canals). This could be done by examining the rehabilitated infrastructure itself and/or water at the tertiary canals even if the tertiary canals themselves were not rehabilitated.

MCC could consider investing in water meters or other monitoring tools that would help water user associations while also providing better measurement of outcomes. Improved water delivery and reduced losses were fundamental expected outcomes of the Infrastructure Activity, but the existing data have not been validated, and there are not accurate measures of water delivery to farmers. This makes it more difficult to know whether water availability has actually improved for individual farmers. Creating the means for WUAs to more precisely measure water delivery would also potentially help them manage their resources more effectively and could possibly be of greater benefit to them than other types of technical and material assistance, beyond the benefits it would have for monitoring purposes.

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I. INTRODUCTION

A. Overview of the Compact with Armenia

The Republic of Armenia was left with the legacy of a centrally planned economy when it declared independence from the Soviet Union in 1991. The Armenian economy was highly dependent on its Soviet trading partners and poorly equipped to function with the lack of infrastructure investment and support after Soviet withdrawal. In 1994, the Armenian government adopted a comprehensive stabilization and reform program that dramatically lowered inflation and led to steady economic growth beginning in 1995. Evidence from the Integrated Living Conditions Survey, however, suggests that this growth occurred primarily in urban areas. As of 2004, the poverty rate in rural areas was 32 percent (National Statistical Service 2010).[2]

Although many rural Armenian households are involved in farming, farmers cannot rely on timely and adequate water to cultivate their crops. Only about 6 percent of farms cultivated more than 10 hectares (National Statistical Service 2015a). Much of the irrigation infrastructure established prior to Soviet withdrawal has continued to deteriorate over the years and has fallen into disrepair and disuse. The land area that was actually irrigated decreased by almost 50 percent between 1985 and 2006 (Food and Agriculture Organization of the United Nations 2009), substantially curbing the viability of higher-value but more irrigation-intensive crops such as fruits and vegetables. Currently, many farming households cultivate high-value agriculture crops such as fruits and vegetables, but they grow them only in small amounts and for household consumption in part because of irrigation constraints. Grains such as wheat constitute most of the crops produced, but grains have limited commercial viability in Armenia (Fortson et al. 2010).

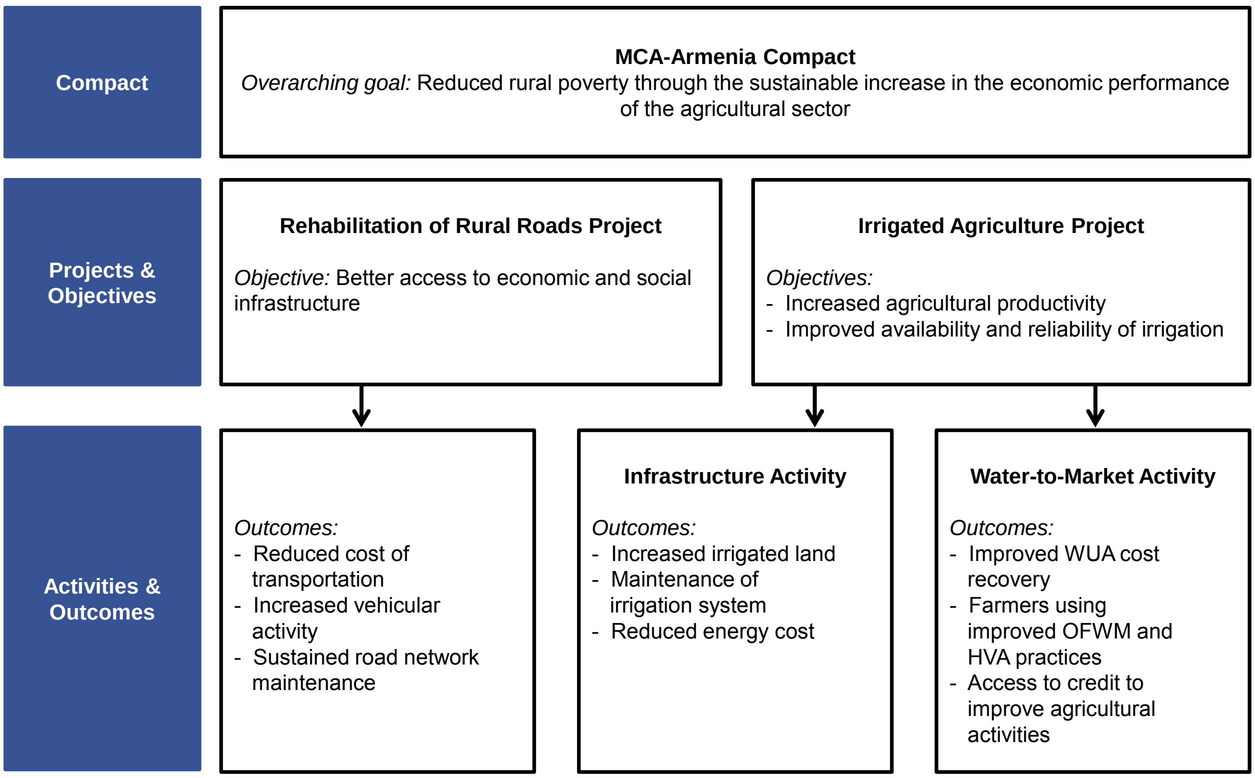
The aim of the Millennium Challenge Corporation's Compact with Armenia ("the Compact"), a five-year agreement signed in March 2006, was to increase household income and reduce poverty in rural Armenia through improved performance of the country's agricultural sector. The Compact, managed by the Millennium Challenge Account with Armenia (MCA-Armenia), was originally designed to include two projects: (1) the Rehabilitation of Rural Roads Project and (2) the Irrigated Agriculture Project.[3] The Irrigated Agriculture Project comprised two complementary activities, the rehabilitation of irrigation infrastructure ("the Irrigation Infrastructure Activity," hereafter, Infrastructure Activity) and the provision of training, technical assistance, and access to credit for farms and agribusiness ("the Water-to-Market Activity"). The Infrastructure Activity was intended to provide adequate and timely delivery of water to crop fields, and the Water-to-Market Activity was intended to help farmers harness these improvements to introduce new technologies and foster a shift to high-value crop

[2] The poverty rate is calculated based on the percentage of households whose consumption per person is less than a threshold that would be required to meet daily caloric requirements.

[3] At the June 2009 Millennium Challenge Corporation board meeting, the decision was made not to continue funding any further road construction and rehabilitation under the $236 million Compact because of concerns about democratic governance. Approximately 25 km of pilot roads had been completed prior to this decision. Many of the road projects designed with funding from MCC were ultimately financed by the World Bank and the Republic of Armenia.

production, both of which would improve household income.[4] The Water-to-Market Activity also included technical support to regional water management organizations (water user associations, or WUAs) through the Institutional Strengthening Subactivity, with the aim of creating more efficient and consistent irrigation supply and sustaining the investments in irrigation infrastructure. The Institutional Strengthening Subactivity also included an irrigation policy reform component whereby a reform strategy was developed through a participatory process with stakeholders. By improving living standards among rural residents, these investments were designed to lead to future economic growth in rural areas and throughout the country. Figure I.1 summarizes the overall goal of the Compact and the planned contribution of each activity to the goal.

Figure I.1. Overview of the Compact with Armenia



WUA = water user association; OFWM = on-farm water management; HVA = high-value agriculture.

The Millennium Challenge Corporation (MCC) has commissioned rigorous impact evaluations to examine each of the three main activities of the MCA-Armenia program. This report focuses on the evaluation plans for the Infrastructure Activity. The Infrastructure Activity was completed near the end of the Compact in 2011 and is the final of the three evaluations MCC commissioned. The Rehabilitation of Rural Roads Project and the Water-to-Market Activity of the Compact were evaluated previously (Fortson et al. 2015; Fortson et al. 2013). The

[4] High-value crops are defined as crops that have relatively high economic value per kilogram, per hectare, or per calorie, such as fruits, vegetables, and nuts. In Armenia, high-value agriculture consists of all crops that are not grain or grass (Gulati et al. 2005).

data used in the Infrastructure Activity evaluation cover the 2013 agricultural season, so the evaluation will examine effects two to three years after completion of the infrastructure work in these communities.

In addition to evaluating the Infrastructure Activity itself, we will also present a simple check on the potential for complementarities between the irrigation infrastructure rehabilitation and select components of the Water-to-Market Activity that were evaluated before the rehabilitation had been completed. We focus on two components of the Water-to-Market Activity that were designed to have particularly strong complementarities with the rehabilitated infrastructure, the Institutional Strengthening Subactivity and Water-to-Market training. The Institutional Strengthening Subactivity was in part intended to enable regional water user associations to sustain the improved infrastructure with repairs and maintenance, and Water-to-Market training provided farmers with training in agricultural practices that would help them harness the more reliable water supply from the Infrastructure Activity. The Institutional Strengthening Subactivity and Water-to-Market training were both evaluated as part of the Water-to-Market evaluation, but the time frame preceded completion of the Infrastructure Activity. If farmers who participated in the Institutional Strengthening Subactivity or Water-to-Market training were waiting for the rehabilitation before changing their agricultural production, then the previous evaluation of the Institutional Strengthening Subactivity and Water-to-Market training could be understating the impacts of the Institutional Strengthening Subactivity or Water-to-Market training. Our test compares households that benefitted from irrigation infrastructure rehabilitation and that participated in the other components of the Water-to-Market Activity with households that only participated in other components of the Water-to-Market Activity; if there were complementarities, we would expect that the former group would have substantially more favorable outcomes on key intermediate measures such as agricultural practices and crop cultivation.

In the remainder of this chapter, we discuss the program logic for the Infrastructure Activity and complementary Water-to-Market components, the research questions that stem from the program logic, and the contributions of the present evaluation to the existing literature on infrastructure investments in developing countries. In Chapter II, we summarize implementation of the Infrastructure Activity and related components. In Chapter III, we present impact estimates from the evaluation of the tertiary canals that were rehabilitated as part of the Infrastructure Activity. In Chapter IV, we present impact estimates from the evaluation of larger infrastructure projects that were rehabilitated such as main canals and pumping stations. In Chapter V, we summarize the impacts of the Infrastructure Activity, describe evidence regarding the sustainability of the rehabilitation efforts, and discuss the estimated benefits relative to costs. In Chapter VI, we present the longer-term assessment of the adoption of agricultural practices that were introduced as part of Water-to-Market farmer training. We discuss the follow-up assessment of the Institutional Strengthening Subactivity in Chapter VII. We cover overarching conclusions of the evaluations in Chapter VIII.

B. Program logic of the Infrastructure Activity and related Water-to-Market components

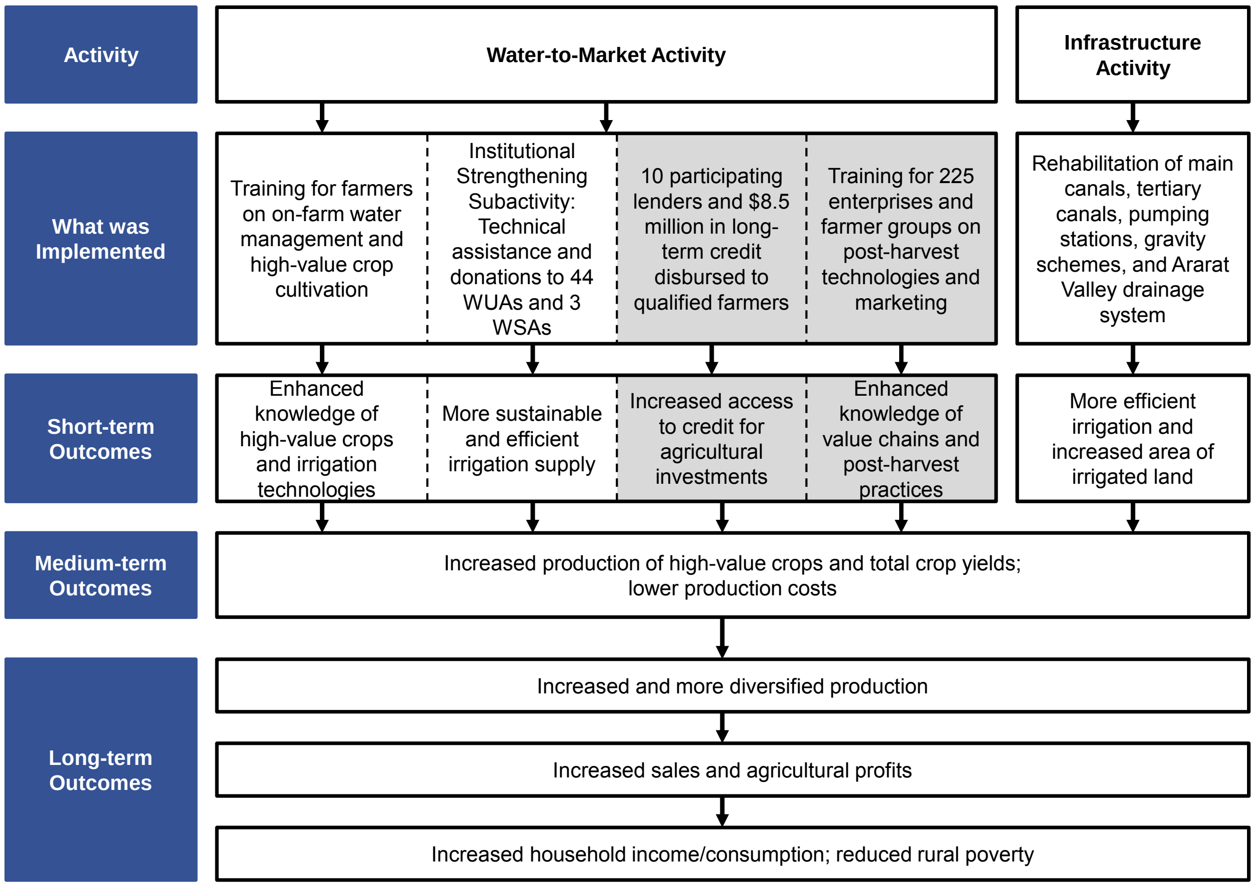
Prior to rehabilitation, water user associations, the regional organizations that manage the distribution of and payment for irrigation water in Armenia, estimated that only 25 to 40 percent of irrigation water actually reached the fields in most of the affected villages. The lost water would instead drain into the land surrounding the canals. The Compact provided $121 million of funding to rehabilitate several different types of irrigation infrastructure throughout rural Armenia from 2008 to 2011, including tertiary canals as well as larger infrastructure projects such as main canals, the Ararat Valley drainage system, pumping stations, and gravity schemes (Table I.1).

Table I.1. Summary of the Infrastructure Improvement Activity

Feature	Description
Objective	Improved efficiency of, access to, and reliability of irrigation water
Target population	Farming households in 298 communities throughout rural Armenia
Funding	$121 million after the Activity was rescoped in October 2008.
Implementing parties	*Tertiary canals:* Yerevanshin Kamurjshin, Spitak-1 OJSC, Zarubezhvodstroy *Main canals:* SADE, ArpaSevan *Drainage system:* Sahakyanshin, SADE *Pumping stations:* FARMEX *Gravity schemes:* ArpaSevan
Time frame	December 2008 to September 2011
Activities	Rehabilitation and improvement of 220 km of tertiary canals serving 100 communities, refurbishment of 260 water structures along main canals, cleaning 470 km of canals to rehabilitate Ararat Valley drainage system, rehabilitation of 17 pumping stations, and construction of 5 gravity-fed systems and associated canals with refurbishment of 40 km of new canal lining.

The short-term goals of the Infrastructure Activity were to improve the efficiency of irrigation and to increase the area of irrigated land (Figure I.2)—both by expanding irrigation to areas that were not irrigated before the project, and to prevent decreases in irrigated area in the absence of the project as unrehabilitated irrigation equipment deteriorated further. With access to a more consistent supply of irrigation water, farmers could increase their agricultural production both by having more land that could be irrigated and greater yield on land that was cultivated. In conjunction with the Water-to-Market Activity, the Infrastructure Activity was designed to increase sales and increase agricultural profits for beneficiary farmers. Fortson et al. (2013) describe the Water-to-Market Activity more extensively, but we focus below on summarizing the specific Water-to-Market components that were intended to strongly complement the Infrastructure Activity.

Figure I.2. Logic model of the Infrastructure and Water-to-Market activities



Note: The Water-to-Market Activity comprises four components, two of which were designed to have particularly strong complementarities with the Irrigation Infrastructure Activity (Water-to-Market farmer training and the Institutional Strengthening Subactivity). The other two components are grayed in the figure. All components of the Water-to-Market Activity are discussed in Fortson et al. (2013).

WUA = water users associations; WSA = water supply agencies.

The Institutional Strengthening Subactivity component of the Water-to-Market Activity, implemented by Mott MacDonald and VISTAA, provided general technical support to water user associations (Table I.2). The Institutional Strengthening Subactivity also provided assistance to three water supply agencies that operate and maintain irrigation dams and pumping stations. The general aim of the Institutional Strengthening Subactivity was to strengthen water user associations' and water supply agencies' managerial, technical, structural, and financial capacity and self-sufficiency. The intent of these improvements was to create more efficient and consistent irrigation supply for water user association members. The Institutional Strengthening Subactivity also included an irrigation policy reform component, in which a reform strategy was developed through a participatory process with stakeholders.

Table I.2. Summary of the Institutional Strengthening Subactivity

Feature	Description
Objective	Improve WUAs'/WSAs' managerial, technical, structural, and financial capacity
Target population	44 WUAs (8 targeted and 36 nontargeted) and 3 WSAs
Funding	4.9 million (USD)
Implementing parties	Mott MacDonald, Euroconsult, and VISTAA
Time frame	September 2008 to October 2011
Activities	*Consultations and management improvement plan development:* Biweekly consultations in targeted WUAs and quarterly consultations in nontargeted WUAs to discuss needs and develop management improvement plans *Software donations:* Donations of budgeting, accounting, and geographic information system software to WUAs and WSAs *Equipment/furniture donations:* Computers, furniture, and loading and welding equipment donations to WUAs and WSAs *Irrigation policy reform:* An irrigation policy and strategy document as well as draft irrigation legislation developed by ISSA consultants *Study tours:* Two international study tours for WUA directors, WSA staff, and government officials, one to the United States in August 2010 and one to Spain and Portugal in June 2011

WUA = water users associations; WSA = water supply agencies; USD = United States dollars.

Water-to-Market farmer training included two types of training conducted from 2007 to 2011 (Table I.3). The first type of training covered on-farm water management techniques aimed at helping farmers learn to use improved irrigation technologies such as modifying furrow spacing. As part of this component, demonstration plots were also established to demonstrate the irrigation technologies in practice. A total of 45,000 farmers was scheduled to be trained in on-farm water management practices from 2007 to 2010. MCA contracted with ACDI/VOCA and its partners, VISTAA and Euroconsult (hereafter referred to collectively as ACDI) to implement the training. The goal of this training was for farmers to adopt new and more efficient irrigation techniques, which would lead to increased and more cost-effective agricultural production and higher sales. The second type of training was high-value agriculture training, which consisted of establishing demonstration plots and conducting training sessions for farmers on high-value crop substitution and cropping intensity. In total, 36,000 farmers who received on-farm water management training were also scheduled to be trained by ACDI in high-value agriculture from 2007 to 2011. The goal of high-value agriculture training was for farmers to adopt new cropping techniques and high-value crops, which would lead to increased and more diverse agricultural production as well as increased sales.

Table I.3. Summary of the Water-to-Market training component

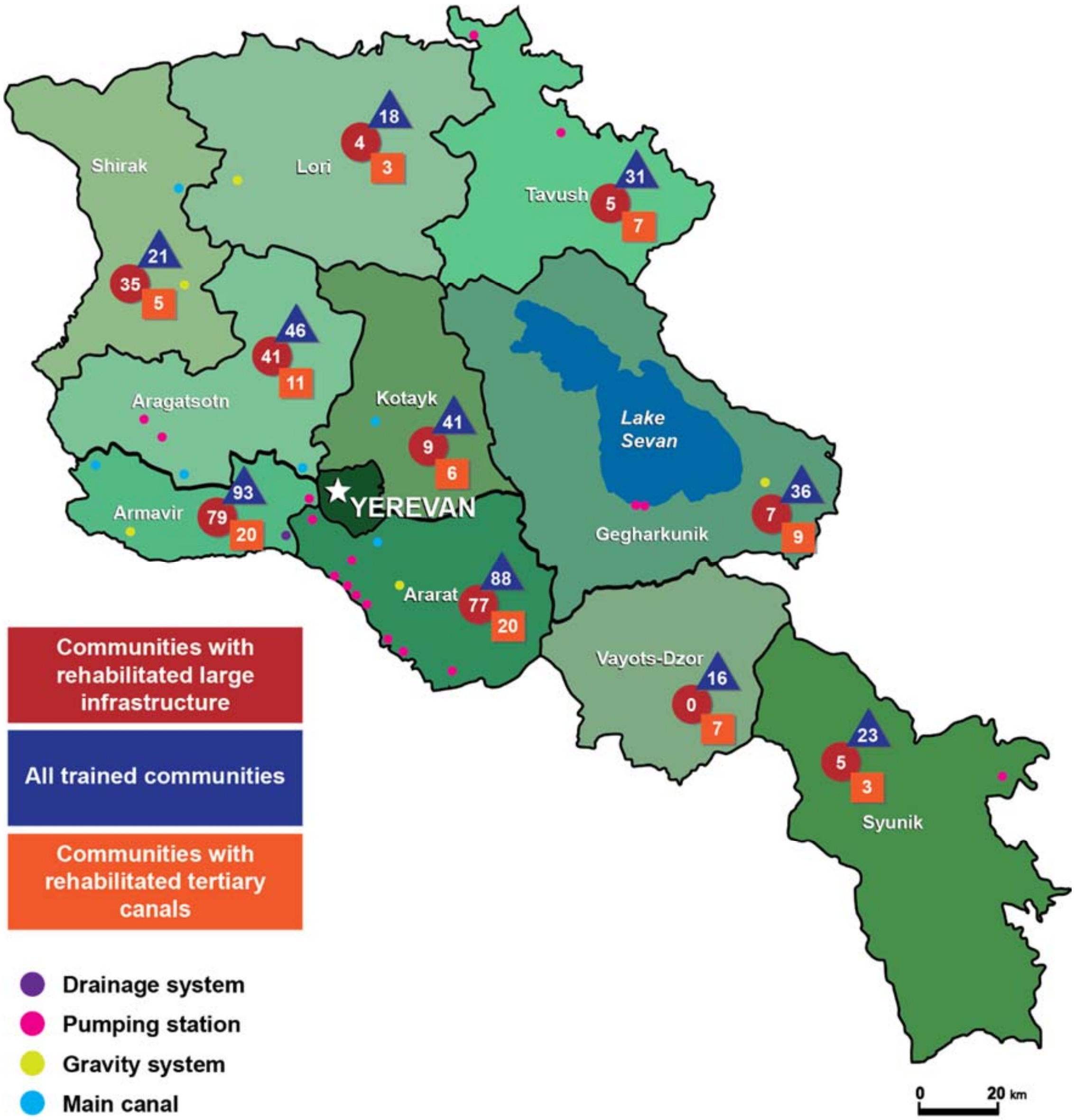
Feature	Description
Objective	Provide training for farmers to transition to more profitable, market-oriented agricultural activities
Target population	Farmers in rural areas of Armenia who are members of water user associations
Funding	14.3 million (USD) after Water-to-Market targets were revised in 2009
Implementing parties	ACDI/VOCA in partnership with VISTAA and Euroconsult
Time frame	2007 to 2011
Activities	*On-farm water management training:* 45,000 farmers trained with emphasis on low-cost irrigation for small-scale farming operations *High-value agriculture training:* 36,000 farmers trained with emphasis on cultivation of new, higher-revenue crops and higher-value varieties of common crops, such as organic varieties. Seventy-eight percent of the participating farmers had also attended on-farm water management training. Both types of training involved three to four days of in-class lessons as well as practical lessons on a demonstration farm set up and maintained for the training. Optional tours of demonstration farms were available during key months of the agricultural cycle to help farmers remember practices covered in training.

USD = United States dollars.

Water-to-Market farmer training in on-farm water management and high-value agriculture was expected to be especially beneficial for farmers who had reliable access to irrigation. Some farmers who participated in Water-to-Market training already had reliable irrigation, but some communities whose irrigation supply was inadequate were provided training with the expectation that the Infrastructure Activity would soon improve their water supply. For the Water-to-Market training evaluation, communities were randomly assigned to receive training in 2008 (Water-to-Market training treatment group), in 2011 (Water-to-Market training comparison group), or in 2009 and 2010 (nonresearch group). The evaluation compared outcomes for the Water-to-Market training treatment group and the Water-to-Market training comparison group using baseline data collected in 2007 and final follow-up data collected in 2010. In comparison, the Infrastructure Activity began in 2009 and concluded in mid-2011; final follow-up data were collected for the 2013 agricultural season. The distribution of rehabilitated tertiary canals, rehabilitated large infrastructure, and communities receiving training across marzes are shown in Figure I.3.

The Water-to-Market training impact evaluation found that as of 2010, there was no evidence that Water-to-Market training had consequential effects on farmers. Agricultural profits and household income were not significantly affected, nor was there evidence of widespread adoption of new agricultural practices that might lead to longer-term impacts in the future. However, it could be that farmers waited to invest in new agricultural practices until after they perceived irrigation was more readily available in their communities upon the completion of the Infrastructure Activity. We address this possibility more explicitly in Chapter VI.

Figure I.3. Distribution of tertiary canals and large infrastructure that was selected for rehabilitation and trained communities, by marz



Source: Millennium Challenge Corporation program data.

The last two components of the Water-to-Market Activity focused on increasing access to agricultural loans for farmers and training agribusinesses in post-harvest technologies and marketing. These components are shaded in gray in Figure I.2 to indicate that they will not be reexamined in this study. The Water-to-Market evaluation (Fortson et al. 2013) found suggestive evidence that Water-to-Market credit and post-harvest training for agribusinesses may have had positive effects on the beneficiaries who participated in these components. These two Water-to-Market components are not reexamined in this study because they do not have the direct linkages to the Infrastructure Activity that Water-to-Market farmer training and the Institutional Strengthening Subactivity have, nor were there reasons to expect that their effects may have substantially increased over time.

C. Research questions for the Infrastructure Activity

Six overarching research questions guide the evaluation of the Infrastructure Activity:

1. Did the program affect the quantity and reliability of irrigation water provided to Armenian farmers?
2. Did farmers adopt new agricultural practices as a result of the program? Further, is there evidence that farmers who received Water-to-Market training postponed adopting new agricultural practices until after the irrigation infrastructure had been rehabilitated?
3. Did the program affect agricultural productivity?
4. Did the program improve household well-being for farmers served by the rehabilitated infrastructure, especially income and poverty?
5. Is there evidence that the infrastructure investments will be sustained after rehabilitation was complete? Are the water user associations themselves financially sustainable?
6. Were the program effects large enough to justify its costs?

Different components of the evaluation focus on different subsets of these questions. The evaluation of the Infrastructure Activity separately examines impacts of rehabilitating tertiary canals and other, larger types of irrigation infrastructure, as discussed in more detail in the respective chapters for each set of irrigation projects. Each of those two (sub)evaluations focuses on questions 1 through 4. The reexamination of possible longer-term effects of Water-to-Market training provides complementary evidence to help answer question 2 as well. The reexamination of the Institutional Strengthening Subactivity is designed to help answer question 5 because one of the key purposes of the Institutional Strengthening Subactivity was to empower water user associations to sustain the irrigation infrastructure investments made under the Infrastructure Activity.

Question 6 will be addressed by reconsidering the benefits and costs of the activity. In 2008, MCC estimated the economic rate of return for the Infrastructure Activity to be 24.4 percent over a 20-year time horizon (revised from an original estimate of 27.5 percent). This estimate is calculated based on the total social costs and benefits associated with the rehabilitation of the canals, gravity schemes, pumping stations, and the Ararat Valley drainage system as well as the Institutional Strengthening Subactivity and MCC's overhead costs. The costs for the rehabilitation projects include investment, contingency, maintenance, design, supervision, and other construction costs. The benefits are measured as the estimated incremental agricultural income generated from the improved infrastructure. The calculated benefits are based on a set of assumptions, such as future irrigated land area, cropping patterns, and crop prices, all of which are covered by separate research questions. Thus, in answering the other research questions in the evaluation of the Infrastructure Activity, we are able to assess the accuracy of the assumptions in the benefit-cost projections and the implications for the net benefits that were ultimately realized.

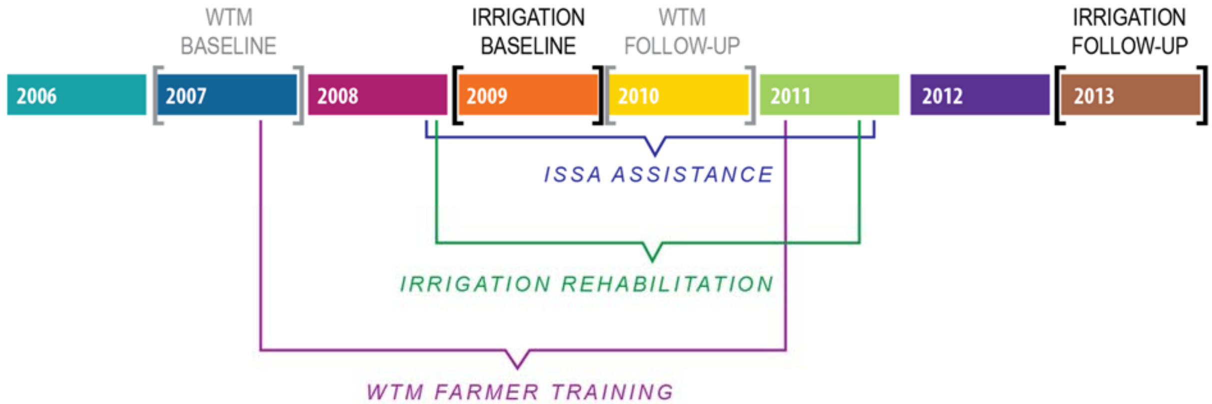
D. Summary of evaluation approaches

As detailed earlier in this chapter, MCA-Armenia's irrigation rehabilitation efforts covered several different types of irrigation infrastructure, including tertiary canals, main canals, the Ararat Valley drainage system, pumping stations, and gravity schemes. However, for most of these types of infrastructure, only a handful of projects was implemented, too few to support a rigorous evaluation, and there were no other hypothetical projects that could serve as a comparison group. Hence, MCC and Mathematica originally agreed to focus the evaluation effort on the tertiary canal rehabilitation efforts because the prospective research design was rigorous and precise enough to yield informative impact estimates on an important intervention.

The evaluation of rehabilitated tertiary canals remains as the most rigorous of the subevaluations in this report, but in 2011 MCC asked Mathematica to expand the evaluation to examine other project components as well. This request was part of a broader initiative by MCC to learn as much as possible about the impacts of its interventions, even if the findings could not be conclusive because of weaker methodologies. In particular, we developed an evaluation design to estimate, as best we can, the impacts of rehabilitating the other, larger irrigation infrastructure using data that already existed or would be collected. 2011 was two years after the TCS and some irrigation projects were already well underway, so it was too late for us to conduct another baseline survey that would have been needed for a strong nonexperimental evaluation of the large infrastructure. Fortunately, the TCS sample covered nearly all large infrastructure that had rehabilitated; the exceptions were five pumping stations and two gravity schemes that served relatively few communities. We also developed plans to conduct longer-term assessments of the Institutional Strengthening Subactivity and Water-to-Market training, two of the components of the Water-to-Market Activity that were evaluated previously (Fortson et al. 2013) but thought to have complementarities with the Infrastructure Activity that may not have been fully realized at the time of the Water-to-Market evaluation. Because the evaluation of rehabilitated tertiary canals is the most rigorous, we discuss it first.

The tertiary canal subevaluation uses a matched comparison group design. Under this approach, communities with tertiary canals for which rehabilitation was implemented (treatment group) were matched to other communities sharing similar geography, pre-rehabilitation conditions, and types of crops cultivated. Examining how outcomes change for farmers in the comparison group, whose canals were not rehabilitated, informs us about how farmers in the treatment group might have fared in the absence of the rehabilitation efforts. We estimate the impacts of the program by comparing the post-rehabilitation outcomes for these two sets of communities. Crucially, the analysis compares how the outcomes have changed relative to the same outcomes measured before the rehabilitation. This approach, which estimates program impacts as the "difference in differences" for the two groups, is stronger than simply comparing post-rehabilitation outcomes because it allows us to adjust for preexisting differences in the two groups. We primarily use data from the Tertiary Canal Survey, a survey of households in the two sets of communities that was designed and administered specifically for this evaluation. The survey covers the 2013 calendar year and agricultural season, which is approximately two years after completion of the Infrastructure Activity, two to three years after communities in our sample had their infrastructure rehabilitated, and four years after the baseline Tertiary Canal Survey (Figure I.4).

Figure I.4. Timeline of Irrigation Infrastructure Activity, Water-to-Market initiatives, and associated data collection



The design for estimating impacts of rehabilitating large infrastructure shares many features with the tertiary canal evaluation described. Most prominently, we determined that data from the Tertiary Canal Survey, which was originally designed exclusively for the tertiary canal evaluation, were appropriate for the evaluation of larger infrastructure as well. We also use a matched comparison group evaluation design, comparing communities served by any large project to other communities whose large infrastructure was not rehabilitated. Another way to measure the impact of rehabilitation would have been to compare communities that were influenced by rehabilitation of tertiary canals and at least one large type of infrastructure to communities that were not influenced by any infrastructure rehabilitation. Unfortunately, we cannot conduct this comparison because of sample size limitations; only 58 treatment communities and 37 comparison communities would be in the sample before doing any matching (Table I.4), and 30 treatment and 17 comparison communities with the bare minimum of matching (as detailed in Chapters III and IV). Consequently, we have evaluated tertiary canal rehabilitation and large infrastructure rehabilitation as separate interventions. In Table I.4, the potential sample for the evaluation of tertiary canal rehabilitation is represented in the last row (89 treatment communities and 86 communities prior to matching), and the potential sample for the evaluation of large infrastructure rehabilitation is represented by the overall totals for large infrastructure in the last column (107 treatment communities and 68 comparison communities before matching).

Table I.4. Communities with rehabilitated tertiary canals and large infrastructure in the Tertiary Canal Survey

	Communities with rehabilitated tertiary canals	Communities without rehabilitated tertiary canals	Total
Communities with rehabilitated large infrastructure	58	49	107
Main canals	41	35	76
Drainage systems	11	14	25
Pumping stations	22	17	39
Gravity schemes	8	5	13
Communities without rehabilitated large infrastructure	31	37	68
Total	89	86	175

Source: 2009–2010 Tertiary Canal Survey and Millennium Challenge Corporation program data

As we did in the Water-to-Market evaluation, in reassessing the Institutional Strengthening Subactivity we rely mainly on water user association administrative data, which were collected directly from water user associations and supplemented by survey data that cover more subjective topics. The survey was already administered and analyzed for the years 2008 through 2010, which were covered in the Water-to-Market evaluation. Our reassessment adds three new years of data but otherwise employs the same methodology of comparing outcomes before and after the Institutional Strengthening Subactivity. There is no comparison group for the water user associations who were assisted by the Institutional Strengthening Subactivity.

Lastly, the reassessment of Water-to-Market training mainly uses simple descriptive analyses to examine longer-term rates of adoption of the technologies taught as part of the training sessions. We also examine crop cultivation. The Tertiary Canal Survey is the data source for this analysis as well. As shown in Figure I.3., the Water-to-Market training evaluation used data as of the 2010 calendar year, a period over which few irrigation projects had been completed. The present analysis extends this by three additional years, the latter two of which are after irrigation rehabilitation was completed.

E. Related research

As context for the Infrastructure Activity, we first note that agriculture is a dominant sector in most developing countries, with many rural households relying on agriculture as their primary source of income. Many irrigation systems in the developing world are nonexistent or in poor condition, inhibiting farming households from engaging in agricultural production or employment that would improve their well-being. Infrastructure that is either lacking or in poor repair may limit farming households from producing sufficient and high-value crops for their own consumption or for sale in agricultural markets. For these reasons, governments, development banks, and foreign aid agencies have made significant investments to rehabilitate irrigation infrastructure in many developing countries: the Food and Agriculture Organization documented 248 different irrigation infrastructure projects totaling more than $8 billion in investment costs from 1980 to 2000 (FAO 2000). The Infrastructure Activity is a significant investment in infrastructure rehabilitation for Armenia, providing $121 million over the Compact period. In comparison, as of 2005, the operations and management requirements for irrigation water services in Armenia were estimated to be $16 million, half of which was contributed by the government (FAO 2009).

In addition to physical infrastructure improvements, many countries are also reconsidering the way that water resources should be managed to encourage efficient water usage.[5] Many are shifting toward a more decentralized system where local water groups assume responsibilities for irrigation operations and maintenance (Hodgson 2007). Our literature review includes studies discussing physical infrastructure improvements relevant to the Infrastructure Activity and irrigation management transfer relevant to the Institutional Strengthening Subactivity.

Armenia and other post-Soviet republics are distinct from many developing countries in that extensive irrigation systems exist and were once functioning well in the Soviet era, but those systems have largely fallen into disrepair following the collapse of the Soviet Union. Many of the projects included in the Infrastructure Activity were efforts to revive existing infrastructure rather than build new systems. To our knowledge, no rigorous studies of irrigation initiatives in a similar setting as the Infrastructure Activity in Armenia exist. However, other studies provide evidence of the effects of irrigation improvements in different settings. These studies generally find that irrigation is associated with a greater level of resources, particularly through higher production and income. One recent empirical review of the literature in Asia shows that across country-specific studies, irrigation is associated with higher cropping intensity, land productivity, and labor employment and wages; irrigated settings also see higher income, lower income inequality, and lower poverty than do rain-fed settings (Hussain and Hanjra 2004). Van Den Berg and Ruben (2006) look at how Ethiopia’s national irrigation improvements have affected income inequality by examining ex post outcomes. They find that households with irrigation have higher expenditures and lower dependence on public programs than do households without irrigation after accounting for preexisting differences. Another study examines how the redistribution of water to canals (through motorized pumps) affects poverty, agricultural production, and nutrition in Northern Mali (Dillon 2008). Over the eight-year evaluation period, households with this type of irrigation access show higher household consumption, agricultural production, and caloric and protein intake than do households without access. They also tend to save more and share more of their resources with fellow village members.

Dams, which are different from the present context in an engineering perspective but nonetheless important in their routing of water to canals, have also featured in the irrigation literature. From the studies reviewed, the welfare impact of dams seems to be ambiguous, yielding economic benefits to some households yet inflicting harm on others, including the costs of relocating individuals and environmental costs. In a seminal paper, Duflo and Pande (2007) evaluate the effect of large dams in India. They show that agricultural productivity increases but poverty reduction is not universal and the impacts depend on the proximity to the dam itself. In downstream districts, agricultural production increases and poverty decreases, but in districts where the dam is built, there is no significant increase in agricultural production and an increase in poverty. On the aggregate level, poverty actually increases. Amacher et al. (2004) also find

[5] More information on irrigation policies of specific countries can be found in the FAO’s AQUASTAT Country Profiles, available at http://www.fao.org/nr/water/aquastat/main/index.stm.

distributional impacts of smaller dams (microdams) in Tigray, Ethiopia. Although microdams are found to increase the productivity of fuelwood collection and crop production, villages close to the site of the microdams face a higher rate of waterborne disease, resulting in more time at home sick or caring for sick family members.

Studies by Del Carpio et al. (2011) and the World Bank Impact Evaluation Group (IEG 2008) are particularly relevant to the present evaluation because they estimate the impacts of rehabilitating existing irrigation infrastructure and do so using a comparison group design. Del Carpio et al. (2011) examine the impact of rehabilitating irrigation infrastructure on expenditure, agricultural production, and income ratio measures in coastal Peru. Using national household survey data from 1998 to 2007, the study identified treatment and comparison groups based on distance to the rehabilitation site. The study shows differential impacts for poor and nonpoor farm households. For poor farm households, the infrastructure rehabilitation decreased agricultural production and sales but increased household well-being overall, which they conclude is because poor households substituted work on their own farms for work on others' larger farms. For nonpoor farm households, these economic measures increased, but the effects were not statistically significant (or very weakly so).

The Impact Evaluation Group study (IEG 2008), commissioned by the World Bank, evaluates command area improvements from both new construction and rehabilitation of existing infrastructure in the Andhra Pradesh region of India. The study finds that there were favorable impacts on yield, cropping intensity, nonfarm income, and wage employment over the one-year evaluation period. However, it also shows that there was less crop diversification than expected, water waste in the upper reaches of the canals, and very significant cost overruns and construction delays. Consequently, despite the positive impacts on income, the calculated economic rate of return for the project was just 2 percent, compared to the *ex ante* estimate of 19 percent. This study illustrates that, considering the cost of most irrigation interventions, examining whether the effects are large enough to justify the costs is crucial.

Our study contributes to the literature by using a rigorous evaluation design to estimate program impacts of rehabilitated tertiary canals and large irrigation infrastructure. We also examine mediating pathways of rehabilitating irrigation infrastructure, which are underexplored in the existing literature, rather than focus solely on longer-term outcomes such as agricultural production, household income, and poverty. Although the longer-term outcomes are certainly important, examining the mediating pathways may help explain why any impacts on longer-term outcomes did or did not materialize.

We also contribute to the literature an evaluation of technical assistance to water user associations under the Institutional Strengthening Subactivity. We are unaware of any existing literature on the causal effect of providing technical assistance to water user associations. Somewhat greater attention has been given to evaluating the effects of irrigation management transfer, including establishing water user associations, though even this literature is thin (Xie 2007). However, Mukherji et al. (2009) review more than 100 case studies of irrigation management transfer in Asia and show that only 43 of 108 were successful according to their definition, with Central Asian countries being particularly weak. To the best of our knowledge, Bandyopadhyay et al. (2007) is the only study to use a comparison group design to measure the impact of irrigation management transfer. The authors find that irrigation associations with irrigation management transfer show higher frequency of canal maintenance and higher farm productivity, though these findings simply compare post-intervention outcomes for associations with and without management transfer. The World Bank study (IEG 2008; discussed above) presented evidence that water user associations in the Andhra Pradesh region have limited control over the operation and management of irrigation infrastructure, fee collection, and dispute resolution and do not greatly empower the poor through participation or leadership. Wang et al. (2006) show that in China, incentives to water managers are more important than farmer participation in water management for water conservation, which in turn is not found to increase poverty or decrease income. A separate study by Wang et al. (2010) shows that water user associations are becoming more common in China and that the World Bank support of water user associations has been successful in terms of participation, reliable water supply, and fee collection but has provided no clear benefits in terms of yield, income, and cropping structure. Although these studies of irrigation management transfer do not directly relate to the Institutional Strengthening Subactivity, the findings from these studies still highlight the strengths and weaknesses found for water user associations in other settings.

A remaining gap in the literature is a rigorous evaluation of irrigation infrastructure rehabilitation using a randomized-controlled trial. The nonexperimental designs used even in the more rigorous studies in the existing literature as well as the present study cannot ensure that the differences in outcomes for the treatment and comparison groups can be attributed to the intervention because not every factor that determines selection of irrigation projects for rehabilitation can be accurately measured and controlled. Randomized-controlled trials have not been used to evaluate irrigation projects mainly because foreign aid agencies understandably choose to fund the projects that are anticipated to provide the greatest net benefits rather than randomly select projects. Irrigation projects might be selected based on estimated economic rates of return, number of beneficiaries who would be served, or perceived demand for the project. However, considering the frequency and scale of irrigation infrastructure rehabilitation programs, it is our hope that an aid agency will consider using a randomized-controlled trial to rigorously evaluate a future irrigation program, perhaps randomizing among a larger set of irrigation projects that would qualify for funding but cannot all be served within a set budget. Tertiary canal rehabilitation would be an especially suitable choice for evaluation in a randomized-controlled trial because the relatively small size of tertiary canals means many projects are considered under each rehabilitation program, and thus the potential sample size for the randomized-controlled trial is larger.

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II. IMPLEMENTATION OF THE IRRIGATION INFRASTRUCTURE ACTIVITY

In this chapter we discuss implementation of the Irrigation Infrastructure Activity, including deviations from the original designs for the activity and reasons for those changes. We summarize qualitative findings on the perceptions of program implementers and beneficiaries as well. We also recap the implementation of the Water-to-Market Activity components that are revisited in the present evaluation, namely, Institutional Strengthening Subactivity and the Water-to-Market training components, but we refer the reader to the Water-to-Market evaluation (Fortson et al. 2013) for more detail.

A. Implementation of the Infrastructure Activity

The Infrastructure Activity underwent several changes from what was originally planned at the outset of the Compact. First, the agreement between MCA-Armenia and the original implementers, the Irrigation Project Implementation Unit of the World Bank, was terminated in 2006, at which time MCA-Armenia assumed responsibility for implementation. MCA-Armenia awarded 11 contracts to seven contractors through competitive procurements: 4 for tertiary canals, 2 for main canals, 2 for Ararat Valley drainage, 1 for pumping stations, and 2 for gravity schemes.

Two factors significantly affected the activity’s budget and required it to be significantly rescoped in October 2008. First, the Compact was funded in U.S. dollars, which lost value relative to other currencies. Additionally, construction prices were much higher relative to original expectations. Both these factors meant that fewer construction projects could be undertaken than were planned at the outset. Originally, MCA-Armenia envisioned construction work on 588 km of tertiary canals, 198 km of main canals, 13 drainage systems, 68 pumping stations, 18 gravity schemes, and 7 reservoirs. However the rescoped Infrastructure Activity did not include any reservoirs, and the remaining outputs were reduced significantly. Ultimately, MCA-Armenia rehabilitated 220 kilometers of tertiary canals, 43 kilometers of main canals, 13 drainage systems, 17 pumping stations, and 5 gravity schemes (Table II.1).

Table II.1. Comparison of IA targets for rehabilitation and outputs

	Original target (as of 2006)	Revised target (as of 2008)	Output (as of 2011)	Actual cost (millions USD)
Tertiary canals (km)	588	220	220	$14.7
Main canals (km)	198	34	42	$22
Drainage systems (number)	13	13	13	$19
Pumping stations (number)	68	17	17	$43
Gravity schemes (number)	18	7	5	$7.9
Reservoirs (number)	7	0	0	$0

Source: *The Program Is Over: All About Results* (MCA-Armenia 2011).

USD = United States dollars.

The construction or rehabilitation of each of these types of infrastructure contributes to increasing the availability and reliability of irrigation water, but in different ways:[6]

- ***Tertiary canal*** rehabilitation should improve availability of reliable irrigation water sources to farmers that previously did not have reliable irrigation. Crucially, rehabilitation was extended to the lower reaches of the tertiary system rather than concentrating on the top of the primary channel, which should ensure adequate performance all the way to the point of distribution. Small discharge channels were upgraded using polyethylene pipes. More sophisticated and robust control gates were introduced as well. Lastly, some sites that are on steep ground had water flows that were too difficult to control, and in these cases drop boxes and collars were used to slow the water flow and limit water losses. Rehabilitating tertiary canals was expected to increase hectares irrigated and yields per hectare.
- ***Main canal*** rehabilitation should reduce water losses in main canals and improve water distribution in the irrigation system. The concrete lining of canals was replaced in many sections of the canals, sometimes with light steel reinforcement. Geomembranes were also used in some sites to reduce seepage into the adjacent soil. Additionally, cross regulators were introduced to control the canal water levels, replacing ad hoc solutions that farmers had implemented themselves. Finally, higher quality control gates were used, replacing gates that had design flaws such as vulnerable screw shafts, gate skins that are likely to jam, and poor quality seals. Main canals are considered a type of large infrastructure. Like tertiary canals, rehabilitating main canals was expected to increase hectares irrigated and yields per hectare.
- ***Drainage system*** rehabilitation in the Ararat Valley drainage area should increase crop productivity in that region, produce more arable land, and better regulate groundwater levels to reduce waterlogging in affected villages. Previous efforts have cleared main drains, but for the first time in decades, secondary and tertiary drains were cleared as well, a process necessary to maintain a stable, low water table. In many cases, drains were deepened rather than widened, which had been the previous practice. The drainage system is a type of large infrastructure. Rehabilitating the Ararat Valley drainage system was not expected to directly increase irrigated hectares, though it was expected to increase the area available for cultivation.
- ***Pumping stations*** had new, more reliable, and energy-efficient pumps installed. In some cases, the building housing the pumping station was repaired as well. This is considered a type of large infrastructure. Rehabilitating pumping stations was mainly intended to increase yields per hectare, with minimal expected changes in hectares irrigated.
- ***Gravity schemes*** were designed to save electricity and provide stable water supply to benefitting communities. These were implemented in areas where pumping water from its source is energy intensive and, consequently, expensive. The new systems avoid pumping by constructing new canals, creating new pipelines, or making existing canals more efficient. Gravity schemes are considered a type of large infrastructure. Rehabilitating

[6] All expected benefits are based on the rescoped projections. In some cases the assumed benefit streams changed from the original plans, such as putting greater emphasis on increased yields.

gravity schemes was primarily expected to increase hectares irrigated and yields per hectare and to a lesser extent save energy costs.[7]

The first construction contract was awarded in late 2008, and most of the work occurred from 2009 to 2011. All construction work was completed by September 2011.

As part of reassessing which irrigation projects to undertake in the rescoped rehabilitation plans, MCA-Armenia also reconsidered how the irrigation projects were grouped. In particular, the original plans for rehabilitation focused on rehabilitating irrigation projects that were related and considered parts of the same irrigation schemes. Each scheme was assessed for engineering and economic viability as a whole, and if the scheme was to be rehabilitated, all projects within the scheme would be rehabilitated. For example, the original plans for rehabilitating several of the simpler irrigation schemes included a main canal or a reservoir, a few pumping stations associated with the main canal or reservoir, and several tertiary canals linked to those. In rescoping the Infrastructure Activity, MCA-Armenia discarded the approach of grouping projects into schemes and instead assessed the engineering and economic viability of each individual infrastructure project, because their assessment was that the projects were not as closely linked as had first been thought. This approach had the additional benefit of making it easier to rehabilitate infrastructure projects throughout Armenia when the scale of the activity had to be reduced, because they could rehabilitate a subset of each irrigation scheme rather than picking a subset of intact schemes in a smaller set of regions. Although this changed how the projects were selected, it did not greatly change the expected benefits of the projects: the key objectives of increasing irrigated land and yields remained, though the expectation was that irrigated land would not increase by as much because of the reduced scale. (Braxein et al. 2008)

MCA-Armenia staff, local officials, and targeted beneficiaries mostly viewed implementation of the rehabilitation projects favorably. Based on interviews and group discussions, Socioscope (2011) found that the farmers whose lands were served by the irrigation infrastructure improvements considered the rehabilitated works to be higher quality relative to other projects that were previously implemented in the area, a sentiment echoed by community leaders. Community residents also noted many visible, immediate improvements, including reduced flooding, orchards becoming livelier, expanded irrigation areas, more people using irrigation, smoother water management with reduced conflicts between and within communities, and decreases in the incidence of water theft or damage to the infrastructure in attempts to extract water illicitly.

At the same time, beneficiaries were not always aware of the construction projects being undertaken or exactly what was being done and by whom because even if the work would ultimately benefit them, the construction site may have been far away. This lack of awareness contributed to some disappointment in the project’s progress. Beneficiaries were also sometimes disappointed that the rehabilitation efforts did not include more infrastructure than was implemented, particularly given the original, more extensive goals of the Compact (Socioscope 2011).

[7] The projected energy savings benefits varied across gravity schemes, but in all cases was 10 percent of the total projected benefits or less.

The beneficiaries' assessment that the rehabilitation work was of high quality corroborated the perceptions of construction firm representatives and MCA-Armenia staff, who reported that a commitment to high quality construction was a defining characteristic of the Infrastructure Activity. Construction was closely supervised both by an official supervisor and by MCA-Armenia staff to comply with international standards; when anything failed to meet standards, it was torn down and rebuilt. Strict sanctions were enforced to ensure compliance with environmental, social, and safety regulations specified under the construction contracts. Construction companies also appreciated that they learned these new standards and, more broadly, gained technical knowledge that could be applied to future construction work (Socioscope 2011).

B. Implementation of the Institutional Strengthening Subactivity

The Institutional Strengthening Subactivity was implemented by a partnership between Mott MacDonald and VISTAA. In implementing the Institutional Strengthening Subactivity, Mott MacDonald and VISTAA staff first completed a needs assessment with all 44 water user associations served by the Institutional Strengthening Subactivity. The commonly cited needs were (1) better collection of irrigation and membership fees and (2) computer software. In response, VISTAA and water user association staff composed management improvement plans to serve as the basis for each water user association's strengthening efforts. The management improvement plan outlined each water user association's strengths and weaknesses and listed concrete milestones to be completed to achieve technical, managerial, and financial self-sustainability. With consultants' help, management improvement plans were further distilled into detailed action plans. These plans prioritized the 12 most important follow-up issues identified by management improvement plans. Beginning in late 2008, VISTAA technical consultations were structured around water user associations' efforts to meet management improvement plan milestones.

A few months after implementation began, MCC, VISTAA, and MCA staff agreed that incentive-based rewards were necessary to motivate water user associations to complete key management improvement plan milestones. For this reason, they implemented a rewards system by which water user associations received a standard equipment package and GIS software upon successful completion of the first five program milestones in the management improvement plan that included establishing a management improvement plan working group and a detailed work plan, installing information boards, and holding representative meetings. Water user associations received an extended package (donations of equipment, including heavy machinery) upon completion of milestones 6 through 9, which included making payments to water supply agencies, improving membership fee collection rates, forming a working dispute resolution committee,[8] and improving service fee collection.[9]

[8] Established by Armenian law in 2002, the primary role of dispute resolution committees is to settle disputes that emerge among WUA members regarding water use and irrigation water distribution. Dispute resolution committees' decisions do not demand compliance, and WUA members can pursue grievances in court if they are not satisfied with dispute resolution committee decisions or if those decisions have not been honored by all parties.

[9] Milestone 8, which largely dealt with establishment of a dispute resolution committee, was eventually excluded from requirements for the extended package because of a lack of a legal precedent for such committees during the initial implementation period. Widespread obstacles to initiating such committees' operations—namely, a lack of

As shown in Table II.2, the Institutional Strengthening Subactivity met all major implementation targets. Consultants and water user association staff completed MIPs for all 44 water user associations that were functioning in Armenia at the time. All 44 water user associations completed the first five milestones, and 40 water user associations completed milestones 6 through 9. In exchange for meeting key milestones, all water user associations received computers, GIS software, furniture, and welding equipment. In addition, most water user associations received backhoe loaders, and a subset of water user associations received evapotranspiration gauges, used to measure crops' water absorption.

In another development related to the Institutional Strengthening Subactivity outputs, national irrigation policy and strategy documents were developed by Mott MacDonald and AVAG Solutions. Technical and material assistance was provided to three water supply agencies as well. Both of these components and the quality of their implementation are discussed in more depth in the Water-to-Market evaluation report (Fortson et al. 2013).

Table II.2. Comparison of the Institutional Strengthening Subactivity targets and outputs

	Target	Output
Technical consultations provided	452	452
Needs assessments completed	47[b]	47[b]
Management improvement plans completed with WUAs	44	44
Computers with budgeting and accounting software donated to WUAs and WSAs	NA	180
Geographic information systems improved or provided	47[a]	47[a]
WUAs and WSAs that received equipment and furniture	47[a]	47[a]

Source: *The Program Is Over: All About Results* (MCA-Armenia 2011).

ISSA = Institutional Strengthening Subactivity; WUA = water user association; WSA = water supply agencies.

C. Implementation of Water-to-Market training

All training was implemented by ACDI/VOCA and its partners, VISTAA and Euroconsult, which we refer to collectively as ACDI. Training topics were organized and presented to farmers in two parts: on-farm water management training and high-value agriculture training. Both types of training were targeted to members of water user associations, the regional organizations that manage the distribution of and payment for irrigation water. On-farm water management training covered region-specific water management practices and technologies to conserve water. High-value agriculture training focused on growing new crops or on ways to cultivate higher-value crop varieties by using higher-quality seeds, establishing greenhouses, or other methods. High-value agriculture practices can be divided into industrial-economical improvements, which emphasize increases in farmers' own production or profits, and social-environmental improvements, which promote safe and environmentally friendly practices.

transportation or vouchers for committee members—also influenced implementers' decision to not require this milestone for the extended donation package.

The initial implementation targets were to train 60,000 farmers in on-farm water management and then train half of them in high-value agriculture as well. When the complementarities from offering both trainings became apparent (and the devaluation of the dollar relative to the Armenian dram caused a reassessment of program resources), the on-farm water management target was lowered to 45,000 to allow the high-value agriculture target to be raised to 36,000, targets that were ultimately met (Table II.3). This revision happened separately from the rescoping of the Infrastructure Activity. A typical training session included 20 to 25 farmers from one or more neighboring communities and was led by a local agricultural expert or irrigation engineer.

Table II.3. Comparison of Water-to-Market training targets and outputs

	Original Target	Revised Target	Output
Farmers trained in on-farm water management	60,000	45,000	45,639
Farmers trained in high-value agriculture processes	30,000	36,000	36,070

Source: *The Program Is Over: All About Results* (MCA-Armenia 2011).

A key theme in implementing training was tailoring sessions to the climatic and agricultural conditions of the region. Each session was led by an agricultural expert from the same region, and the content of the training was customized to each region. Participants were all from the same region, so concerns and experiences were based on a shared context. The training also supplemented three to four days of theoretical lessons in classrooms with practical lessons at a nearby demonstration farm. Each demonstration farm was carefully selected to serve one to five communities, and farmers who received training were encouraged to revisit the demonstration farms after the official training to see on-farm water management and high-value agriculture practices in use. ACDI also operated tours of the demonstration farms for trained farmers during key months of the agricultural season. A primary factor in designating demonstration farms was whether the farmer was willing to set up and operate a demonstration farm and to promote other farmers' understanding of the demonstrated technologies. In return for farmers' willingness to operate a demonstration farm, ACDI provided the farmer with the needed equipment. Other selection criteria included the site's proximity to other farms in the community, topography, and soil characteristics. Findings from Socioscope (2011) and other qualitative data from stakeholders are presented in the Water-to-Market evaluation report.

III. EVALUATION OF REHABILITATED TERTIARY CANALS

This chapter describes our empirical approach for evaluating MCC's rehabilitation of tertiary canals in Armenia and the findings. As discussed in Chapter II, tertiary canals route irrigation water from larger infrastructure such as main canals or reservoirs to the farmers' land.

More than one hundred communities throughout Armenia were initially selected to have their tertiary canals rehabilitated. MCA-Armenia provided most of the financing for the rehabilitated canals, but villages were responsible for paying a small portion (15 percent) of the rehabilitation costs; if they were unable to contribute the co-funding amount, the canal would not be rehabilitated. This co-funding arrangement was designed in large part so that villages would feel ownership over the canals and would be more likely to maintain them over the longer term. In total, 220 kilometers of tertiary canals were rehabilitated at a cost of $15.9 million, affecting about 100 communities. These communities were distributed throughout the 10 marzes in Armenia excluding Yerevan, the national capital.[10]

The core of our evaluation approach is to compare outcomes in the communities for which tertiary canals were rehabilitated to outcomes in communities that were otherwise similar, except their canals were not rehabilitated. We used a two-stage process to identify those comparison communities. In the first stage, we enlisted agricultural experts and water user association directors to help us identify communities that were prospective candidates for the comparison group. In the second stage, we used statistical matching to further refine the comparison group.

The remainder of this chapter is structured as follows. Section III.A describes the research questions and data used in the evaluation. Section III.B presents the sampling approach, including details on how the preliminary set of comparison communities was identified, and Section III.C presents our evaluation design, including details on the refinement of the comparison group.

A. Research questions and data

The primary research questions, key outcome measures of interest, and main data sources for the evaluation of tertiary canals are presented in Table III.1. These research questions pertain to the potential intermediate and long-term impacts that were identified in the program logic for the Infrastructure Activity (Section I.B).

Our primary data source is the Tertiary Canal Survey, a detailed household-level longitudinal survey designed specifically for the evaluation that asks farmers about their demographics, use of irrigation, irrigation practices, crop cultivation, crop production, crop sales, nonagricultural income, and household expenditures. The Tertiary Canal Survey is modeled closely on the household survey used in the evaluation of the Water-to-Market Activity, the Farming Practices Survey (FPS) and was fielded by the same survey team led by AREG.

[10] A marz is a regional division similar in size and administrative function to a U.S. county.

Table III.1. Primary research questions and key outcome measures

Research Question	Key Outcome Measures	Main Data Sources
Did the program affect the quantity and reliability of irrigation water provided to Armenian farmers?	Hours of irrigation; reliability of irrigation; land irrigated; sources of irrigation	Tertiary Canal Survey; Village Mayor Survey
Did farmers adopt new agricultural practices as a result of the program?	Adoption rates of agricultural practices	Tertiary Canal Survey
Did the program affect agricultural productivity?	Crop cultivation and production; value of crops harvested; revenues from crops sold; agricultural profit	Tertiary Canal Survey; Village Mayor Survey
Did the program improve household well-being for farmers served by those canals, especially income and poverty?	Total income; poverty status; consumption	Tertiary Canal Survey; Village Mayor Survey

AREG conducted two rounds of the Tertiary Canal Survey in communities where tertiary canals were rehabilitated and in similar communities identified by agricultural experts as prospective comparison communities, as described in more detail in Chapter III.B. The baseline Tertiary Canal Survey was fielded from December 2009 to March 2010. The final round was fielded from December 2013 to March 2014 and attempted to interview the same households who responded to the baseline survey. Thus, the follow-up data were collected four years (and four agricultural seasons) after the baseline data were collected (2009–2010) and at least two years after irrigation infrastructure rehabilitation was completed (2011).

In addition, the Village Mayor Survey is a repeated survey of village mayors that is intended to provide contextual information for Tertiary Canal Survey respondents. The Village Mayor Survey gathered information on population size and total land in the village; other rehabilitation projects that were implemented in the villages that could influence any observed impacts; and whether any major events, such as droughts or heavy rains, had occurred that affected agricultural production. This survey was fielded during the same periods as the Tertiary Canal Survey.

We report estimated impacts for many outcome measures across a range of topical domains, which means we are likely to see some estimated impacts that are statistically significant by chance. For example, if the program has no true impact on any outcome, then we would expect to see about 5 percent of the estimates would be statistically significant at the 5 percent level because of sampling variability. This is known as the multiple comparisons problem. To account for this issue, we discuss not only whether individual estimates are statistically significant but also whether they are part of a broader pattern of effects that we would expect if there were a true program impact.[11]

[11] Researchers sometimes will explicitly adjust statistical tests to account for the increased likelihood that a subset of estimates will be statistically significant by chance when testing many outcomes. However, doing so increases the likelihood that we overlook interesting findings because they do not meet this higher threshold of significance. It is also difficult to properly account for the correlation across different tests when making these adjustments. Hence, we present significance levels that are not adjusted for multiple comparisons and instead address each significant finding in the context of other related estimates.

B. Sampling approach

Most of the canals that were initially selected for rehabilitation were included in the present evaluation, and the communities served by those canals form the treatment group. Four were pilot canals that were not considered for the evaluation because they were rehabilitated well before the other canals and pre-rehabilitation survey data could not be collected. Others were eventually excluded from the evaluation because the community did not contribute the requisite co-funding, so the canal was not rehabilitated.

The sample frame for the evaluation comprises the farming households served by the rehabilitated tertiary canals and farming households in communities that were selected to be similar on a set of criteria listed below.[12] To construct the set of potential comparison communities, MCA staff who were knowledgeable about the agricultural conditions in Armenia worked with water user association directors to identify suitable potential comparison communities for each treatment community. The Tertiary Canal Survey and Village Mayor Survey were then fielded in both the tertiary canal communities and these potential comparison communities. The potential comparison communities were selected with a focus on the following three criteria prior to any irrigation rehabilitation:

1. **Geography and water management.** Potential comparison communities were required to be in the same geographic areas and served by the same water users associations as the treatment communities. These factors aimed to identify communities that would face similar agricultural conditions as the treatment community.
2. **Condition of irrigation infrastructure.** WUA directors and MCA staff aimed to identify potential comparison communities with tertiary canals of similar functionality. This was a subjective, qualitative assessment that took into consideration factors such as water losses and sources of irrigation water. The comparison communities were not screened on whether other types of irrigation rehabilitation were expected to occur, either by farmers or through outside funders. This is reflective of the comparison condition being "business as usual" and the comparison group behaving as if the Infrastructure Activity did not exist.
3. **Crop cultivation.** Because crop cultivation relates to agricultural production, which influences household income, potential comparison communities were required to cultivate a portfolio of crops similar to the treatment communities'.

These potential comparison communities were then refined using statistical matching methods, as described in the next section, to ensure that the comparison group was similar to the treatment group on observable pre-intervention characteristics. Along with the above characteristics, the statistical matching focused on balancing pre-intervention measures taken from the baseline survey, such as household income.

[12] Matched comparison groups are often chosen using statistical methods that would identify, for each treatment unit, as close a match as possible on the characteristics that could affect the outcomes of interest. However, no existing data were available with detailed information about crop production, irrigation sources, and other baseline characteristics for all of the individuals and communities in the regions where irrigation projects were planned as well as all individuals and communities that could serve as potential comparison communities. Consequently, a matched comparison group could not be constructed before the Tertiary Canal Survey was administered.

Once the tertiary treatment and potential comparison communities were identified, the survey team contacted each village mayor to complete the baseline Village Mayor Survey. The Village Mayor Survey was only administered to village mayors, though their staff often helped find records to answer some questions. In treatment communities, the survey team then worked with village mayors to identify the farmers served by each tertiary canal and to arrange interviews for the baseline Tertiary Canal Survey with a subset of the identified farmers. The survey team requested farmers served by each tertiary canal because some communities have more than one canal, and the rehabilitated canal might serve only a portion of farmers in the village. In most treatment communities, 15 farmers were sampled to participate in the baseline Tertiary Canal Survey, with rare deviations if a sampled farmer did not report for the survey. In communities that would not have their tertiary canals rehabilitated, the survey team attempted to identify farmers who were served by the nonrehabilitated tertiary canals, grew similar crops, and had similar land sizes as the farmers in the treatment group. Twenty farmers were interviewed for the Tertiary Canal Survey in each comparison community. Overall, all but one village mayor completed the baseline Village Mayor Survey, and 2,997 farmers were interviewed across 175 communities for the baseline Tertiary Canal Survey.

The survey team attempted to conduct follow-up surveys with all village mayors and households who completed the baseline survey, except for two communities (one treatment and one comparison) that were avoided because of gunfire from across the Armenian border with Azerbaijan. Of the 173 communities that remained, 97 are in the tertiary canal treatment group and 76 are potential comparison communities. Nine additional communities that were in the tertiary canal treatment group are excluded from the tertiary canal evaluation because their canals were ultimately not rehabilitated, as described previously, but we collected follow-up data in those communities for use in the large infrastructure evaluation. Including these nine communities, the sample is approximately evenly split, with about 1,500 farmers in each group. In the 173 communities in which interviews were attempted, all of the mayors and 83 percent of the farmers were successfully reinterviewed for the follow-up Village Mayor Survey and Tertiary Canal Survey, respectively.

C. Evaluation design

The tertiary canal and potential comparison communities differed in measurable ways before any infrastructure was rehabilitated, even though the potential comparison communities had been identified for the Tertiary Canal Survey based on the criteria in Section III.B (Fortson et al. 2010). These baseline differences suggest that the treatment and potential comparison communities would have had different outcomes without the intervention. To address these differences, we used statistical methods to identify a smaller set of comparison communities that were similar to the treatment communities on a range of baseline characteristics measured in the Tertiary Canal Survey. Next, with this smaller analytic sample, we estimated impacts with regression adjustment to compare how outcomes of the treatment and matched comparison communities changed relative to the same outcomes measured before the rehabilitation. The baseline Tertiary Canal Survey and Village Mayor Survey thus provided crucial data on key outcome measures prior to the intervention. In this chapter, we describe how these statistical adjustments were implemented.[13] We also conducted several sensitivity analyses that are reported in Appendix A in which we used alternative statistical adjustments, including applying propensity score weights, using regression adjustment without restricting to the common support, and different definitions of the common support. The main findings are substantively similar to those in our main specification. Appendix A also contains additional information about our analyses, such as survey response rates, baseline means for the analytic sample, and *ex ante* and *ex post* minimum detectable impacts.

Identifying matched comparison communities

We applied propensity score methods to the treatment communities and the potential comparison communities that were identified by agricultural experts. The key concept underlying propensity score methods is to construct the comparison group for the tertiary canal impact analysis to look similar on observable characteristics to the treatment group. A propensity score is the probability that a community received the tertiary canal infrastructure improvement. We estimated these probabilities using household and community-level variables, including variables where the treatment and comparison groups were not similar at baseline.

We calculated and applied propensity score methods with regression adjustment through the following process:

1. **Identified characteristics to calculate propensity scores.** Because whole communities are selected for the intervention, the propensity score model utilized community-level variables. Our approach was to include all community-level characteristics that could influence agricultural production. We used Village Mayor Survey and aggregated Tertiary Canal Survey data to construct geographic indicators and measures of community size, household characteristics, land owned or rented, land irrigated by network irrigation water, household income, agricultural production, and indicators for other types of irrigation infrastructure that were rehabilitated.[14]

[13] We applied this same general process for the evaluation of rehabilitated large infrastructure (Chapter IV). The analytic samples in the evaluations of rehabilitated tertiary canals and rehabilitated large infrastructure are similar (Tables A.1, A.5)

[14] The following community-level variables were used from the Village Mayor Survey: marz indicators; number of households in the village; number of available livestock; percentage of households that farm as their main occupation; hectares of total land cultivated, total land irrigated by network water, arable land, arable land irrigated by network water, orchard land, vineyard land, kitchen plot land, and kitchen plot land irrigated by network water; whether the community received enough water when needed; and indicators for other types of infrastructure aside from tertiary canals that were rehabilitated. We constructed community-level averages based on the following household-level measures in the Tertiary Canal Survey: head of household's age, sex, and education; number of people in the household and number of children in the household; WUA membership; tank ownership and pump ownership; receipt of training through the WtM program; farm expenditures, nonagricultural income, and total value of agricultural production; poverty status; and perception of the condition of the irrigation system. This model does not account for whether communities applied for canal rehabilitation, as the TCS only included one comparison community that applied for rehabilitation but did not ultimately receive it. This community was ultimately excluded from the analysis of tertiary canals because it did not meet the other criteria to be in the common support.

2. **Estimated a logistic regression relating treatment status to baseline characteristics.** We used a logistic regression to estimate a model with the variables from step 1 as the independent variables and a binary indicator variable for treatment status as the dependent variable.

3. **Predicted propensity scores using the logistic regression.** Using the estimated logistic regression in step 2, we then estimated the propensity score p_c for each community as the predicted value based on the estimated model parameters and the community's baseline variables.

4. **Created the analytic sample of treatment and comparison communities.** To assess the similarity of the treatment and potential comparison communities, we compared the distributions of their estimated propensity scores. We excluded from the analysis communities with estimated propensity scores that are off the shared "common support" of the treatment and comparison groups—that is, treatment communities that are unlike any comparison group community and comparison communities that are unlike any treatment community. We defined the common support as consisting of the propensity scores that were higher than or equal to the minimum propensity score in the treatment group but lower than or equal to the maximum propensity score in the comparison group. This resulted in an analytic sample containing 117 communities (63 treatment, 54 comparison), out of 173 communities that were initially selected for the Tertiary Canal Survey.

Once we restricted the analytic sample to the common support, we assessed whether there were statistically or substantively significant baseline differences between the treatment and comparison groups on demographic characteristics, key outcome measures at baseline, and other key determinants of household well-being. The full set of characteristics on which we assessed balance is provided in Appendix Table A.2. The key outcomes included agricultural practices, land holdings, agricultural expenditures, crop cultivation, crop sales, market value of crop harvests, household income, and poverty rates. Other determinants of household well-being that we examined included the perceived condition of the irrigation system, geographic location of the community, rehabilitation of irrigation infrastructure other than tertiary canals, and participation in the Water-to-Market evaluation. We found no statistically significant differences at a significance level of 10 percent, and few measures had statistically significant differences at a significance level of 20 percent. In terms of magnitude, no baseline differences were larger than 0.25 standard deviations.

Researchers commonly use the estimated propensity score to further adjust for baseline differences between the treatment and comparison groups (Imbens and Wooldridge 2009), and indeed, our research protocol planned to use inverse probability weighting based on the estimated propensity score. Theoretically, combining inverse probability weighting on the propensity score with regression adjustment would lead the estimates to be robust to either misspecification in the propensity score or misspecification in the regression model. Consequently, this method is sometimes referred to as being "doubly robust" (Schafer and Kang 2008).

However, we deviated from the research protocol and instead used regression adjustment alone after restricting the analysis sample to the communities sharing the common support of the estimated propensity score distribution. We found that the propensity score weights were highly variable, which made statistical inference uninformative.[15] At the same time, the treatment and comparison communities that shared the common support were already well balanced on baseline characteristics and baseline averages for the outcome measures, so there was little need to further adjust with weighting. The estimates for our chosen approach were more statistically precise, but as shown in the sensitivity analyses in Appendix B, the estimated values were similar when we instead used inverse probability weighting.

Measuring impacts

As an additional means of adjusting for preexisting differences and increase precision of the estimates, we used the basic regression model:

$$(\text{III.1}) \quad y_{iv,F} = \beta' x_{iv,B} + \gamma T_v + \eta_v + \varepsilon_{iv},$$

where $y_{iv,F}$ is the outcome of interest for household i in village v at the follow-up survey, $x_{iv,B}$ is a vector of baseline characteristics including indicators for whether the household is in a community where other types of infrastructure were rehabilitated, T_v is an indicator equal to one if village v is in the treatment group and zero if it is in the comparison group, η_v is a village-specific error term, and ε_{iv} is a random error term for the household. The parameter estimate for γ is the estimated impact of the program.

The regression models must also account for the fact that because farmers served by the same canal are exposed to the same effects of weather and other idiosyncratic shocks, their outcomes will be correlated and cannot be considered statistically independent. This "clustering" of farmers is reflected in the village-specific error term η_v.

In Equation (III.1), we did not adjust for household nonresponse because response rates were high and similar in the treatment and comparison groups (83.4 and 82.4 percent, respectively) and have similar patterns across regions (Appendix A). We also do not apply sampling weights in the analysis because the sample of rehabilitated tertiary canals for the evaluation was selected purposively by MCC and is not representative of a larger population of canals.

Given Equation (III.1), we additionally prevented impact estimates from being unduly influenced by outliers in the data by top-coding continuous variables in the Tertiary Canal Survey at the 98th percentile. Some continuous variables in the Tertiary Canal Survey with

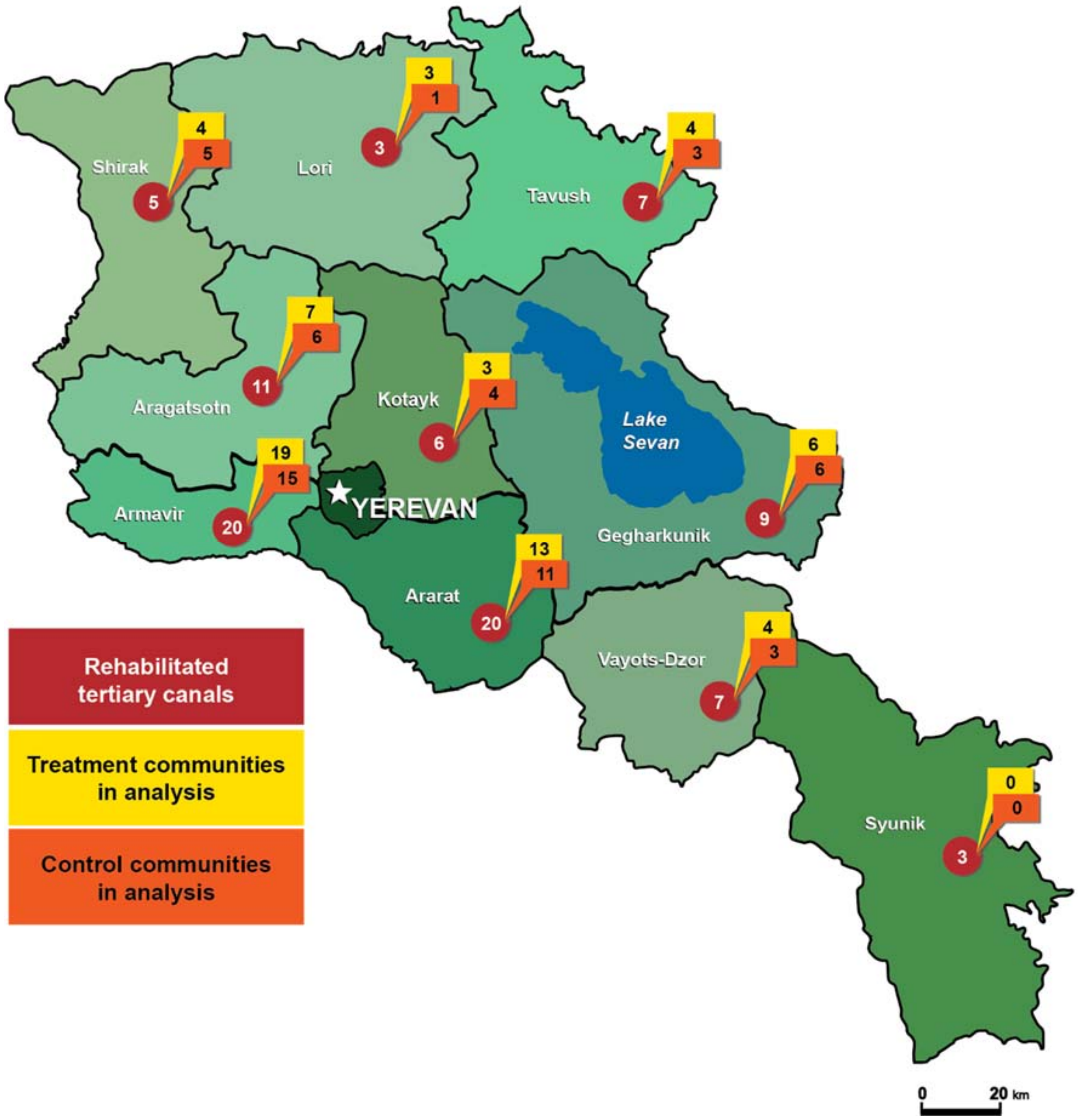
[15] Our process for generating impact estimates with inverse probability weighting used "bootstrapping" to obtain the standard errors of the impact estimates. Bootstrapping here involved, for each outcome, taking many iterations of selecting a number of communities from the analytic sample, then estimating a propensity score model to derive the common support, and finally calculating an impact estimate with that set of communities. Bootstrapping allowed us to measure how much noise is in the propensity score weights, which are estimates themselves. The standard deviation of the impacts from each bootstrap sample represents the impact estimate's standard error. When we bootstrapped, we found that some distributions of impacts had very large outliers, leading to implausibly large standard errors. For instance, the impact estimate on nonagricultural income had a standard error that was more than 10 times as large, and the impact estimates nonplausibly ranged from less than -$400,000 to greater than $300,000. This was due to chance exclusions of certain communities in a sample or a particularly skewed distribution of propensity scores in a sample—particularly low propensity scores could lead to very large weights for a single community in a sample.

negative values were also bottom-censored at the second percentile (see Appendix A). Each continuous covariate and continuous outcome measure was censored in this way separately, within the analytic sample generating a particular impact estimate. Following the censoring procedures in the Tertiary Canal Survey, we addressed item nonresponse by imputing missing values of variables, usually with a community-level average or a prediction from a relevant baseline measure (see Appendix A), though item nonresponse was very low. These data processing decisions were carried through the entire modeling and estimation process. We did not top- or bottom-code variables from the Village Mayor Survey because the Village Mayor Survey did not have as much variation in the continuous variables. Item nonresponse was also much more limited in the Village Mayor Survey than in the Tertiary Canal Survey, which contains many more questions.

D. Description of analytic sample

Our analytic sample is composed of households in communities that are distributed throughout Armenia except for Yerevan and the Syunik marz (Figure III.1). Yerevan is the nation's capital. Ararat and Armavir marzes each contained 20 rehabilitated tertiary canals and thus contribute the highest number of communities to our analytic sample.

Figure III.1. Distribution of tertiary canals that were selected for rehabilitation, by marz



Source: Millennium Challenge Corporation program data.

Our longitudinal data included information on 1,802 households (by coincidence rather than by design, there are 901 households in both the treatment and comparison groups) with the demographic characteristics shown in Table III.2. At follow-up, the heads of household in the treatment group were about 56 years old, and 89 percent of them were male. Only 10 percent of the heads of household have not completed secondary school, compared to 21 percent of heads of household who had more education than secondary school.

Table III.2. Household characteristics of the analytic sample for the evaluation of rehabilitated tertiary canals (percentages except where indicated)

	Mean
Head of household's age (years)	56
Female-headed household	11
Head of household's education	
Less than secondary	10
Full secondary	43
Secondary vocational	27
More than secondary	21
Number of people in household	5.0
Number of children in household	1.1
Number of households	1,802
Number of communities (Treatment, Comparison)	**117 (63, 54)**

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Because our regression adjustment accounts for differences in these characteristics, the treatment and comparison groups have the same regression-adjusted characteristics. Demographic characteristics are measured at follow-up.

To provide context, we also explored what other irrigation rehabilitation projects had been implemented in these communities, particularly in the comparison group communities. This is important because the estimated impacts of the tertiary canals are relative to the experiences of the comparison communities. If, for example, another foreign aid donor made significant irrigation investments in the comparison communities, that would affect how we interpret our findings. To explore this, we first conducted online searches to see what irrigation investments were made in Armenia by the World Bank, USAID, the Asian Development Bank, and others. We found several projects, but only two of these projects could have affected the communities in our sample during the time frame covered by the study. Both projects were funded by the World Bank and designed to supplement MCC's rehabilitation efforts. Based on the World Bank's documentation online, we found that only one of the comparison communities in our analytic sample for tertiary canals was included in these projects.

We also measured the conditions in the comparison group by asking households and village mayors about repair and rehabilitation of irrigation infrastructure in their communities to corroborate our online searches. We asked the households in each community whether they were aware of any efforts to rehabilitate the irrigation infrastructure in their communities, who had performed the rehabilitation, and what the households' perceptions were of the condition of the irrigation infrastructure. We also asked farmers about their perceptions of irrigation rehabilitation to learn whether farmers in the treatment group knew about the rehabilitation and could have changed behaviors accordingly. We asked the village mayors in each community more detailed questions about irrigation infrastructure projects because they were believed to have a better knowledge of large projects. We also asked village mayors whether there had been any natural disasters that could influence the agricultural production of the communities.

Most of the farmers in the treatment communities reported awareness that repairs or rehabilitation had occurred in the past five years and their irrigation infrastructure had been rehabilitated by MCA-Armenia (Table III.3). About 9 percent of the farmers in the treatment group, however, believed that the rehabilitation had been by completed the rural community, community council, or water user association. These responses might be referring to routine maintenance to irrigation infrastructure or misconceptions by the farmer about the implementer. Eight percent of the treatment group was unaware of or forgot about the tertiary canal rehabilitation.

In the comparison group, more than one-third of households reported that their community had some type of recent repair or rehabilitation to their infrastructure. The most common sources of these repairs or rehabilitation efforts were the rural community or community council (5 percent) and the water user association (16 percent). These entities are typically responsible for routine maintenance; there is otherwise no evidence of significant outside investments in the comparison communities.

Table III.3. Farmer knowledge of rehabilitation of irrigation infrastructure in past 5 years (percentages)

	Treatment Group Mean	Comparison Group Mean	Difference	*p*-value
No repair or rehabilitation	8	56	-49***	0.00
Any repair or rehabilitation	79	36	43***	0.00
Rehabilitated by farmers	0	1	-1	0.19
Rehabilitated by rural community or community council	2	5	-2	0.27
Rehabilitated by WUA	7	16	-9**	0.02
Rehabilitated by government	2	3	-1	0.50
Rehabilitated by MCA-Armenia	73	8	64***	0.00
Rehabilitated by World Bank	0	4	-3*	0.07
Rehabilitated by other	0	0	0	1.00
Sample size	901	901		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

WUA = water users association.

We also examined whether farmers in the treatment group perceived their irrigation systems to be in better condition at follow-up than farmers in the comparison group did (Table III.4). The farmers were asked to assess the condition of the irrigation system in their community on a 5-item scale, ranging from “very bad” to “very good.” Farmers in the treatment group were more likely to report the condition of the system to be good or very good (27 percent) than were farmers in the comparison group (14 percent). This difference was statistically significant and provides additional support that the comparison group did not experience large improvements to their irrigation infrastructure as well as evidence that the rehabilitation made meaningful improvements for the treatment group.

Farmers who did not report their irrigation system condition to be good or very good were asked to indicate the top three problems contributing to the subpar condition of the system. The unconditional percentages for their responses are shown in Table III.4; that is, it shows the percentage of the full sample that said that the irrigation system was not good or very good and also reported the specified problem. The three most commonly cited problems were the bad condition of the tertiary canals, the bad condition of the main canals, and the lack of tertiary canals. Farmers in the comparison group were nearly 12 percent more likely than farmers in the treatment group to point to the bad condition of main canals as a primary problem with the irrigation system ($p < 0.05$). Farmers in the comparison group were also about 13 percent more likely to describe a lack of tertiary canals as a primary problem ($p < 0.05$).

Table III.4. Farmers' perception of main irrigation problems (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Evaluated condition of irrigation system as "very good" or "good"	27	14	13***	0.01
Main problems in irrigation systems that were not in "very good" or "good" condition				
Bad condition of main canals	29	42	-12**	0.04
Lack of tertiary canals	30	43	-13**	0.01
Bad condition of tertiary canals	39	44	-5	0.36
Bad condition of pump for deep well	1	3	-2	0.16
Bad condition of artesian well	4	5	-1	0.64
Bad condition of irrigation pump	3	9	-6**	0.04
No clear water supply schedule	15	11	4	0.17
Disorganized water supplier	14	8	6*	0.05
No water supply at all	3	7	-4	0.17
High prices for water	1	3	-2*	0.08
Other	1	1	0	0.98
Don't see any serious problem	2	1	1	0.33
Sample size	899	899		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. All reported percentages are unconditional.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

To examine impacts with the Village Mayor Survey data, we merged the village mayors' responses with the household data, so the percentages and sample sizes we show are at the household level. We asked mayors of households a series of questions about recent irrigation system rehabilitation projects. The main goal was to learn about the experiences of the comparison communities, since we only have implementation data for the MCA-funded rehabilitation projects in the treatment communities. We asked these questions to mayors in both the treatment and comparison groups so that we could examine a measure that was gathered consistently for all of the mayors.

Most of the households in the treatment communities had a mayor who reported that there had been at least one irrigation system rehabilitation project since 2009, with nearly 81 percent of households indicating that there had been tertiary canal rehabilitation (Table III.5). About 6 percent of the households in the treatment group, however, had mayors who believed there had been no rehabilitation at all. Most village mayors in the treatment group reported that MCA-Armenia funded the rehabilitation projects along with the community itself. Other sources of funding that were reported included the World Bank (8 percent) and the water user association (7 percent), which suggest there might have been routine maintenance, misinformation, or smaller scale additional projects. Overall, 94 percent of village mayors reported that their communities had co-funded an irrigation rehabilitation project. Conditional on reporting a co-funding arrangement, mayors indicated that their communities provided 18 percent of the funding, which is consistent with the conditions set forth by MCA-Armenia for rehabilitation that the communities must contribute 15 percent of the construction costs or otherwise the tertiary canal will not be rehabilitated.

In the comparison group, only 48 percent of households lived in communities whose village mayors reported that their community had some type of irrigation system rehabilitation project, though nearly 27 percent reported that a tertiary canal had been rehabilitated. These results reaffirm that communities in the comparison group had some types of infrastructure maintenance or rehabilitation, but communities in the treatment group were far more likely to have had any kind of project. This difference was statistically significant. Mayors from the comparison group reported a variety of funding sources, including the community (8 percent), MCA-Armenia (12 percent), and the Republic of Armenia (9 percent). Conditional on co-funding, comparison group mayors indicated that their communities contributed a higher percentage of co-funding (63 percent) compared to the percentage reported by mayors from the treatment communities.

Table III.5. Households with infrastructure reported by village mayors to have been rehabilitated since 2009 (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Irrigation system rehabilitation project implemented since 2009	94	48	46***	0.00
Reported rehabilitation of...				
Tertiary canal(s)	81	27	55***	0.00
Main canal(s)	17	13	4	0.45
Pumping station(s)	1	9	-8**	0.03
Other	6	4	2	0.64
None	6	52	-46***	0.00
Project(s) reported to have been funded by…				
Community only	2	8	-5	0.18
WUA	7	5	1	0.75
World Bank	8	6	2	0.70
MCA-Armenia	84	12	73***	0.00
USAID	0	0	0	.
RA Government	1	9	-8**	0.04
Other	8	12	-4	0.44
Unsure of source	0	0	0	.
None	6	52	-46***	0.00
Community co-funded rehabilitation	93	44	49***	0.00
Percentage contributed by community, conditional on community co-funding	18	63	-45***	0.00
Sample size	901	901		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys linked to 2013–2014 Village Mayor Survey.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. Respondents could indicate multiple funders, so the percentages of responses for funders do not sum to 100 percent.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

WUA = water user association; RA = Republic of Armenia USAID = United States Agency for International Development.

A notable difference between the treatment and comparison villages is that the village mayors in the comparison communities reported higher incidence of natural disasters that seriously affected harvesting in the past agricultural season, particularly drought (25 percent) and hail or other downfall (56 percent), despite the treatment and comparison communities being matched on region. Village mayors in the treatment group reported substantially lower incidence of these natural disasters (13 and 44 percent, respectively). These differences could signify that the comparison group had bad weather and thus had worse harvests than the true counterfactual for the treatment group. This would lead to the estimated impacts being overstated. Alternatively, the rehabilitation of tertiary canals under the Infrastructure Activity might have mitigated the effects of droughts and hail or other downfall on treatment communities, keeping these natural disasters from seriously impacting the harvest in the past agricultural season.[16]

Table III.6. Natural disasters reported by village mayors as seriously affecting harvests during the past agricultural season (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Natural disasters that seriously affected harvests during the past agricultural season				
Flood	2	0	2	0.32
Drought	13	25	-12*	0.05
Hail/other downfall	44	56	-11	0.13
Frostbite/freeze	19	21	-2	0.79
Other	4	7	-3	0.37
None	36	14	23***	0.00
Sample size	901	901		

Sources: 2009–2010 and 2013–2014 Village Mayor Surveys linked to 2013-2014 Village Mayor Survey.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

E. Impacts of rehabilitated tertiary canals on water use

We would expect an impact on households' income only if we observe that a substantial proportion of the targeted farmers actually had improved irrigation (Section III.E), adopted different agricultural practices (Section III.F), and/or improved their agricultural productivity (Section III.G). This section discusses whether the short-term objectives of increasing the availability and reliability of irrigation water were met. The survey data allow us to examine detailed measures of farmers' water use for the survey sample, including water from different sources and water used for different types of land. In Section VII, we examine aggregated data

[16] We could not find detailed data on precipitation for the analysis sample during the study period. However, national annual precipitation did not appear to vary widely from 2009 through 2014. Annual precipitation in this period was centered around average levels from 1961 to 1990 (National Statistical Service 2015b).

from water user associations to examine total water deliveries and total irrigated land area, including farms that are not covered by the survey sample.

We first assessed the impacts of tertiary canal rehabilitation on water user association membership in the treatment and comparison groups. We expected water user association membership rates at follow-up to be higher in the treatment group relative to the comparison group since the rehabilitated tertiary canals could provide more households with access to water. More generally, water user association membership rates are a useful indicator for understanding the proportion of our sample using irrigation water regularly.[17] Farmers who access network irrigation water regularly are expected to be water user association members and pay the water user association for their water, although there may be a small number who do not comply and still access water. Further, since water user associations are expected to maintain the irrigation projects, high water user association membership rates are an important factor in whether any positive impacts of the irrigation rehabilitation are sustained over time.

We found that most households in the treatment and comparison groups at follow-up were water user association members (Table III.7). In the treatment group, 85 percent of households were water user association members, compared to 77 percent of the comparison group. This difference was statistically significant. The most common reasons for why households were not water user association members were shared by the treatment and comparison group; they were that (1) household believed there was no water user association, (2) household did not know about the water user association, and (3) household did not want irrigation water. Taking the first two reasons together, 14 percent of all households in the comparison group believed there was no water user association in the village or did not know about the water user association, compared to about 5 percent of all households in the treatment group.

Our findings on water user association membership are corroborated by a positive, statistically significant impact of rehabilitated tertiary canals on the exclusive use of network irrigation water (Table III.7). Because tertiary canals can improve access to water, we expected to see that more households in the treatment group would use network irrigation water instead of other sources such as rainwater or potable water. The magnitude is small, however: households in the treatment group were 10 percentage points more likely than were households in the comparison group to irrigate their land exclusively with network irrigation water.

[17] As a basis of comparison, at baseline, 31 percent of farmers in the tertiary canal analysis sample reported that they did not receive water when needed and they did not receive as much water as needed, and 43 percent irrigated some arable land at baseline.

Table III.7. Impacts of rehabilitated tertiary canals on water user association membership and exclusive use of network irrigation water for irrigation (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
WUA member	85	77	8**	0.04
Not a WUA member	15	23	-8**	0.04
Main reason for not being a WUA member				
No WUA in village	2	10	-8**	0.02
Did not know membership process for WUA	0	0	0	1.00
Did not know about WUA	3	4	0	0.86
Did not want irrigation water	5	4	2	0.36
Costs of WUA membership	0	1	0	0.82
WUA is not effective	1	2	-1	0.30
Other	2	3	-1	0.70
Irrigated with network irrigation water exclusively	74	64	10**	0.03
Sample size	899	896		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

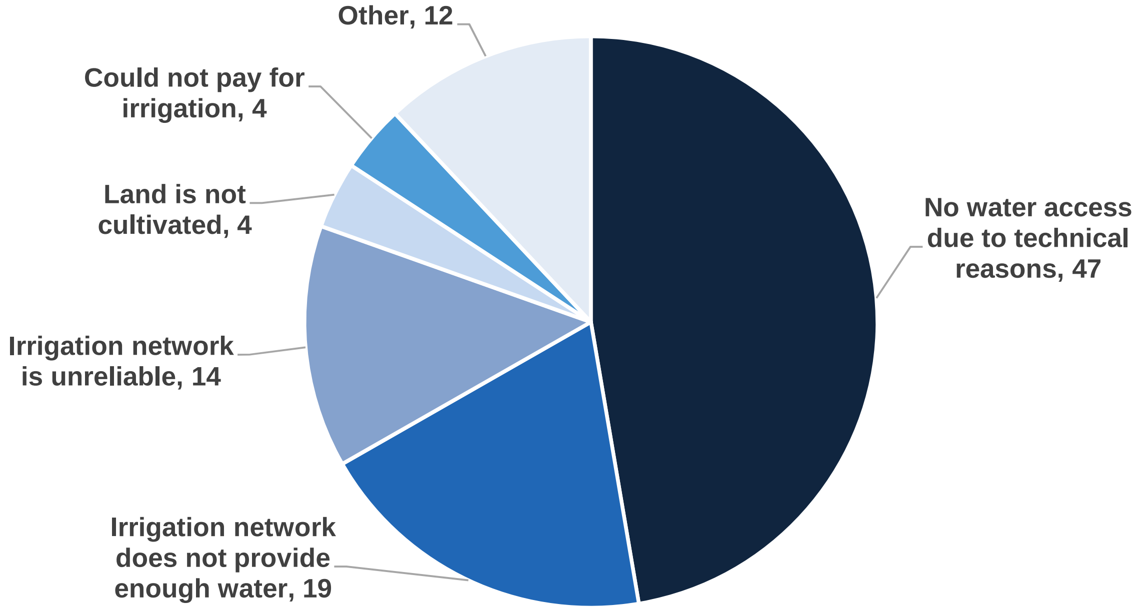
Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. “Other” includes other reasons and other personal reasons.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

WUA = water user association.

Figure III.2 shows the 5 most prevalent reasons (along with “other” that includes the remainder of 14 total reasons) listed by the approximately 200 households in the treatment group that did not irrigate their land exclusively with network irrigation water. The conditional percentages shown include households that did not irrigate their land as well as individuals who irrigated with other sources of water. Among households that did not irrigate their land exclusively with network irrigation water, about half of the treatment group reported having no water access due to technical reasons. The next two prevalent reasons were related to the access and reliability of network irrigation water; these reasons were that the irrigation network did not provide enough water and the irrigation network was unreliable.

Figure III.2. Reasons for not using network irrigation water exclusively (treatment group only, percentages)

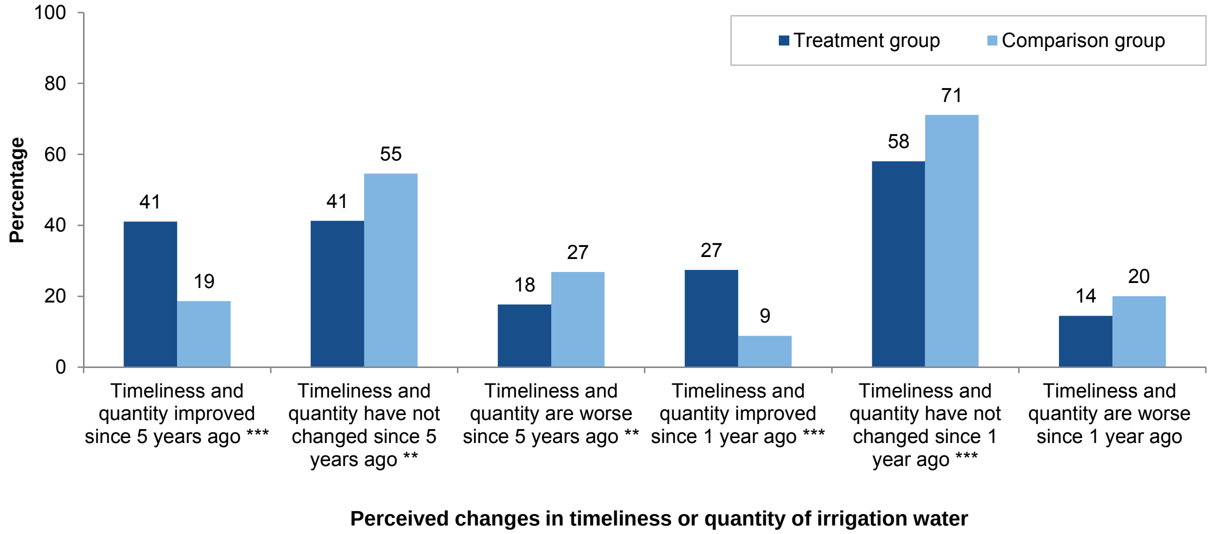


Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Percentages are calculated among the 211 farmers who do not use network irrigation water exclusively and responded to this survey item. "Other" reasons for the treatment group include that land was normative, no water access due to organizational/managerial reasons, water not delivered as promised, irrigation water was not necessary due to weather, need additional equipment, other, unprofitable because it is too expensive, no water supply in the village, and border/landslide land.

Next, we evaluated the impacts of the tertiary canal rehabilitation on farmers' perceptions of timeliness or quantity of irrigation water since five years ago and since one year ago (Figure III.3). Across all of these measures, the treatment group was more likely to report improvements in the timeliness or quantity of water. More households in the treatment group than in the comparison group believed that timeliness or quantity of irrigation water had improved, and fewer households in the treatment group than in the comparison group believed that timeliness or quantity of irrigation water had worsened. More than 40 percent of households in the treatment group reported improved timeliness or quantity of water since five years ago, compared to less than 20 percent of the comparison group. The impacts on measures of perceptions relative to five years ago were statistically significant, as well as the impact on whether timeliness or quantity of irrigation water had improved since one year ago.

Figure III.3. Impacts of rehabilitated tertiary canals on perceptions of irrigation supply system (percentages)



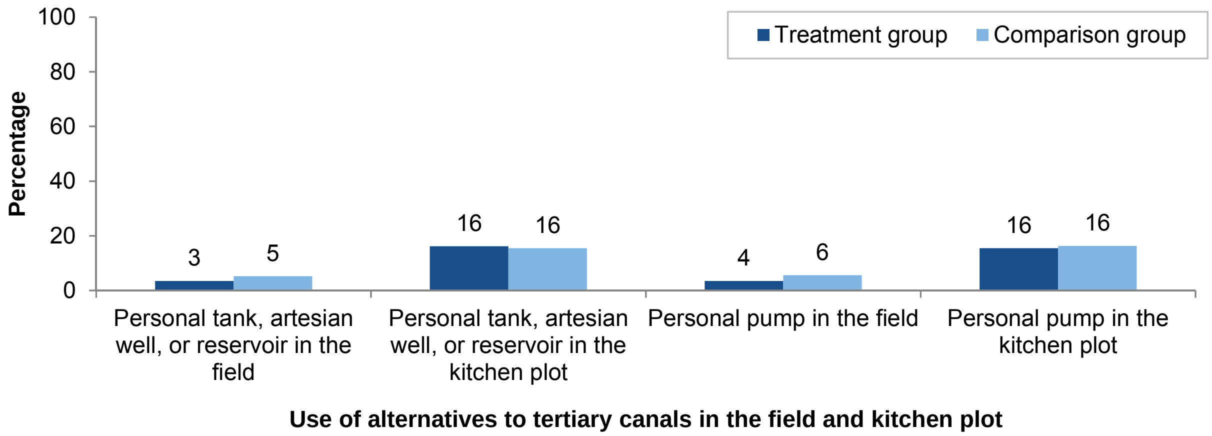
Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Another way to understand how irrigation water rehabilitation affected access to water is examining whether the irrigation rehabilitation allowed farmers to substitute away from using personal tanks, artesian wells, or reservoirs (Figure III.4). Farmers were asked whether they used these water sources for the field and in the kitchen plot, areas that are often not located next to each other and might require different amounts of water. Kitchen plots are typically small plots of land (0.1 to 0.2 hectares) located adjacent to the homes. Fields are not usually very close to farmers' homes. Some but not all kitchen plots are served by tertiary canals, depending on whether the canals go through the residential part of a given town. These areas might require different amounts of water because the field is where we would expect most crop cultivation, including grains, to occur, whereas the kitchen plot is typically used for subsistence farming. Overall, there were no differences in the treatment and comparison group's rates of using a personal tank, artesian well, reservoir, or personal pump in the field or kitchen plot, so we do not find evidence that treatment farmers substituted away from these personal alternatives. Since we found a positive impact on the exclusive use of network irrigation water, we can infer that the treatment farmers who began using network irrigation exclusively were more likely to have used drinking water or other natural sources for irrigation without the use of personal tanks or pumps (Table III.7).

Figure III.4. Use of personal alternatives to tertiary canals in the field and kitchen plot



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

We then compared the amounts of land cultivated and irrigated by households in the treatment and comparison groups (Table III.8). This comparison was conducted over all agricultural land and over specific types of land, such as arable land, orchards, vineyards, kitchen plots, and other land. Distinguishing between the types of land is important because farmers tend to grow different crops across these land types, which would require different levels of irrigation. The purposes of the crops that are grown also vary. For instance, high-value crops such as tree fruit are more likely to be grown in orchards and vineyards. Ideally, farmers would shift production away from lower-value cultivation in arable land and toward expanded cultivation of high-value crops in orchards or vineyards. This would also be a leading indicator of future expansions in the production of high-value crops even if newly planted orchards (for example) are not mature enough yet to bear fruit.

Despite the increased use of irrigation water by households in the treatment group, we did not find any sizable or statistically significant differences in the amount of land that was cultivated or irrigated, neither overall nor for any type of land.[18] Thus, although farmers in the treatment group have improved perceptions about the irrigation water supply, we found no evidence that they changed how they irrigated their land (Figure III.4) and what land they irrigated (Table III.8). This suggests that any impacts we find on agricultural production or household well-being are due to changes in the efficiency or use of irrigation water on land that was already irrigated prior to the Infrastructure Activity. Further, any impacts will not be driven by large shifts in the use of land for different crops. The remainder of this chapter focuses on

[18] Given our analysis sample size and the standard error of our impact estimate for irrigated land, the minimum detectable impact for irrigated land is 0.39 hectares. More information about minimum detectable impacts for key outcomes is shown in Table A.4.

impacts of the rehabilitated tertiary canals on the intensity of use of irrigation water and the ongoing need for improving the irrigation water supply.

Table III.8. Impacts of rehabilitated tertiary canals on land owned or rented and land irrigated (hectares)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Total Agricultural Land				
All	1.7	1.8	-0.1	0.38
Irrigated	0.8	0.9	0.0	0.80
Arable Land				
All	1.2	1.3	-0.1	0.58
Irrigated	0.4	0.4	0.0	0.89
Orchard				
All	0.1	0.1	0.0	0.27
Irrigated	0.1	0.1	0.0	0.28
Vineyard				
All	0.1	0.1	0.0	0.62
Irrigated	0.1	0.1	0.0	0.34
Kitchen Plot				
All	0.2	0.2	0.0	0.93
Irrigated	0.2	0.1	0.0	0.58
Other				
All	0.0	0.0	0.0	0.77
Irrigated	0.0	0.0	0.0	0.38
Sample size	901	901		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

To assess whether the rehabilitated tertiary canals allowed farmers to use more network irrigation water, we measured impacts on the frequency and duration of irrigation in a week, by type of land. Water gauges were not installed on tertiary canals to track how much network irrigation water was used before and after the rehabilitation. Instead, households were asked for the number of times their land was irrigated in a week and the total hours their land was irrigated in a week.

Although there were no detectible impacts on the amount of land cultivated (Table III.8), we observed marginally significant, positive impacts on the overall measures of the frequency and duration of irrigation for arable land and for kitchen plots (Table III.9). There were no statistically significant impacts on any measures of the average frequency and duration of irrigation for orchards, vineyards, or other land. Households in the treatment group typically irrigated their arable land 0.2 more times per week and their kitchen plot 0.7 more times per week than did households in the comparison group. This corresponded to approximately 4.6 extra hours of irrigation per week for arable land and 2.4 extra hours of irrigation per week for kitchen plots. Total hours of irrigation overall were greatest for arable land; farmers in the treatment and comparison groups irrigated their land for about two hours a week.

Table III.9. Impacts of rehabilitated tertiary canals on frequency and duration of irrigation

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Arable land				
Number of times land was irrigated	2.1	1.9	0.2	0.44
Total hours of irrigation	19.0	14.3	4.6*	0.05
Orchards				
Number of times land was irrigated	0.7	0.9	-0.1	0.34
Total hours of irrigation	4.8	5.5	-0.7	0.47
Vineyards				
Number of times land was irrigated	0.7	0.7	0.0	0.93
Total hours of irrigation	5.5	5.3	0.2	0.85
Kitchen plot				
Number of times land was irrigated	5.0	4.4	0.7	0.15
Total hours of irrigation	13.3	10.9	2.4*	0.09
Other				
Number of times land was irrigated	0.1	0.1	0.0	0.44
Total hours of irrigation	0.5	0.3	0.2	0.40
Sample size	882	879		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

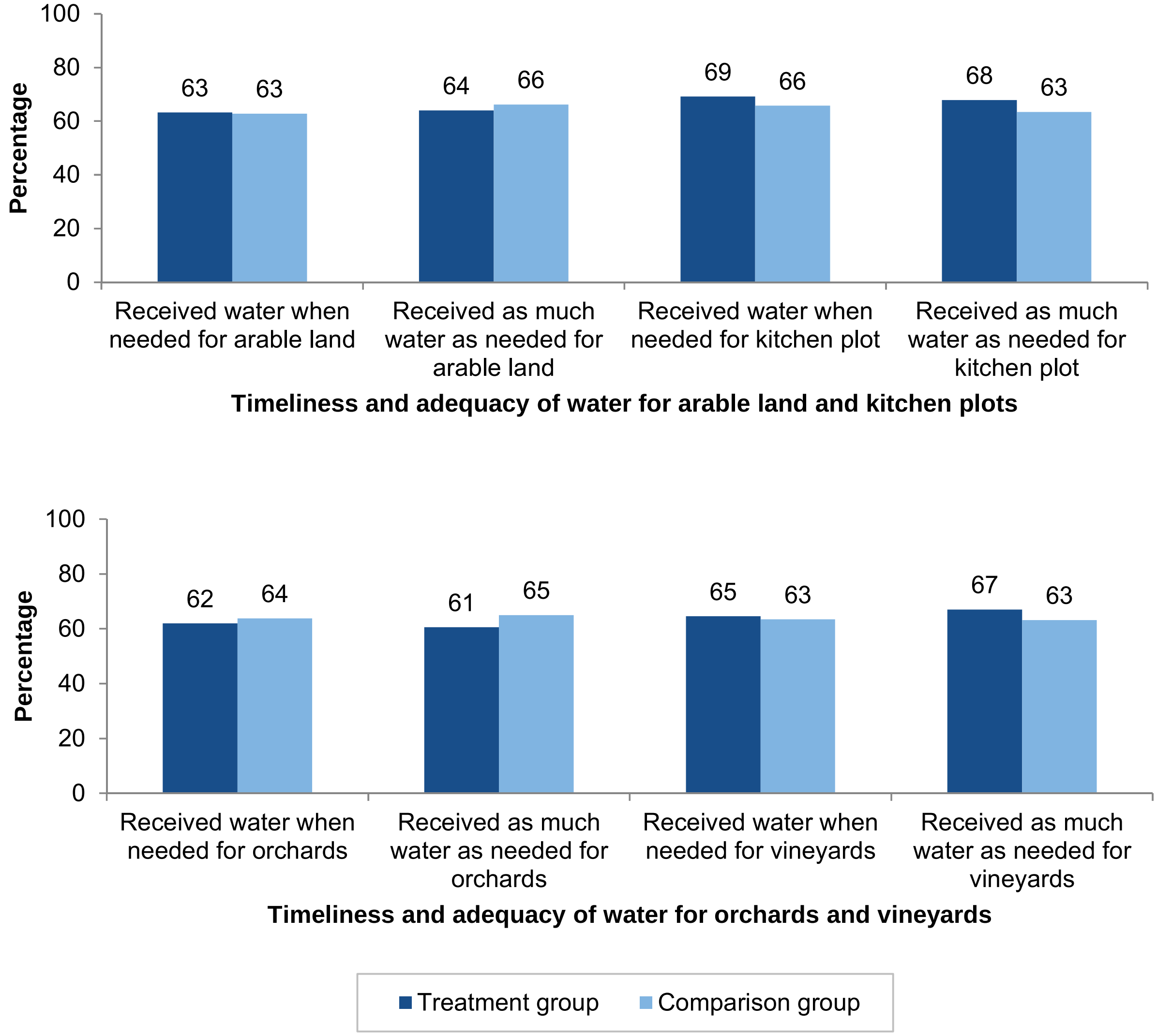
Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

To document ongoing need for access to and reliability of irrigation water, farmers were also asked in the Tertiary Canal Survey to assess whether they received water when needed and whether they received as much water as needed. Figure III.5 compares the responses of the treatment and comparison group for arable land, kitchen plots, orchards, and vineyards. These responses are conditional on farmers having the type of land being examined and responding to this survey item, so the sample sizes differ by land type. For instance, 709 farmers had arable land, and 1,181 farmers had kitchen plots. However, only 308 farmers had orchards, and 303 farmers had vineyards. We note that as reported previously there were no impacts on the type of land cultivated, so the differences in Figure III.5 reflect changes in farmers’ perceptions rather than changes in the farmers who cultivated each type of land.

Figure III.5 shows that among farmers with each type of land, the perceptions of receiving water when needed and receiving as much water as needed did not vary by treatment status or by land type. In the treatment group, farmers provided the most favorable responses about access to irrigation water in their kitchen plots. In the comparison group, farmers responded the most favorably about access to water in their arable land and kitchen plots. Access to irrigation water was lowest for orchards among farmers in both the treatment and comparison groups. Overall, we found that a substantial portion of farmers did not receive enough water for their land in a timely manner, and there is ongoing need for improved irrigation infrastructure.

Figure III.5. Farmers' perceptions of receiving enough water in a timely manner, by land type



Based on the measured impacts on these intermediate outcomes, we found that the rehabilitated tertiary canals possibly increased the intensity of irrigation water used but did not change where the water was used. For some key intermediate outcomes, we also estimated impacts on female-headed households. For completeness, we report impacts on male-headed households separately. The subgroup of female-headed households was relatively small, so the impacts are not estimated as precisely as they are for the full sample. No impacts were statistically significant for the female-headed households. The differences between male- and female-headed households are also not statistically significant.

Table III.10. Impacts of rehabilitated tertiary canals on key intermediate outcomes of irrigation water use and land cultivation for female- and male-headed households

	Impact among Households with Female Head of Household	*p*-value	Impact among Households with Male Head of Household	*p*-value
WUA member (percentage)	17**	0.03	7*	0.07
Irrigated land with network water exclusively (percentage)	8	0.41	10**	0.03
Arable land				
All (hectares)	-0.2	0.30	-0.1	0.66
Irrigated (hectares)	-0.1	0.42	0.0	0.89
Total hours of irrigation	-3.1	0.54	5.6**	0.02
Orchards				
All (hectares)	0.0	0.91	0.0	0.22
Irrigated (hectares)	0.0	0.69	0.0	0.26
Total hours of irrigation	-2.1	0.35	-0.9	0.37
Vineyards				
All (hectares)	0.0	0.15	0.0	0.76
Irrigated (hectares)	0.0	0.22	0.0	0.35
Total hours of irrigation	-1.8	0.38	0.4	0.69
Kitchen plot				
All (hectares)	0.0	0.39	0.0	0.95
Irrigated (hectares)	0.0	0.70	0.0	0.59
Total hours of irrigation	-2.0	0.55	2.9**	0.04
Sample size (T; C)	94; 100		805; 795	

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

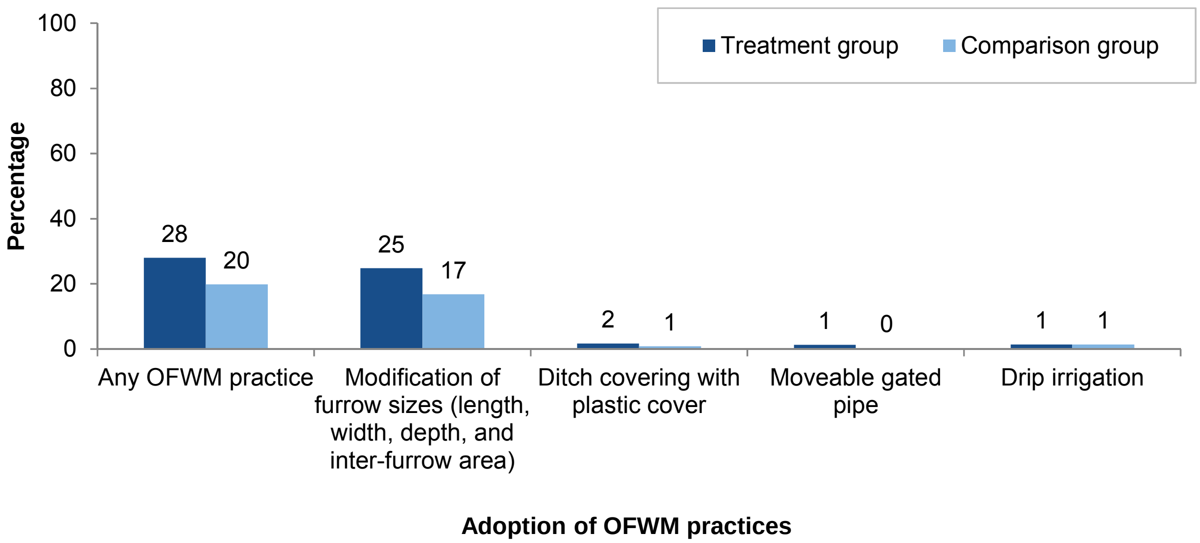
WUA = water users association.

F. Impacts of rehabilitated tertiary canals on agricultural practices

This chapter explores whether the rehabilitation of tertiary canals led to changes in farmers' on-farm water management practices and high-value agriculture practices. As indicated in the program logic model, these agricultural practices promote increases in farmers' productivity and environmental sustainability, and having better access to water could lead to improvements in household well-being. These practices were also the topics of the Water-to-Market farmer training program in Armenia that occurred in a portion of the communities in our analytic sample and was designed to complement the irrigation infrastructure investments. At follow-up, 63 percent of farmers in the treatment group and 53 percent of farmers in the comparison group reported attending a training about on-farm water management or high-value agriculture, both of which are likely to have been through the Water-to-Market program, though as we discuss more in Chapter VI, probably include training received through other programs as well. Our analysis controlled for the availability of Water-to-Market farmer training, so the impacts in this chapter are focused on the Infrastructure Activity. We explore in Chapter VI the adoption rates of these practices among the subset of communities who received Water-to-Market farmer training.

We first examined the impacts of the tertiary canal rehabilitation on the four most common on-farm water management practices, which aim to improve efficient water use (Figure III.6). In our analytic sample, the most popular on-farm water management practices included modifying furrow sizes, covering ditches with plastic, using moveable gated pipes, and drip irrigation. However, the adoption rates of on-farm water management practices were generally low.[19] Overall and for the individual practices shown, we did not find evidence for impacts on these more common on-farm water management practices. Less than 1 percent of households adopted other on-farm water management practices.

Figure III.6. Impacts of rehabilitated tertiary canals on on-farm water management practices (percentages)



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. Modification of furrow sizes includes modifying the length, width, depth, and spacing of furrows.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

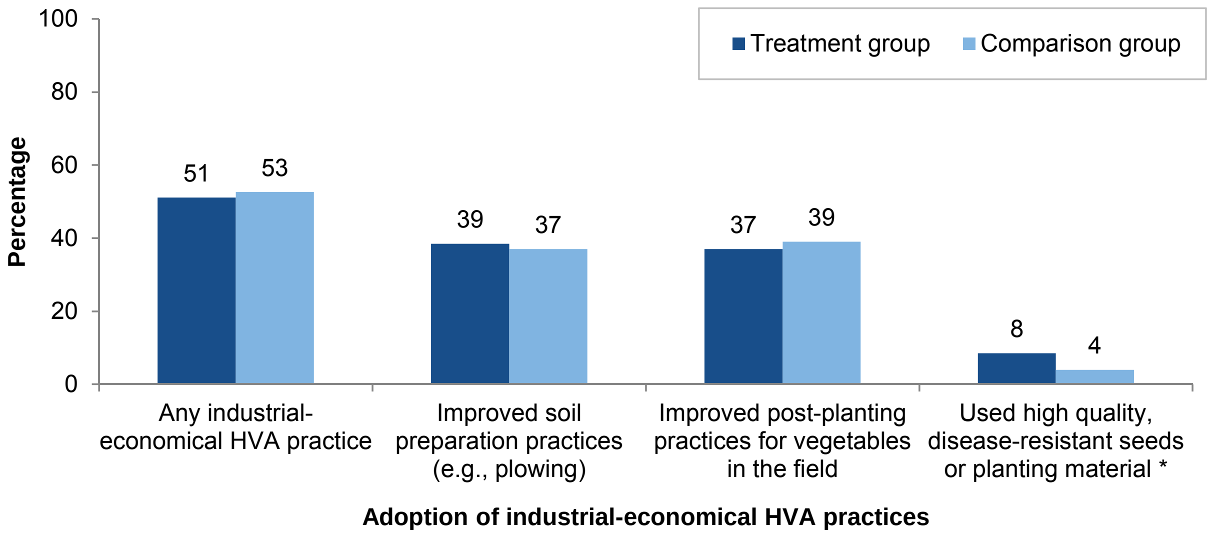
OFWM = on-farm water management.

The tertiary canal rehabilitation also did not systematically induce farmers to adopt industrial-economical high-value agriculture practices. The largest difference was for the use of high-quality, disease-resistant seeds or planting material; farmers in the treatment group were five percentage points more likely to implement this practice, and this difference was statistically

[19] At baseline, 53 percent of farmers reported modifying furrow sizes, which contributed to an overall on-farm water management practice adoption rate of 59 percent in both the treatment and comparison groups (Table A.1). However, these rates are not directly comparable to the on-farm water management adoption rates at followup because of differences in how the survey enumerators described furrow spacing to respondents. Baseline information was not collected on industrial-economical and social-environmental high-value agricultural practices.

significant, but the adoption rates were low. We also note that we are assessing impacts on a large number of practices, so there is a substantial probability that a few impact estimates of adoption rates will be statistically significant by chance.

Figure III.7. Impacts of rehabilitated tertiary canals on industrial-economical HVA practices (percentages)



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

HVA = high-value agriculture.

The last set of agricultural practices we examined were social-environmental high-value agriculture practices, where we also did not observe a systematic difference in the adoption rates (Table III.11). No impacts were statistically significant at a 5 percent level. In addition, two impact estimates related to the proper use of pesticides were statistically significant at a 10 percent level, but they point in opposite directions—farmers in the treatment group were less likely to use permitted pesticides but more likely to pay attention to the packaging of pesticides. In light of the large number of estimates considered both overall and for this particular domain, it is likely these impact estimates are statistically significant by chance.

Table III.11. Impacts of rehabilitated tertiary canals on social-environmental HVA practices (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Any social-environmental HVA practice	78	84	-6*	0.06
Have used only the pesticides permitted in the Republic of Armenia	65	73	-8*	0.07
Have bought pesticides only for a specific problem, avoiding the residuals	47	52	-5	0.38
Have bought pesticide from licensed stores	48	54	-7	0.25
Have followed the pesticide's waiting period before harvest	35	34	0	0.95
Have used personal protection equipment while working with pesticides	34	33	1	0.81
Have paid attention to the packaging and the tare completeness of pesticides	32	22	10*	0.07
Have used organic fertilizers applying the right technology	28	29	-1	0.86
Have paid attention to the normalized usage of chemical fertilizers	25	21	4	0.39
Have not burned or dumped pesticides' residuals and tare	25	18	7	0.21
Have used nonchemical methods of pest and disease management	10	6	4	0.23
Sample size	901	900		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Based on the impact estimates presented in this section, we conclude that the rehabilitated infrastructure did not influence adoption rates of on-farm water management and high-value agriculture practices.

G. Impacts of rehabilitated tertiary canals on agricultural production

We next discuss whether the rehabilitation of tertiary canals led to changes in farmers' agricultural production, either through higher yields or cultivation of higher-value crops. Our measures of agricultural production span crop cultivation, land area used for crop cultivation, crop production amounts, revenues from crop sales, and estimated values of farmers' harvests for 46 crop types. Assessing differences on multiple production measures allows us to determine whether the impacts we ultimately observed on household well-being were due to changes in agricultural income from increases in crop sales or increased agricultural production for home consumption.

We first examined the amount of land cultivated to assess whether the rehabilitation of the tertiary canals allowed farmers in the treatment group to cultivate more land than farmers in the comparison group (Table III.12). We separated the impacts by land used to cultivate high-value crops and non-high-value crops because high-value crops require reliable access to water. There were no large differences or statistically significant impacts on the amount of land cultivated, overall or specifically for high-value agriculture and non-high-value crops.[20,21] This is consistent with our findings that there were no impacts on land holdings and the area of land irrigated (Table III.8).

Table III.12. Impacts of rehabilitated tertiary canals on the amount of land cultivated (hectares)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Total	1.4	1.4	-0.1	0.61
HVA crops	0.5	0.5	0.0	0.83
Non-HVA crops	0.8	0.9	-0.1	0.50
Percentage of total land that is HVA crops	0.6	0.6	0.0	0.27
Sample size	901	901		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

HVA = high-value agriculture.

We also explored which types of crops were cultivated in case there were changes at the crop level rather than in the total amount of land cultivated for high-value agriculture and non-high-value crops. We disaggregated high-value crops into five categories: grape, other fruits or nuts, tomato, vegetables and herbs, and potato. Non-high-value crops were grouped into grain and grass. Overall, we found that almost all farmers grew at least one high-value crop, and many farmers also grew at least one non-high-value crop (Table III.13; see Appendix B, Table B.1 for impacts on each crop). About one-quarter of farmers grew grapes, and more than 60 percent of farmers reported growing other fruits or nuts.[22]

We found no systematic impacts of the rehabilitated tertiary canals on crop cultivation two to three years after tertiary canals had been rehabilitated. To address the possibility that farmers might have needed to gain experience with the rehabilitated infrastructure before they changed

[20] High-value crops include apple, grape, peach, apricot, pear, prunes, plum, fig, pomegranate, sweet cherry, cherry, cornel, quince, watermelon, melon, pumpkin, lemon, Malta orange, walnut/hazelnut, strawberry, tomato, cucumber, eggplant, pepper, cabbage, carrot, squash, onion, garlic, potato, red beet, sunflower, haricot, tobacco, greens, planting stock, flowers, other fruits, and other vegetables. Non-high-value crops include wheat, emmer wheat, barley, maize, sorgo, grass, and gramma or other special feed.

[21] Given our analysis sample size and the standard error of our impact estimate on land under cultivation for HVA crops, the minimum detectable impact on land under cultivation for HVA crops is 0.18 hectares. More information about minimum detectable impacts for key outcomes is shown in Table A.4.

[22] Other fruits or nuts include apple, peach, apricot, pear, prunes, plum, fig, pomegranate, sweet cherry, cherry, cornel, quince, watermelon, melon, lemon, Malta orange, walnut/hazelnut, strawberry, and other fruits. Vegetables and herbs include pumpkin, cucumber, eggplant, pepper, cabbage, carrot, squash, onion, garlic, red beet, greens, and other vegetables.

their cropping patterns, we also asked farmers whether they had changed their cropping patterns from the last agricultural season. This measure is a leading indicator for impacts that have not yet been realized but could be in the future. For example, if we observed that farmers in the treatment group were changing their cropping patterns during the most recent agricultural season at a higher rate than farmers in the comparison were, we might anticipate that there would be impacts on crop cultivation or production in the future. However, there was no impact of the tertiary canal rehabilitation on farmers changing cropping patterns since the last agricultural season. Only about 5 percent of farmers in the treatment group reported switching crops. Overall, to summarize the impacts on land use and crop cultivation thus far, we found that farmers did not change how much land they irrigated, what type of land they irrigated, and what types of crops they cultivated, even though farmers perceived improvements in the irrigation water supply and might have changed how much irrigation water was used.

Table III.13. Impacts of tertiary canals on farmers' cultivation of crop types (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
HVA crops	94	97	-3*	0.07
Grape	25	23	2	0.51
Other fruits or nuts	65	63	2	0.66
Tomato	29	31	-2	0.64
Vegetables and herbs	38	39	-1	0.77
Potato	32	36	-4	0.20
Non-HVA crops	57	53	4	0.30
Grain	38	35	3	0.34
Grass	27	30	-3	0.46
Changed cropping pattern since last agricultural season	5	6	0	0.89
Sample size	901	901		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

HVA = high-value agriculture.

To assess whether the changes in water usage affected the amount or value of production in the treatment group, we present impacts of the tertiary canal rehabilitation on agricultural production, revenues from crops sold, and market values of harvests (Table III.14). Harvest values include revenues from crops sold as well as the value of households' own consumption of their production. Because many farmers, especially those outside of Ararat Valley, are subsistence farmers who sell little of their harvest, revenues do not reflect the full value of farmers' production.[23] These impacts are presented for overall crops, for high-value crops and

[23] Market values were determined from reported revenues. In the absence of revenues, market value was calculated by the number of units sold and the median price of the crop in a household's WUA. In cases where the WUA

non-high-value crops, and for the major crop categories within high-value crops and non-high-value crops. All monetary amounts are reported in U.S. dollars using the exchange rate for Armenian drams from October 1, 2013, which corresponds to the end of the agricultural season shortly before the follow-up Tertiary Canal Survey was fielded.

We found that there were no impacts of tertiary canal rehabilitation on agricultural production as measured in tons produced, revenue from crop sales, or market values of harvests.[24] This was true overall, for high-value crops and non-high-value crops separately, and for major categories of high-value and non-high-value crops. We also measured impacts for individual crops as reported in Appendix B and did not find other evidence of systematic changes in production. While there is no evidence of impacts on agricultural production, farmers in both the treatment and comparison groups have increased their production relative to baseline, when they produced 7.7 and 5.5 tons, respectively (Table A.5).

Table III.14. Impacts of rehabilitated tertiary canals on production, revenues, and market value of harvests (USD except where indicated)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Agricultural Production (Metric Tons)				
Total	9.02	9.70	-0.67	0.54
HVA crops	6.00	6.16	-0.17	0.81
Grape	0.88	0.72	0.16	0.35
Other fruits or nuts	1.15	1.18	-0.03	0.88
Tomato	0.57	0.53	0.04	0.73
Vegetables and herbs	0.81	0.94	-0.12	0.53
Potato	1.29	1.74	-0.46	0.26
Non-HVA crops	2.40	2.64	-0.24	0.53
Grain	1.10	1.16	-0.06	0.75
Grass	1.14	1.16	-0.02	0.93
Revenues from Crops Sold				
Total	1,716	1,809	-93	0.72
HVA crops	1,427	1,476	-48	0.80
Grape	294	244	50	0.43
Other fruits or nuts	254	327	-73	0.20
Tomato	142	128	14	0.66
Vegetables and herbs	254	220	34	0.57
Potato	166	209	-42	0.51
Other HVA crops	28	15	13	0.12
Non-HVA crops	191	201	-10	0.85
Grain	127	135	-8	0.84
Grass	30	32	-3	0.74
Other non-HVA crops	21	1	20	0.28

median price was missing, the median price of the crop in the household's zone was used. In cases where both the WUA and zone median prices were missing, the median price over all households was used.

[24] The "Total" group excludes a few crop categories whose harvest amounts are not reported in tons: sorgo, greens, planting stock, and flowers.

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Market Value of Harvests				
Total	2,671	2,825	-154	0.62
HVA crops	1,963	2,058	-96	0.66
Grape	331	266	65	0.33
Other fruits or nuts	426	499	-74	0.27
Tomato	176	161	15	0.66
Vegetables and herbs	329	301	29	0.69
Potato	301	403	-102	0.26
Other HVA crops	41	21	20*	0.05
Non-HVA crops	561	587	-26	0.76
Grain	368	401	-33	0.61
Grass	146	145	0	0.99
Other non-HVA crops	21	1	20	0.28
Sample size	901	901		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. Other high-value crops include sunflower, haricot, tobacco, planting stock, and flowers. Other non-high-value crops include sorgo.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.
USD = United States dollars; HVA = high-value agriculture.

Next, we measured impacts on agricultural expenditures to assess whether the rehabilitated tertiary canals increased the efficiency of agricultural production—for instance, the rehabilitated infrastructure could have allowed farmers to lower their agricultural expenditures while maintaining their production levels (Table III.15). Increased expenditures could also be a leading indicator for future increases in agricultural production or profits. There were no impacts on total expenditures or for any individual type of expenditure, and the overall difference of $7 in total expenditures was not meaningful.

Table III.15. Impacts of tertiary canals on agricultural expenditures (USD)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Total	928	934	-7	0.93
Irrigation	124	104	20	0.11
Seeds and seedlings	125	122	2	0.90
Fertilizers and pesticides	238	257	-20	0.32
Hired labor, equipment, and tools	294	312	-19	0.56
Taxes and duties	50	48	2	0.55
Cellophanes	46	40	6	0.64
Other major expenses	5	3	2	0.34
Sample size	901	901		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.
USD = United States dollars.

H. Impacts of rehabilitated tertiary canals on income and poverty

This section explores the effects of the rehabilitation of tertiary canals on the key measures of interest for our evaluation—measures of economic well-being, in particular household income, consumption, and position relative to the poverty line. We examined both income and consumption because consumption tends to have lower variance than income and is thus a useful alternative measure of household well-being.

We created a series of income measures using the Tertiary Canal Survey to separate different sources of income. The first is nonagricultural income, which is the sum of annual pensions, remittances, salaries, and income from other benefits. Although we do not expect nonagricultural income to be directly influenced by the program, there might be a trade-off between nonagricultural and agricultural income. Farmers might substitute away from nonagricultural activities and toward agricultural activities on their own farms once they have better access to irrigation water. Earning a salary from agricultural work on another farm would also be counted as nonagricultural income. The second is economic agricultural profit, which is the difference between the market values of harvests and total agricultural expenditures. The third is total economic income, which is the sum of nonagricultural income and economic agricultural profit.

We do not observe any impacts for nonagricultural income, economic agricultural profit, and total economic income (Table III.16). Although the impact estimates are negative, this is likely due to chance because it is not supported by any systematic pattern of negative impacts on intermediate outcomes.[25] We also note that, while there are no impacts on total economic income, farmers in the treatment and comparison groups experienced large gains in economic income. At baseline, farmers in the treatment group had an average of $3,660 USD, and the average in the comparison group was $3,394 (Table A.5).

Table III.16. Impacts of rehabilitated tertiary canals on annual economic household income (USD)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Nonagricultural income	3,764	4,012	-247	0.23
Agricultural income				
Total value of harvest	2,671	2,825	-154	0.62
Economic agricultural profit (value – costs)	1,654	1,803	-149	0.52
Total economic income	5,610	6,004	-395	0.32
Sample size	901	901		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.
USD = United States dollars.

[25] Given our analysis sample size and the standard errors of our impact estimates, the minimum detectable impacts for agricultural profits and economic income are $650 USD and $1,098 USD, respectively. More information about minimum detectable impacts for key outcomes is shown in Table A.4.

To determine whether the tertiary canal rehabilitation helped lift households out of poverty through consumption rather than increases in income, we assessed whether households' consumption fell below several measures of the poverty line. Our approach to poverty measurement was based on the calculations used for the Integrated Living Conditions Survey, an annual household survey conducted by Armenia's National Statistical Service. We first constructed a monthly measure of consumption based on household-reported expenditures on food, housing, utilities, transportation, cigarettes, health, education, insurance, and other goods along with the market value of crops consumed by the household. This construct was then adjusted for the number of adults and children in the household to allow for comparability across households. Finally, our estimate of total consumption per person was compared to three distinct poverty lines calculated for 2013 by the National Statistical Service in collaboration with the World Bank: the "food poverty" line, the "lower general poverty" line (or lower poverty line), and the "upper general poverty" line (upper poverty line). The food poverty line represents the cost to consume the average caloric requirement for a person in Armenia.[26] The lower and upper general poverty lines add the values of some nonfood consumption to the food poverty line.[27] Consequently, poverty rates calculated relative to the food poverty line will be lower than poverty rates calculated relative to the lower and upper poverty lines.

In our sample, most households' consumption did not fall under the food poverty line: less than 2 percent of the treatment group and about 3 percent of the comparison group had adult-equivalent consumption that fell below the food poverty level. A greater proportion of households fell below the less severe poverty lines. About 9 percent of households had adult-equivalent consumption that was below the lower poverty line, whereas between 15 and 16 percent of households had adult-equivalent consumption that was below the upper poverty line. These poverty rates demonstrate that the farmers who had tertiary canals rehabilitated were better off than the farmers who were likely to receive training in the Water-to-Market evaluation; for the Water-to-Market evaluation, 5 percent of farmers were in food poverty, 15 percent were in lower poverty, and 28 percent were in upper poverty.

We did not find evidence of impacts on poverty rates according to any of the poverty lines (Table III.17).[28] Thus, the rehabilitated tertiary canals did not lead to reductions in poverty.

[26] The average caloric requirement for an Armenian is 2,232 calories per day, as calculated in 2004 by the National Statistical Service and the World Bank. The cost of this caloric amount is based on the specific food items consumed by a reference population, scaled to that number of calories.

[27] The primary difference between the lower and upper general poverty lines is the reference population used to identify the share of expenditures on nonfood items. The lower poverty line examines the consumption of households whose total consumption is near the food poverty line. This is known as the Consumption Basket Method. In Armenia in 2009, about 70 percent of this reference population's total consumption was food. The upper poverty line examines the consumption of households whose food consumption is near the food poverty line. This is known as the Food Expenditures Method. In Armenia in 2009, about 57 percent of this reference population's total consumption was food (National Statistical Service 2010).

[28] Given our analysis sample size and the standard error of our impact estimate for the lower poverty rate, the minimum detectable impact for the lower poverty rate is 3.7 percentage points. More information about minimum detectable impacts for key outcomes is shown in Table A.4.

Table III.17. Impacts of rehabilitated tertiary canals on poverty rates (percentages)

	Treatment Group Percentage	Comparison Group Percentage	Impact	*p*-value
Households in food poverty	2.2	3.2	-1.0	0.28
Households below lower poverty line	8.6	8.9	-0.3	0.84
Households below upper poverty line	16.0	14.8	1.2	0.53
Sample size	899	900		

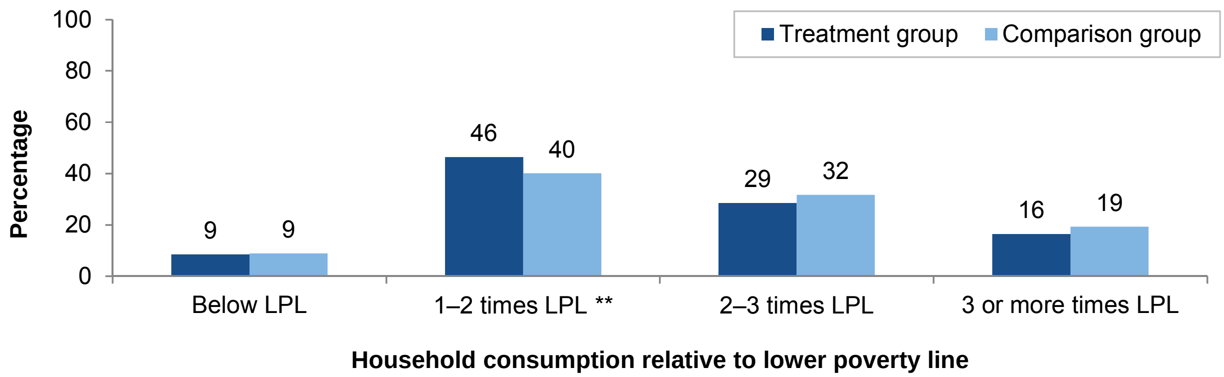
Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from 0 at the .10/.05/.01 levels, respectively, two-tailed test.

An additional lens through which we examined economic well-being was the ratio between a household's consumption and the poverty line, a measure that represents the size of the buffer between the household's current economic position and a state of poverty. In Figure III.8, we show the distributions of farmers' consumption amounts relative to the lower poverty line for the treatment and comparison groups. The distributions overall look similar. Households in both the treatment and comparison groups are most likely to have a consumption amount between one and two times the lower poverty line (46 percent and 40 percent, respectively) and least likely to have a consumption amount below the poverty line. The difference in the percentages of households consuming between one and two times the poverty line is statistically significant.

Figure III.8. Consumption of respondent households relative to the lower poverty line (percentages)



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from 0 at the .10/.05/.01 levels, respectively, two-tailed test.

The similarity of the overall distributions in Figure III.8 is consistent with the lack of impacts on average consumption relative to each of the three poverty lines (Table III.18). In Table III.18, 100 percent corresponds to exactly the poverty line; 200 percent means consumption is twice the poverty line; and so on. The overall impacts on average consumption are small and negative but still statistically significant at the 10-percent level.

Table III.18. Impacts of rehabilitated tertiary canals on consumption relative to poverty lines (percentages of the poverty line)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Consumption relative to food poverty line	305	322	-17*	0.09
Consumption relative to lower poverty line	217	229	-12*	0.09
Consumption relative to upper poverty line	179	189	-10*	0.09
Sample size	899	900		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

To test more directly whether the tertiary canal rehabilitation had distributional effects, we calculated impacts on consumption of households relative to the lower poverty line at follow-up by the size of the buffer that households had from the lower poverty line at baseline (Table III.19). Thus, we can examine whether households that had more or less consumption at baseline (relative to the lower poverty line) experienced larger or smaller impacts on consumption at follow-up. We find that the rehabilitated tertiary canals reduced consumption for households that were below the lower poverty line at baseline. Among households that were below the lower poverty line at baseline, the difference between consumption of households in the treatment group and comparison group at follow-up was 28 percent of the lower poverty line. There is also marginally significant evidence that consumption also decreased for households that had consumption between one and two times the lower poverty line at baseline.

Table III.19. Impacts of rehabilitated tertiary canals on consumption of respondent households relative to the lower poverty line, by baseline consumption level (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact on Consumption Relative to LPL	*p*-value	Sample Sizes (T; C)
Below LPL at baseline	174	202	-28**	0.03	134; 125
1–2 times LPL at baseline	198	212	-13*	0.08	423; 423
2–3 times LPL at baseline	234	247	-13	0.26	203; 230
3 or more times LPL at baseline	294	285	9	0.69	120; 107

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.
LPL = lower poverty line.

In summary, our findings suggest that the rehabilitated tertiary canals did not improve households' economic well-being as the program logic had anticipated. Even though households in the treatment group reported improvements in their irrigation water supply and also used more irrigation water, the magnitudes of these changes were modest and did not translate into changes in agricultural practices, land cultivation, cropping patterns, or agricultural production. Although it is possible that the rehabilitated tertiary canals affected other dimensions that we did not observe as intermediate outcomes, there were ultimately no impacts on income (overall or by source), consumption, or poverty. We do, however, find some evidence that the consumption of the poorest households at baseline fell because of the intervention. This is interpreted with caution, however, because the evaluation examined a wide range of outcomes, and in such cases, some impact estimates will be identified as statistically significant by chance.

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IV. EVALUATION OF REHABILITATED LARGE INFRASTRUCTURE

This chapter describes our empirical approach for evaluating MCC's rehabilitation of large infrastructure in Armenia. As discussed in Chapter II, "large infrastructure" comprises MCC's rehabilitation projects in Armenia that were larger than tertiary canals: main canals, drainage systems, pumping stations, and gravity schemes. The large infrastructure rehabilitation projects resulted in the rehabilitation of 42 kilometers of main canals and 35 pumping stations, gravity schemes, and drainage systems. This affected 262 communities throughout Armenia, and the cost of rehabilitating the large infrastructure was about $104 million. The scale of the large infrastructure investments was much higher than for tertiary canals alone ($15.9 million in costs affecting 100 communities).[29]

As in the evaluation of tertiary canals in Chapter III, our evaluation of large infrastructure aims to compare outcomes in the communities for which at least one type of large infrastructure was rehabilitated to communities that were otherwise similar, except they were not influenced by large infrastructure rehabilitation. This evaluation uses the data that were already collected to evaluate the rehabilitation of tertiary canals. Of the 173 communities where the Tertiary Canal Survey was fielded, 107 were influenced by a large infrastructure project and are considered to be the large infrastructure treatment group, and the remaining 66 communities form the potential comparison group. About 54 percent of the large infrastructure treatment group also received tertiary canal rehabilitation, compared to about 45 percent of the large infrastructure potential comparison communities. We used a similar process to refine the comparison group for the large infrastructure treatment group, and then we estimated impacts using regression adjustment.

The remainder of this chapter describes the research questions that will be addressed using the Tertiary Canal Survey (Section IV.A); the prevalence of large infrastructure projects among communities in the Tertiary Canal Survey sample (Section IV.B); and our evaluation design (Section IV.C), including details on the refinement of the comparison group. We then present some key characteristics of our analytic sample (Section IV.D), followed by estimated impacts on irrigation water use (Section IV.E), agricultural practices (Section IV.F), agricultural production (Section IV.G), and measures of household well-being (IV.H).

A. Research questions and data

The large infrastructure evaluation shares the same primary research questions, key outcome measures of interest, and main data sources as the evaluation of tertiary canals. These research questions pertain to the potential intermediate and long-term impacts that were identified in the program logic for the Infrastructure Activity (Section I.B).

[29] An additional $1.6 million in administrative costs was incurred, bringing the total costs of the Infrastructure Activity to $121 million.

Table IV.1. Primary research questions and key outcome measures

Research Question	Key Outcome Measures	Main Data Sources
Did the program affect the quantity and reliability of irrigation water provided to Armenian farmers?	Hours of irrigation; reliability of irrigation; land irrigated; sources of irrigation	Tertiary Canal Survey; Village Mayor Survey
Did farmers adopt new agricultural practices as a result of the program?	Adoption rates of agricultural practices	Tertiary Canal Survey
Did the program affect agricultural productivity?	Crop cultivation and production; value of crops harvested; revenues from crops sold; agricultural profit	Tertiary Canal Survey
Did the program improve household well-being for farmers served by those canals, especially income and poverty?	Total income; poverty status; consumption	Tertiary Canal Survey

B. Sampling approach

As discussed in Chapter I, the Tertiary Canal Survey was originally designed to facilitate only the evaluation of tertiary canals. The design and sampling frame for the Tertiary Canal Survey did not take large infrastructure rehabilitation into account, but the survey remains the best data source for the evaluation of large infrastructure rehabilitation because, by happenstance, it contains groups of communities that are similar on key agricultural characteristics. By construction, the Tertiary Canal Survey sample contains groups of communities that are similar in location and served by the same water user associations, have similar conditions of irrigation infrastructure prior to rehabilitation, and cultivate similar crops. However, the data set was not constructed to have equal representation of communities that received large infrastructure rehabilitation and similar communities that did not. As described in the next chapter, we refined the potential comparison communities using statistical matching methods to identify similar treatment and comparison communities.

C. Evaluation design

We addressed differences between communities with rehabilitated large infrastructure and communities without by using the same statistical methods that were applied in the tertiary canal evaluation: identifying a set of comparison communities that were similar to the treatment communities on an expanded set of baseline characteristics, then comparing how outcomes of the treatment and matched comparison communities have changed relative to the same outcomes measured before the rehabilitation.

Identifying matched comparison communities

We identified the analytic sample for the evaluation of large infrastructure through the following steps:

1. **Identified the same characteristics applied in the tertiary canal evaluation.** As in the tertiary canal evaluation, we predicted propensity scores for every community using all of

the community-level variables that could influence agricultural production, including whether the community had rehabilitated tertiary canals.[30]

2. **Estimated a logistic regression relating treatment status to baseline characteristics.** As in the evaluation of rehabilitated tertiary canals, we estimated a community-level logistic regression where the dependent variable was a binary indicator for whether the community had rehabilitated large infrastructure and the independent variables were the measures from step 1.
3. **Predicted propensity scores using the logistic regression.** We then used the estimated logistic regression from step 2 to predict the propensity score for each community. This is our estimated probability that a given community could have received large infrastructure rehabilitation, based on the estimated model parameters and the community's baseline variables.
4. **Created the analytic sample of treatment and comparison communities.** We compared the distributions of the estimated propensity scores to assess the similarity of the potential treatment and comparison communities. Unlike the distribution of propensity scores we estimated in the evaluation of rehabilitated tertiary canals, we found that this distribution of propensity scores had outliers in both the treatment and potential comparison groups. That is, one community in the treatment group had a propensity score that was substantially lower than the propensity scores of all other communities in the treatment group, and one community in the potential comparison group had a propensity score that was substantially higher than the propensity scores of all other communities in the potential comparison group. To avoid including these outliers in the analytic sample, we defined the common support as consisting of the propensity scores that were higher than or equal to the second-lowest propensity score in the treatment group but lower than or equal to the second-highest propensity score in the comparison group.[31] The common support covered 88 communities in the Tertiary Canal Survey sample (52 treatment, 35 comparison) for the large infrastructure evaluation, compared to the 117 communities (63 treatment, 54 comparison) covered by the common support for the tertiary canal evaluation.

Once we restricted the analytic sample to the common support, we assessed whether there were statistically or economically significant baseline differences between the treatment and comparison groups on the same range of characteristics examined for the tertiary canal

[30] We identified the same variables as we did in the tertiary canal evaluation. From the Village Mayor Survey, we used marz indicators; number of households in the village; number of available livestock; percentage of households that farm as their main occupation; hectares of total land cultivated, total land irrigated by network water, arable land, arable land irrigated by network water, orchard land, vineyard land, kitchen plot land, and kitchen plot land irrigated by network water; whether the community received enough water when needed; and indicators for having tertiary canals that were rehabilitated. We constructed community-level averages based on the following household-level measures in the Tertiary Canal Survey: head of household's age, sex, and education; number of people in the household and number of children in the household; WUA membership; tank ownership and pump ownership; receipt of training through the WtM program; farm expenditures, nonagricultural income, and total value of agricultural production; poverty status; and perception of the condition of the irrigation system.

[31] In the tertiary canal evaluation, we defined the common support as consisting of the propensity scores that were higher than or equal to the minimum propensity score in the treatment group and lower than or equal to the maximum propensity score in the comparison group, which is more common in propensity score approaches.

evaluation (Section III.C). This included demographic characteristics, key outcome measures at baseline, and other key determinants of household well-being. The key outcomes included agricultural practices, land holdings, agricultural expenditures, crop cultivation, crop sales, market value of crop harvests, household income, and poverty rates. Other determinants of household well-being that we examined included the perceived condition of the irrigation system, geographic location of the community, rehabilitation of tertiary canals, and participation in the Water-to-Market evaluation. We found only two statistically significant differences—heads of households in the comparison group were 7 percentage points more likely to have more than a secondary education, and households in the treatment group had an average of 1.2 children compared to an average of 1.1 children in the comparison group. An additional measure had a statistically significant difference at a 10 percent level—farmers in the treatment group had 0.4 less hectares on average than did farmers in the comparison group. The full set of characteristics on which we assessed balance is provided in Appendix Table A.4.

Measuring impacts

Because baseline differences remain after restricting the analytic sample to the common support, it is crucial that we further adjust for preexisting differences between the treatment and comparison groups. We use the basic regression model

$$\text{(IV.1)} \qquad y_{iv,F} = \beta' x_{iv,B} + \gamma T_v + \eta_v + \varepsilon_{iv},$$

where $y_{iv,F}$ is the outcome of interest for household i in village v at the follow-up survey; $x_{iv,B}$ is a vector of baseline characteristics including education level, number of children in the household, land holdings, and indicators for whether the household is in a community where other types of infrastructure (such as tertiary canals) were rehabilitated; T_v is an indicator equal to one if village v is in the treatment group and zero if it is in the comparison group; η_v is a village-specific error term; and ε_{iv} is a random error term for the household. The parameter estimate for γ is the estimated impact of the program. This is the same model that was applied in the tertiary canal evaluation, but T_v now represents whether or not a village was in the large infrastructure treatment group. We account for the correlation of outcomes within communities ("clustering") in the village-specific error term η_v.

An alternative approach to estimating impacts would use the inverse of the propensity scores to weight households in Equation (IV.1). As with the evaluation of rehabilitated tertiary canals, however, we decided to use the regression adjustment approach without the inverse weights because it yields more stable impact estimates on key outcomes and because applying inverse probability weights based on the estimated propensity scores did not appreciably improve covariate balance.

D. Description of analytic sample

After the common support restrictions, our analytic sample included longitudinal information on 1,348 households (825 households in the treatment group, 523 households in the comparison group). In our analytic sample, about 49 percent of the households in the comparison group were in communities that had some rehabilitation of tertiary canals, compared to about 46 percent of households in the treatment group. The geographic distribution of the large infrastructure projects and the analytic sample are shown in Figure IV.1. The analytic sample includes communities that were expected to be influenced by the rehabilitation of a main canal, the Ararat Valley drainage system, 10 pumping stations (of 17 total that were rehabilitated by MCC), and 3 gravity schemes (of 5 total that were rehabilitated by MCC). Compared to the tertiary canal evaluation, the distribution of treatment and comparison communities is less balanced by marz, with two marzes (Lori, Vayots-Dzor) containing comparison communities but no treatment communities. We elected to keep these comparison communities in the sample despite their location because they could still serve as meaningful comparison units for communities in neighboring marzes that have similar climate, topography, and agricultural conditions.

The household characteristics of the large infrastructure analytic sample are qualitatively similar to the analytic sample for the tertiary canal evaluation (See Tables A.1, A.5). At follow-up, the heads of household in the treatment group were about 57 years old, and 12 percent of the households had a female head of household. About 11 percent of the heads of household had not completed secondary school, and 20 percent of the heads of household had more education than secondary school.

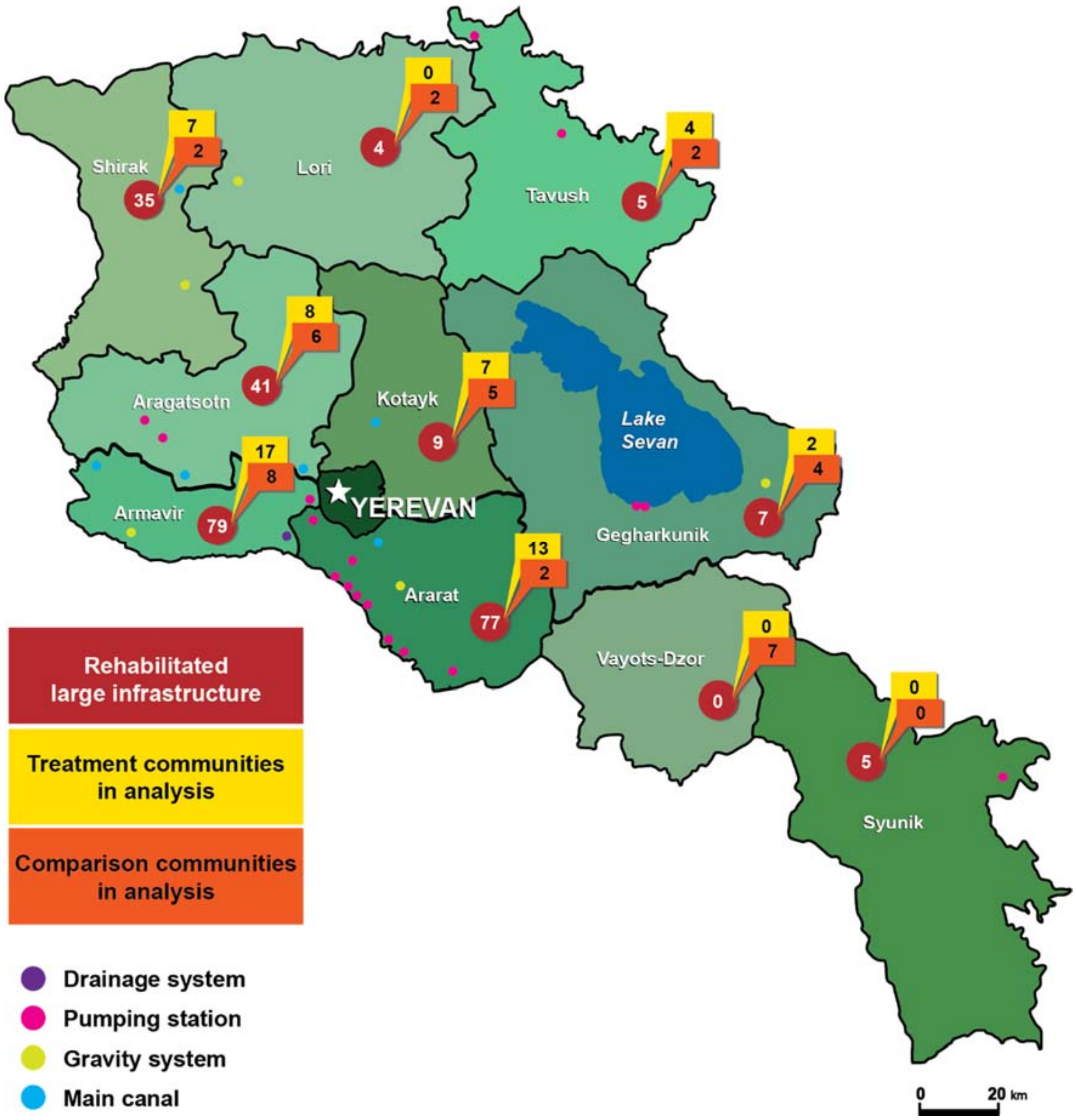
Table IV.2. Household characteristics of the analytic sample for the evaluation of rehabilitated large infrastructure (percentages except where indicated)

	Mean
Head of household’s age (years)	57
Female-headed household	12
Head of household’s education	
Less than secondary	11
Full secondary	42
Secondary vocational	27
More than secondary	20
Number of people in household	5.0
Number of children in household	1.1
Sample size	825

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Because our regression adjustment accounts for differences in these characteristics, the treatment and comparison groups have the same regression-adjusted characteristics. Demographic characteristics are measured at follow-up.

Figure IV.1. Distribution of large infrastructure that was selected for rehabilitation, by marz



Source: Millennium Challenge Corporation program data.

As described in Chapter III, we confirmed through Internet searches that no other infrastructure rehabilitation projects had occurred in the comparison villages at the same time as the rehabilitation of large infrastructure under the Infrastructure Activity. The two World Bank projects that included one comparison community in the tertiary canal evaluation did not influence any comparison communities in the large infrastructure evaluation.

Farmers' perceptions of irrigation rehabilitation describe their awareness of the Infrastructure Activity and of routine maintenance by regional authorities such as water user associations. We also asked farmers about their perceptions of irrigation rehabilitation to learn whether farmers in the treatment group knew about the rehabilitation and could have changed behaviors accordingly. Most of the farmers in the treatment communities reported awareness that repairs or rehabilitation had occurred in the past five years, primarily by MCA-Armenia (Table IV.3). However, nearly 40 percent of the treatment group was unaware of or forgot about any irrigation repair or rehabilitation.

Notably, a higher proportion of households in comparison communities than in treatment communities believed that there had been any repair or rehabilitation in the past five years and that this rehabilitation had been performed by the government or by MCA-Armenia. This question was stated broadly in the survey, and responses could reference any type of infrastructure, including tertiary canals. In fact, the most common source of this repair was perceived to be MCA-Armenia. This is possibly due to the presence of communities in the comparison group that had their tertiary canals rehabilitated by MCA-Armenia, though there was only a small difference between the treatment and comparison groups in terms of the percentage of communities that had rehabilitated tertiary canals. Large infrastructure usually serves multiple communities and is located away from many of them, so construction may not have been visible enough to be salient to the farmers.

Table IV.3. Farmer knowledge of rehabilitation of irrigation infrastructure in past 5 years (percentages)

	Treatment Group Mean	Comparison Group Mean	Difference	*p*-value
No repair or rehabilitation	39	28	11	0.11
Any repair or rehabilitation	50	60	-10	0.17
Rehabilitated by farmers	1	0	1	0.41
Rehabilitated by rural community or community council	3	2	1	0.41
Rehabilitated by WUA	6	14	-8*	0.09
Rehabilitated by government	2	5	-3	0.36
Rehabilitated by MCA-Armenia	37	43	-5	0.34
Rehabilitated by World Bank	2	0	1	0.26
Rehabilitated by other	0	0	0	0.21
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

WUA = water users association.

We also examined whether farmers in the treatment group perceived their irrigation systems to be in better condition at follow-up than farmers in the comparison group did (Table IV.4). The farmers were asked to assess the condition of the irrigation system in their community on a 5-item scale ranging from “very bad” to “very good.” Surprisingly, farmers in the treatment group were *less* likely to report the condition of the system to be good or very good (18 percent) compared to farmers in the comparison group (26 percent), though this difference was not statistically significant. Although we do not have a credible hypothesis for why farmers in the communities whose infrastructure was rehabilitated would have perceived that infrastructure was worse, this does at least indicate that the treatment group did not perceive the large infrastructure rehabilitation as improving their irrigation supply.

The three most commonly cited problems among farmers who did not report their irrigation system condition to be "good" or "very good" were shared by the treatment and comparison groups. Table IV.4 shows the unconditional percentages of farmers who identified each reason as the main problem with irrigation. The main problems were the bad condition of the main canals, a lack of tertiary canals, and bad condition of tertiary canals. There were no statistically significant differences in the prevalence of these three issues. However, farmers in the treatment group were more likely than the comparison group to point to the main problems being bad condition of artesian wells (impact: 6 percentage points) and lack of a clear water supply schedule (impact: 8 percentage points).

Table IV.4. Farmers' perception of main irrigation problems (percentages)

	Treatment Group Mean	Comparison Group Mean	Difference	*p*-value
Evaluated condition of irrigation system as "very good" or "good"	18	26	-8	0.18
Main problems in irrigation systems that were not in "very good" or "good" condition				
Bad condition of main canals	39	34	5	0.46
Lack of tertiary canals	37	36	1	0.85
Bad condition of tertiary canals	39	45	-6	0.39
Bad condition of pump for deep well	3	0	3	0.16
Bad condition of artesian well	6	0	6**	0.03
Bad condition of irrigation pump	6	3	3	0.16
No clear water supply schedule	19	10	8**	0.02
Disorganized water supplier	16	10	6	0.12
No water supply at all	4	8	-4	0.37
High prices for water	2	1	1	0.14
Other	1	0	1	0.30
Don't see any serious problem	1	3	-3*	0.08
Sample size	822	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Most of the village mayors in the treatment and comparison communities reported that there had been at least one irrigation system rehabilitation project since 2009, but comparison communities were 15 percent more likely to report a rehabilitation project than the treatment communities (Table IV.5). About 43 percent of the village mayors in the treatment group, however, believed that there had been no rehabilitation at all since 2009. Again, these percentages seem to reflect a lack of awareness about the large infrastructure rehabilitation efforts by MCC, and the difference appears to be driven by comparison communities being 17 percentage points more likely to report the rehabilitation of a tertiary canal. This difference is unexpected because we control for other types of irrigation infrastructure that actually were rehabilitated under the Compact, including tertiary canals. We did not identify any other efforts to rehabilitate infrastructure within communities that coincided with the timing of the Infrastructure Activity. It could be that there were other donor-funded projects that we did not identify, or it could simply be misreporting.

Table IV.5. Infrastructure reported by village mayors to have been rehabilitated since 2009 (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Irrigation system rehabilitation project implemented since 2009	57	71	-15**	0.05
Reported rehabilitation of...				
Tertiary canal(s)	37	54	-17**	0.02
Main canal(s)	17	12	5	0.45
Pumping station(s)	3	4	-1	0.77
Other	4	5	-1	0.78
None	43	29	15**	0.05
Project(s) reported to have been funded by…				
Community only	2	0	2	0.28
WUA	5	3	2	0.58
World Bank	4	2	2	0.46
MCA-Armenia	46	48	-2	0.70
USAID	0	0	0	.
RA Government	1	6	-5	0.28
Other	3	15	-12**	0.02
Unsure of source	0	0	0	.
None	43	29	15**	0.05
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. Respondents could indicate multiple funders, so the percentages of responses for funders do not sum to 100 percent.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

WUA = water users association; MCA-Armenia = Millennium Challenge Account with Armenia; USAID = United States Agency for International Development; RA = Republic of Armenia.

Compared to village mayors in the treatment group, village mayors in the comparison group were 18 percent more likely to say that there were no natural disasters that severely impacted harvesting. To the extent that these natural disasters decreased the agricultural production of treatment communities in the past year, our estimated impacts will understate the benefits of the large infrastructure rehabilitation. We also note that the incidence of natural disasters in this analytic sample is reversed from the tertiary canal evaluation, where natural disasters were more frequently reported by the tertiary canal comparison group communities than by the tertiary canal treatment communities; there, we surmised that households with improved infrastructure might be better able to shield their harvests from natural disasters. Here, it is also possible that the comparison group had access to other improvements in infrastructure that we did not observe. This reversal in the incidence of natural disasters holds even though the regression-adjusted means presented here control for whether tertiary canals were rehabilitated in the community.[32]

Although differences in weather would affect estimates on production and income, this should not affect farming behavior. Consequently, in interpreting our results, we pay special attention to outcomes such as water use that would have been determined before disasters could have affected harvests. This will help disentangle the effects of those disasters.

Table IV.6. Natural disasters reported by village mayors as seriously affecting harvests during the past agricultural season (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Natural disasters that seriously affected harvests during the past agricultural season				
Flood	2	0	4	0.13
Drought	17	14	3	0.62
Hail/other downfall	48	44	4	0.70
Frostbite/freeze	19	14	4	0.57
Other	7	0	7*	0.06
None	23	41	-18*	0.07
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Village Mayor Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

E. Impacts of rehabilitated large infrastructure on water use

This section discusses whether the short-term objectives of increasing the availability and reliability of irrigation water were met. We examined the following outcomes from the Tertiary Canal Survey that were also used in the tertiary canal evaluation: water user association membership, use of irrigation water, perceptions of improvements to the irrigation supply system, amount of land irrigated, frequency and duration of irrigation, and perceived timeliness and adequacy of irrigation water. The survey data thus allow us to examine detailed measures of farmers' water use for the survey sample. In Section VII, we examine aggregated data from water user associations to examine total water deliveries and total irrigated land area, including farms that are not covered by the survey sample.

Examining water user association membership rates, we found that about 75 percent of households at follow-up were water user association members, and the rates of water user

[32] As described in the evaluation of tertiary canals, national annual precipitation did not appear to vary widely from 2009 through 2014. Annual precipitation in this period was centered around average levels from 1961 to 1990 (National Statistical Service 2015b).

association membership were similar for the treatment and comparison groups (Table IV.7). Water user association membership rates are a useful indicator for understanding the proportion of our sample that is using irrigation water regularly. At baseline, 32 percent of farmers in the large infrastructure analysis sample reported that they did not receive water when needed and they did not receive as much water as needed, and 40 percent irrigated some arable land at baseline.

There was no evidence of systematic differences between the treatment and comparison group in the reasons why households were not water user association members. The percentage of farmers who reported each reason are reported in Table IV.7. Households in the treatment group were more likely than those in the comparison group to state that the main reason for not being a water user association member was that the water user association was not effective ($p < 0.01$)—however, this reason is still cited infrequently (4 percent in the treatment group; 0 percent in the comparison group). There was also no difference in the percentage of households that irrigated with network irrigation water exclusively.

Table IV.7. Impacts of rehabilitated large infrastructure on water user association membership and exclusive use of network irrigation water for irrigation (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
WUA member	78	74	5	0.38
Not a WUA member	22	26	-5	0.38
Main reason for not being a WUA member				
No WUA in village	6	11	-5	0.30
Did not know membership process for WUA	0	0	0*	0.10
Did not know about WUA	4	2	2	0.25
Did not want irrigation water	3	7	-4	0.14
Costs of WUA membership	1	2	-2	0.25
WUA is not effective	4	0	3***	0.01
Other	4	3	0	0.75
Did not irrigate with network irrigation water exclusively	31	33	-2	0.71
Sample size	819	522		

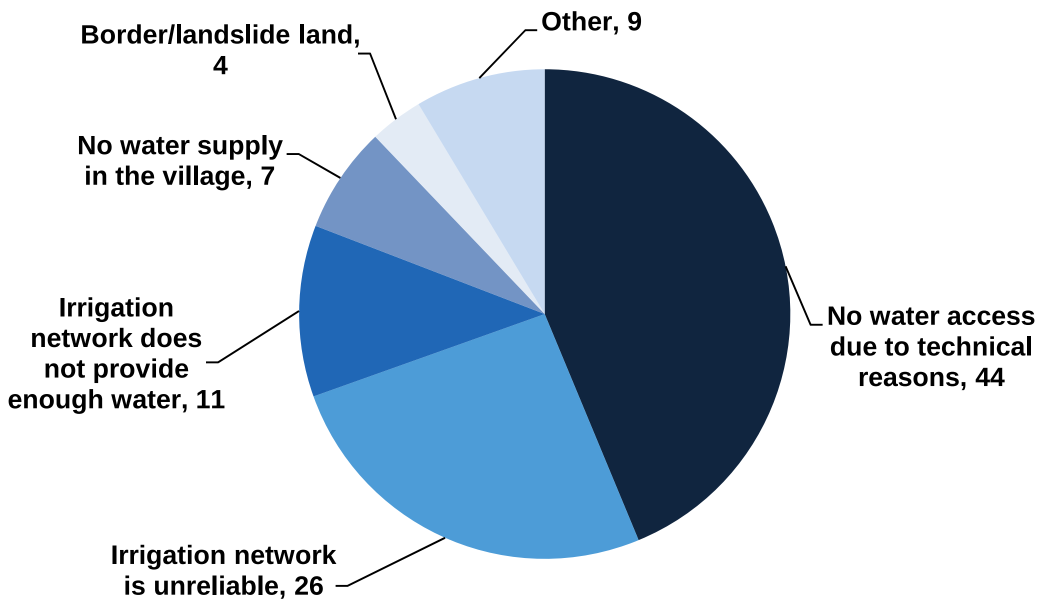
Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. “Other” includes other reasons and other personal reasons.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

We then explored why households did not irrigate with network irrigation water exclusively (Figure IV.2). In the treatment group, 81 percent of households did not use network irrigation water exclusively for three reasons; among that group, most farmers said they had no water access due to technical reasons (44 percent), believed the irrigation network was unreliable (26 percent), or thought the irrigation network did not provide enough water (11 percent). The latter two reasons reflect dissatisfaction with the irrigation system.

Figure IV.2. Reasons for not using network irrigation water exclusively (treatment group only, percentages)

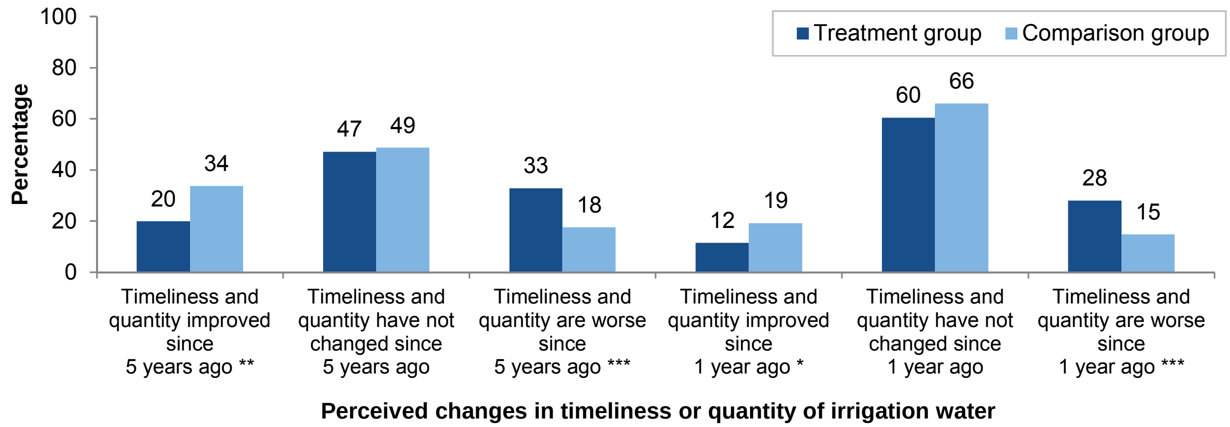


Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Percentages are calculated among farmers who do not use network irrigation water exclusively. “Other” reasons for the treatment group include could not pay for irrigation, land was normative, no water access due to organizational/managerial reasons, water not delivered as promised, irrigation water was not necessary due to weather, need additional equipment, land is not cultivated, other, and unprofitable because it is too expensive.

We examined farmers’ perceptions of changes in irrigation supply compared to five years ago as a way of assessing perceived improvements from before the MCA-funded infrastructure rehabilitation (Figure IV.3). We also examined perceived changes in irrigation supply compared to one year ago, in the period after irrigation infrastructure was rehabilitated, to help assess sustainability of the infrastructure after rehabilitation was complete. Comparing farmers’ perceptions of changes in irrigation supply, we found that the comparison group was significantly more likely to perceive improvements in the timeliness and quantity of irrigation water since five years ago and since one year ago. This is consistent with the relatively high proportions of the treatment group that did not use network irrigation water exclusively for reasons that indicate dissatisfaction with the irrigation network (Figure IV.2) but unexpected given that, as far as we are aware, there were no major investments in infrastructure for the comparison group. In contrast, households in the treatment group were significantly more likely than households in the comparison group to report that timeliness and quantity had worsened since five years ago and since one year ago. The majority of households in both the treatment and comparison groups, however, reported that there had been no change in the timeliness and quantity of irrigation water since one year ago.

Figure IV.3. Impacts of rehabilitated large irrigation on perceptions of irrigation supply system (percentages)



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

We then compared the amounts of land owned or rented and irrigated by households in the treatment and comparison groups (Table IV.8). We found that the rehabilitated large infrastructure led to statistically significant decreases of about 0.3 hectares for the treatment group in the amounts of total agricultural land and arable land. There were no meaningful differences on other types of land, either overall or for irrigated land.[33]

[33] Given our analysis sample size and the standard error of our impact estimate for irrigated land, the minimum detectable impact for irrigated land is 0.41 hectares. More information about minimum detectable impacts for key outcomes is shown in Table A.8.

Table IV.8. Impacts of rehabilitated large infrastructure on land owned or rented and land irrigated (hectares)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Total agricultural land				
All	1.4	1.8	-0.3**	0.05
Irrigated	0.7	0.8	0.0	0.70
Arable land				
All	1.0	1.3	-0.3*	0.05
Irrigated	0.4	0.4	0.0	0.65
Orchard				
All	0.1	0.1	0.0	0.49
Irrigated	0.1	0.1	0.0	0.57
Vineyard				
All	0.1	0.1	0.0	0.24
Irrigated	0.1	0.1	0.0	0.43
Kitchen plot				
All	0.2	0.2	0.0*	0.05
Irrigated	0.1	0.2	0.0	0.13
Other				
All	0.0	0.0	0.0	0.84
Irrigated	0.0	0.0	0.0**	0.05
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Despite the decreases in the amount of land that was irrigated, there were no significant reductions in the frequency or duration of irrigation on arable land (Table IV.9). We found some evidence, however, of farmers irrigating some crop types more intensively. Farmers in the treatment group provided about 3.2 more hours of irrigation for vineyards and 0.5 more hours for other land per week than did farmers in the comparison group.

Table IV.9. Impacts of rehabilitated large infrastructure on frequency and duration of irrigation

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Arable land				
Number of times land was irrigated	1.7	2.0	-0.3	0.47
Total hours of irrigation	16.0	12.8	3.2	0.26
Orchards				
Number of times land was irrigated	0.7	0.7	0.0	0.97
Total hours of irrigation	4.1	4.0	0.2	0.87
Vineyards				
Number of times land was irrigated	0.5	0.4	0.1	0.18
Total hours of irrigation	5.0	1.8	3.2**	0.02
Kitchen plot				
Number of times land was irrigated	4.5	4.8	-0.3	0.70
Total hours of irrigation	11.4	12.2	-0.8	0.67
Other				
Number of times land was irrigated	0.1	0.0	0.1**	0.03
Total hours of irrigation	0.5	0.0	0.5**	0.04
Sample size	809	509		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

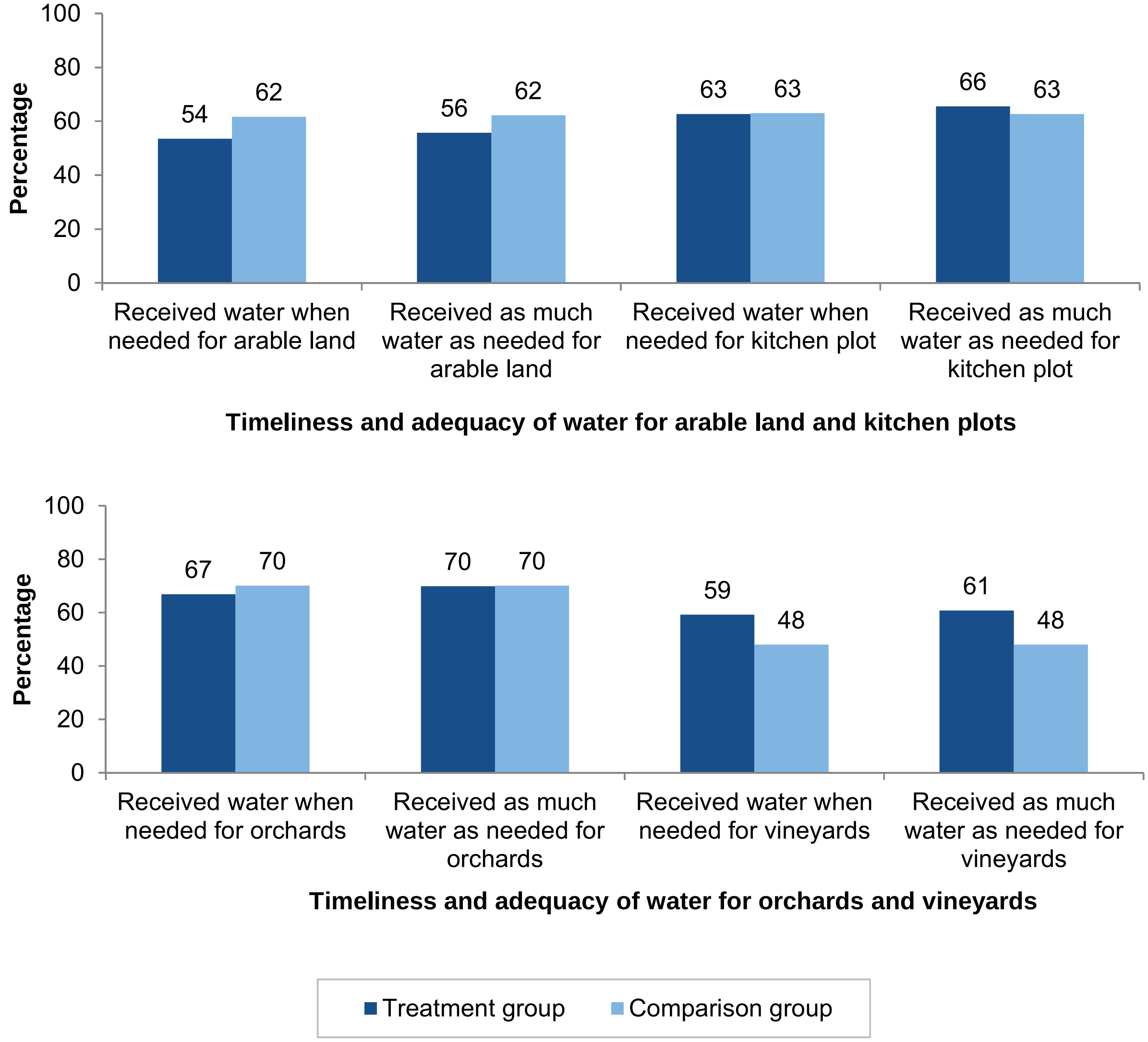
Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

When asked about the sufficiency of the amount of irrigation water, farmers in the treatment group had more or less positive responses than the comparison group depending on the type of land (Figure IV.4). As in the tertiary canal evaluation, the responses shown are conditional on farmers having the type of land being examined, so the sample sizes differ by land type. As in Figure III.5, we did not do statistical testing because the percentages are conditional. Most farmers had kitchen plots (888) or arable land (506), whereas only 175 farmers had vineyards and 210 farmers had orchards.

Treatment farmers were roughly as or more likely to say that they received water when needed and they received as much water as needed for all types of land except arable land. Farmers in the treatment group who had orchards provided the most favorable responses about access to irrigation water, and farmers who had kitchen plots in the comparison group were the least likely to provide favorable responses about access to irrigation water.

Figure IV.4. Farmers' perceptions of receiving enough water in a timely manner, by land type (percentages)



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: The reported percentages are conditional on the farmer owning arable land, a kitchen plot, orchards, or vineyards.

For some key intermediate outcomes, we assessed whether there were impacts on outcomes among female-headed households (Table IV.10). This subgroup is small, containing only 89 households in the treatment group and 66 households in the comparison group. However, we see a similar pattern of irrigating less arable land and increasing the duration of irrigation for vineyards.

Table IV.10. Impacts of rehabilitated large infrastructure on intermediate outcomes for female- and male-headed households

	Impact among Households with Female Head of Household	*p*-value	Impact among Households with Male Head of Household	*p*-value
WUA member (percentage)	1	0.87	5	0.31
Irrigated land with network water exclusively (percentage)	-11	0.21	3	0.62
Arable land				
All (hectares)	-0.4**	0.04	-0.3*	0.06
Irrigated (hectares)	-0.2*	0.08	0.0	0.66
Total hours of irrigation	-7.6	0.32	3.8	0.18
Orchards				
All (hectares)	0.0	0.40	0.0	0.46
Irrigated (hectares)	0.0	0.70	0.0	0.56
Total hours of irrigation	1.5	0.52	0.1	0.92
Vineyards				
All (hectares)	0.0	0.62	0.0	0.20
Irrigated (hectares)	0.0	0.85	0.0	0.46
Total hours of irrigation	1.7	0.34	3.4**	0.02
Kitchen plot				
All (hectares)	0.0	0.16	0.0*	0.06
Irrigated (hectares)	0.0	0.50	0.0*	0.10
Total hours of irrigation	-2.1	0.68	-0.6	0.72
Sample size (T; C)	89; 66		730; 456	

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

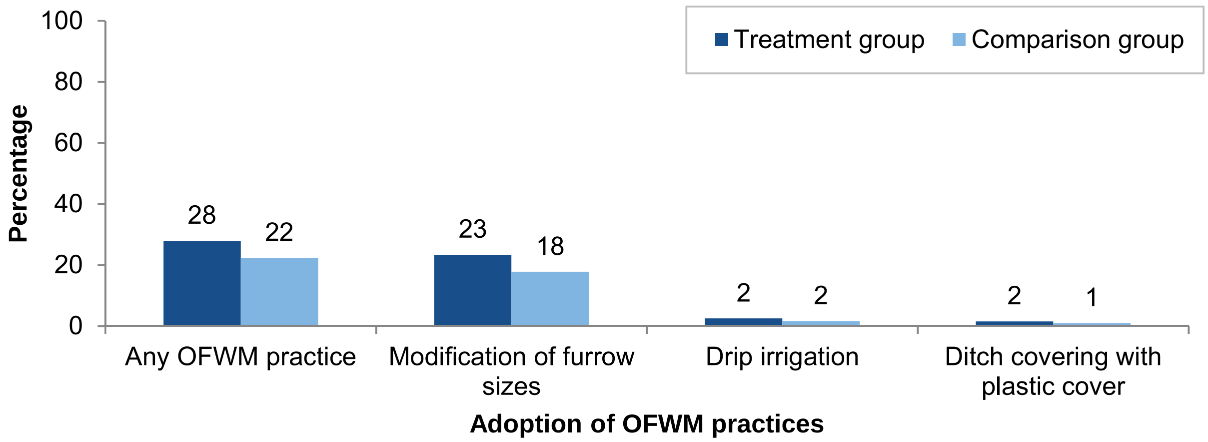
WUA = water users association.

F. Impacts of rehabilitated large infrastructure on agricultural practices

This section explores whether the rehabilitation of large infrastructure led to changes in farmers' on-farm water management practices and high-value agriculture practices. These agricultural practices were emphasized in Water-to-Market training, and we expected that they would be especially valuable to farmers once they had access to improved irrigation water supply that would influence agricultural production. At follow-up, 55 percent of farmers in the treatment group and 57 percent of farmers in the comparison group reported attending a training about on-farm water management or high-value agriculture, both of which could have been through the Water-to-Market program, though as we discuss more in Chapter VI, probably include training received through other programs as well. Our analysis controlled for the availability of Water-to-Market farmer training, so the impacts in this chapter are focused on the Infrastructure Activity.

We did not find any impacts on the adoption of on-farm water management practices (Figure IV.5). About 28 percent of households in the treatment group used any on-farm water management practice, a figure driven primarily by higher rates of modifying furrow sizes; there was no meaningful adoption of any other practices.[34]

Figure IV.5. Impacts of rehabilitated large infrastructure on on-farm water management practices (percentages)



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. Modification of furrow sizes includes modifying the length, width, depth, and spacing of furrows.

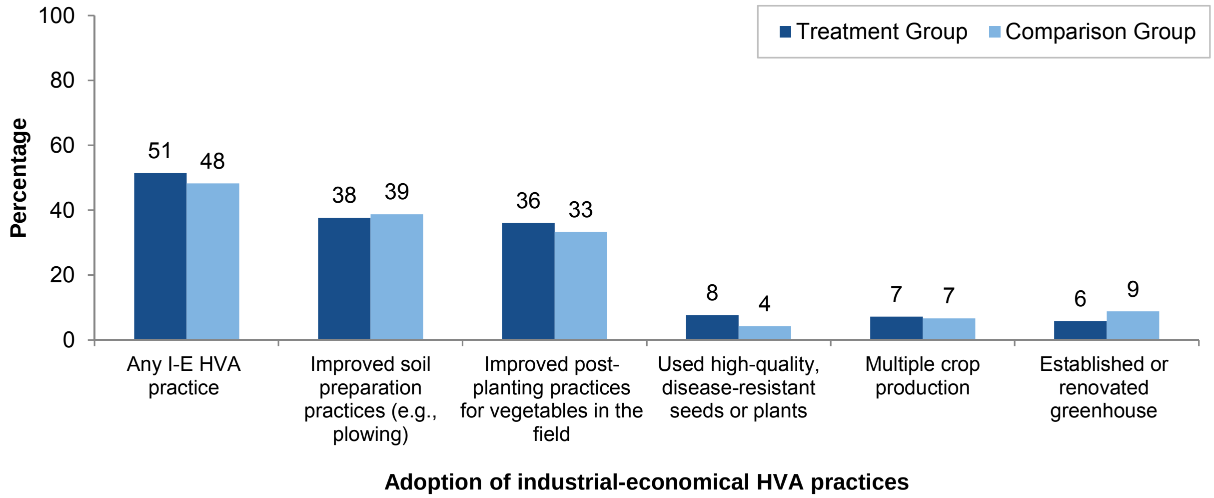
*/**/*** Significantly different from 0 at the .10/.05/.01 levels, respectively, two-tailed test.

OFWM = on-farm water management.

There was also little evidence that treatment group farmers were more likely to adopt industrial-economical high-value agriculture practices (Figure IV.6). About half of the treatment and comparison group farmers adopted at least one industrial-economical high-value agriculture practice. There were no meaningful differences in the adoption rates among the five most prevalent industrial-economical high-value agriculture practices.

[34] At baseline, 45 percent of farmers reported modifying furrow sizes, and this contributed to an overall on-farm water management practice adoption rate of 51 percent in the treatment group and 50 percent in the comparison group (Table A.5). However, as described in the evaluation of rehabilitated tertiary canals, these rates are not directly comparable to the on-farm water management adoption rates at follow-up because of differences in how the survey enumerators described furrow spacing to respondents. Baseline information was not collected on industrial-economical and social-environmental high-value agricultural practices.

Figure IV.6. Impacts of rehabilitated large infrastructure on industrial-economical HVA practices (percentages)



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. Modification of furrow sizes includes modifying the length, width, depth, and spacing of furrows.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

HVA = high-value agriculture; I-E = industrial-economical.

Finally, we did not observe systematic impacts in the adoption of social-environmental high-value agriculture practices (Table IV.11). Overall, about 80 percent of farmers used at least one social-environmental high-value agriculture practice. The impact estimate for using the practice of buying pesticides for a specific problem, avoiding residuals, was marginally significant (14 percentage points). However, given the number of agricultural practices we examine in this section, we were likely to find at least one impact estimate that approached significance by chance, especially considering that there is no compelling reason to expect that pesticide purchases would be more affected by the infrastructure rehabilitation than are other on-farm water management and high-value agriculture practices.

Overall, we have found no evidence that the rehabilitated large infrastructure led to changes in agricultural practices.

Table IV.11. Impacts of rehabilitated large infrastructure on social-environmental HVA practices (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Any social-environmental HVA practice	82	78	4	0.30
Have used only the pesticides permitted in the Republic of Armenia	71	63	8	0.13
Have bought pesticide from licensed stores	53	48	4	0.51
Have bought pesticides only for a specific problem, avoiding the residuals	53	39	14*	0.05
Have followed the pesticide's waiting period before harvest	29	32	-3	0.68
Have used personal protection equipment while working with pesticides	33	39	-6	0.35
Have paid attention on the packaging and the tare completeness of pesticides	37	37	-1	0.94
Have used organic fertilizers applying the right technology	23	27	-4	0.57
Have paid attention on the normalized usage of chemical fertilizers	8	10	-2	0.67
Have not burned or dumped pesticides' residuals and tare	22	22	-1	0.92
Have used nonchemical methods of pest and disease management	3	2	0	0.78
Have stopped burning plants that are remaining after harvesting	0	1	0	0.62
Have prepared compost and used it as an organic fertilizer	30	29	1	0.88
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

G. Impacts of rehabilitated large infrastructure on agricultural production

Next, we discuss whether the rehabilitation of large infrastructure led to changes in farmers' agricultural production, either through higher yields or cultivation of higher-value crops.

We first examined the amount of land cultivated to assess whether the rehabilitation of the large infrastructure allowed farmers in the treatment group to cultivate more land than farmers in the comparison group did (Table IV.12). We found no impacts on land cultivation, either overall or for land specifically used to cultivate high-value and non-high-value crops.[35,36] This was also observed for the tertiary canal evaluation, though the average land areas here are smaller than in the tertiary canal rehabilitation sample.

Table IV.12. Impacts of rehabilitated large infrastructure on land cultivation (hectares)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Total	1.2	1.4	-0.1	0.45
HVA crops	0.4	0.4	0.0	0.69
Non-HVA crops	0.7	0.9	-0.2	0.22
Percentage of total land that is HVA crops	0.6	0.5	0.0	0.33
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from 0 at the .10/.05/.01 levels, respectively, two-tailed test.

HVA = high-value agriculture.

We then explored which types of crops were cultivated by the two groups of farmers. The rehabilitation of large infrastructure was expected to increase high-value crop production because high-value crops require reliable access to water. As in Chapter III, we found that almost all farmers grew at least one high-value crop, though only about half of farmers grew at least one non-high-value crop (Table IV.13; see Appendix Table B.3 for impacts on each crop). Less than a quarter of farmers grew grapes, and more than 60 percent of farmers reported growing other fruits or nuts.[37]

There was no impact of the large infrastructure rehabilitation on whether farmers grew at least one high-value crop. However, there were negative impacts for specific crop categories. The largest decreases in high-value agriculture crop cultivation were for tomatoes, followed by vegetables and herbs. Farmers in the treatment group were about 11 percentage points less likely

[35] High-value crops include apple, grape, peach, apricot, pear, prunes, plum, fig, pomegranate, sweet cherry, cherry, cornel, quince, watermelon, melon, pumpkin, lemon, Malta orange, walnut/hazelnut, strawberry, tomato, cucumber, eggplant, pepper, cabbage, carrot, squash, onion, garlic, potato, red beet, sunflower, haricot, tobacco, greens, planting stock, flowers, other fruits, and other vegetables. Non-high-value crops include wheat, emmer wheat, barley, maize, sorgo, grass, and gramma or other special feed.

[36] Given our analysis sample size and the standard error of our impact estimate for land under cultivation for HVA crops, the minimum detectable impact for land cultivated for HVA crops is 0.16 hectares. More information about minimum detectable impacts for key outcomes is shown in Table A.8.

[37] Other fruits or nuts include apple, peach, apricot, pear, prunes, plum, fig, pomegranate, sweet cherry, cherry, cornel, quince, watermelon, melon, lemon, Malta orange, walnut/hazelnut, strawberry, and other fruits. Vegetables and herbs include pumpkin, cucumber, eggplant, pepper, cabbage, carrot, squash, onion, garlic, red beet, greens, and other vegetables.

to grow tomatoes ($p < 0.01$) and 9 percentage points less likely to grow vegetables and herbs ($p < 0.10$).

Farmers in the treatment group were about 8 percentage points less likely than farmers in the comparison group to grow at least one non-high-value agriculture crop ($p < 0.10$). This difference is largely driven by the likelihood to grow grain, where farmers in the treatment group were about 9 percentage points less likely to grow grain than farmers in the comparison group ($p < 0.05$).

Farmers were also asked whether they changed cropping patterns from the last agricultural season during the most recent agricultural season. This measure functions as a leading indicator for impacts that have not yet been realized but could be in the future. Observing farmers in the treatment group changing their cropping patterns during the most recent agricultural season could suggest later impacts on production. However, we found that there was no impact of the large infrastructure rehabilitation on farmers changing cropping patterns since the last agricultural season ($p > 0.10$). Only about 5 percent of farmers in the treatment and comparison groups reported switching crops. Given the low incidence of this measure and the negative sign of the estimate, it is unlikely that there would be marked changes in agricultural production in the future.

Table IV.13. Impacts of rehabilitated large infrastructure on crop types cultivated by farmers (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
HVA crops	94	94	0	0.97
Grape	22	19	3	0.50
Other fruits or nuts	64	70	-6	0.27
Tomato	26	37	-11***	0.01
Vegetables and herbs	38	47	-9*	0.09
Potato	28	28	1	0.89
Non-HVA crops	53	61	-8*	0.10
Grain	28	37	-9**	0.02
Grass	36	36	0	1.00
Changed cropping pattern since last agricultural season	5	5	-1	0.82
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

HVA = high-value agriculture.

Despite the differences in the types of crops cultivated, we did not find any impacts on agricultural production, revenues from crops sold, or market values of harvests (Table IV.14). As before, these impacts are presented for overall crops, for high-value agriculture crops and non-high-value agriculture crops, and for the major crop categories within high-value agriculture crops and non-high-value agriculture crops.[38] Crop-specific impacts are presented in Appendix Tables B.3 and B.4.

Table IV.14. Impacts of rehabilitated large infrastructure on production, revenues, and market value of harvests (USD except where indicated)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Agricultural Production (Metric Tons)				
Total	7.92	8.81	-0.88	0.32
HVA crops	4.77	5.55	-0.78	0.24
Grape	0.62	0.47	0.15	0.35
Other fruits or nuts	1.23	1.20	0.03	0.90
Tomato	0.46	0.60	-0.14	0.30
Vegetables and herbs	0.97	1.29	-0.31	0.23
Potato	0.67	1.25	-0.58	0.18
Non-HVA crops	2.39	2.68	-0.29	0.51
Grain	0.78	1.04	-0.25	0.16
Grass	1.44	1.43	0.00	0.99
Revenues from Crops Sold				
Total	1,559	1,606	-47	0.82
HVA crops	1,313	1,369	-55	0.77
Grape	208	162	46	0.44
Other fruits or nuts	250	265	-15	0.82
Tomato	139	161	-23	0.60
Vegetables and herbs	346	318	28	0.71
Potato	92	144	-52	0.46
Other HVA crops	19	16	3	0.74
Non-HVA crops	172	158	13	0.77
Grain	97	114	-17	0.65
Grass	44	26	18	0.19
Other non-HVA crops	0	0	0	0.31
Market Value of Harvests				
Total	2,337	2,743	-406*	0.08
HVA crops	1,748	2,029	-281	0.23
Grape	229	204	25	0.67
Other fruits or nuts	435	462	-27	0.77
Tomato	171	223	-51	0.28
Vegetables and herbs	412	437	-25	0.81
Potato	172	315	-143	0.14
Other HVA crops	25	23	2	0.86
Non-HVA crops	484	591	-107	0.23
Grain	273	372	-99	0.12
Grass	192	188	4	0.93
Other non-HVA crops	0	0	0	0.31
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding. Other high-value agriculture crops include sunflower, haricot, tobacco, planting stock, and flowers. Other non-high-value agriculture crops include sorgo.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

USD = United States dollars; HVA = high-value agriculture.

[38] The “Total” group excludes a few crop categories whose harvest amounts are not reported in tons: sorgo, greens, planting stock, and flowers.

Examining the costs of production, we found limited evidence that the rehabilitated large infrastructure influenced agricultural expenditures (Table IV.15). The only significant impact was observed for expenditures on irrigation, on which treatment farmers spent $31 more than comparison farmers. This might be evidence of increased agricultural investments that would complement irrigation infrastructure. However, we again caution that our report covers a wide range of outcome measures, and this statistically significant finding could be due to chance.

Table IV.15. Impacts of rehabilitated large infrastructure on agricultural expenditures (USD)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Total	839	808	30	0.69
Irrigation	104	73	31**	0.02
Seeds and seedlings	112	120	-8	0.73
Fertilizers and pesticides	213	209	4	0.82
Hired labor, equipment, and tools	251	267	-17	0.65
Taxes and duties	43	39	4	0.31
Cellophanes	57	51	7	0.72
Other major expenses	4	6	-2	0.47
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

USD = United States dollars.

The program logic anticipated that communities with rehabilitated large infrastructure would increase and diversify their agricultural production. We have observed instead that farmers in the treatment group did not cultivate as many types of crops. In addition, there were no impacts on agricultural production. These two observations suggest that large infrastructure rehabilitation allowed farmers to specialize. However, it is possible that these impacts instead reflect differences between the treatment and comparison groups that are not fully addressed by our methods, such as the incidence of natural disasters as described earlier in this chapter. To provide a more complete view of the impacts of the large infrastructure on household well-being and to learn more about potential alternative mechanisms, we next describe the impacts of large infrastructure rehabilitation on income and poverty.

H. Impacts of rehabilitated large infrastructure on income and poverty

We examined the impacts of large infrastructure on household income and its two components: nonagricultural income and agricultural profit (agricultural income based on the market value of harvests minus agricultural expenses). Nonagricultural income includes income from all sources other than the household's own agricultural production. In Table IV.16, the sum of the impact estimates on nonagricultural income and agricultural profit do not equal the impact on economic income because each variable is censored separately to address outliers. The estimates for agricultural profit follow from the findings on agricultural income and agricultural expenses, discussed in Section IV.G.

We found limited evidence that the rehabilitated large infrastructure led to decreases in agricultural profits that might have been offset by increases in nonagricultural income; overall, there was no impact on total economic income.[39] Large infrastructure rehabilitation decreased agricultural profits by $398. This decrease is both statistically and economically significant, representing nearly 22 percent of the comparison group's agricultural profits. Our impact estimate for nonagricultural income is not statistically significant; its magnitude is similar but with the opposite sign as the impact on agricultural profits ($389; $p < 0.12$).

Nonagricultural income was not expected to be impacted by large infrastructure in the program logic. Although we cannot conclusively identify the mechanisms for this impact, one hypothesis is that large infrastructure improvements benefitted agricultural production of larger farms that were not in our analytic sample—the increased production by these farms might have made agricultural production less attractive for the smaller farms that make up our analytic sample, leading household members to seek nonagricultural income (perhaps at the larger farms). The typical household in our sample cultivated less than 1.5 hectares of land. We also emphasize that remaining differences between the treatment and comparison groups, such as the higher incidence of natural disasters among the treatment group, might be driving these results.

Table IV.16. Impacts of rehabilitated large infrastructure on annual economic household income (USD)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Nonagricultural income	4,042	3,653	389	0.11
Agricultural income				
Total value of harvest	2,337	2,743	-406*	0.08
Economic agricultural profit (value – costs)	1,452	1,850	-398**	0.02
Total economic income	5,693	5,625	68	0.83
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

USD = United States dollars.

To identify whether these changes reduced poverty, we examined whether households' consumption fell below several measures of the poverty line: the food poverty line, the lower poverty line, and the upper poverty line. We examined poverty based on consumption rather than income because consumption has lower variance than income. Consistent with what we observed for the tertiary canal sample, most households' consumption did not fall under the food poverty line: less than 3 percent of the treatment and comparison groups had adult-equivalent consumption that fell below the food poverty level. Although a greater proportion of households

[39] Given our analysis sample size and the standard error of our impact estimate for total economic income, the minimum detectable impact for economic income is $854. More information about minimum detectable impacts for key outcomes is shown in Table A.8.

fell below the less severe poverty lines, these rates were on par with the tertiary canal sample and, again, lower than those observed in the Water-to-Market sample.

There were no impacts on the poverty rates (Table IV.17), although there was a negative, marginally significant decrease in the lower poverty rate. Farmers in the treatment group were 2.8 percentage points less likely to fall below the lower poverty line than were farmers in the comparison group ($p < 0.10$).

Table IV.17. Impacts of large infrastructure on poverty rates (percentages)

	Treatment Group Percentage	Comparison Group Percentage	Impact	*p*-value
Households in food poverty	2.7	2.5	0.2	0.82
Households below lower poverty line	7.4	10.3	-2.8*	0.09
Households below upper poverty line	15.1	17.9	-2.9	0.26
Sample size	825	523		

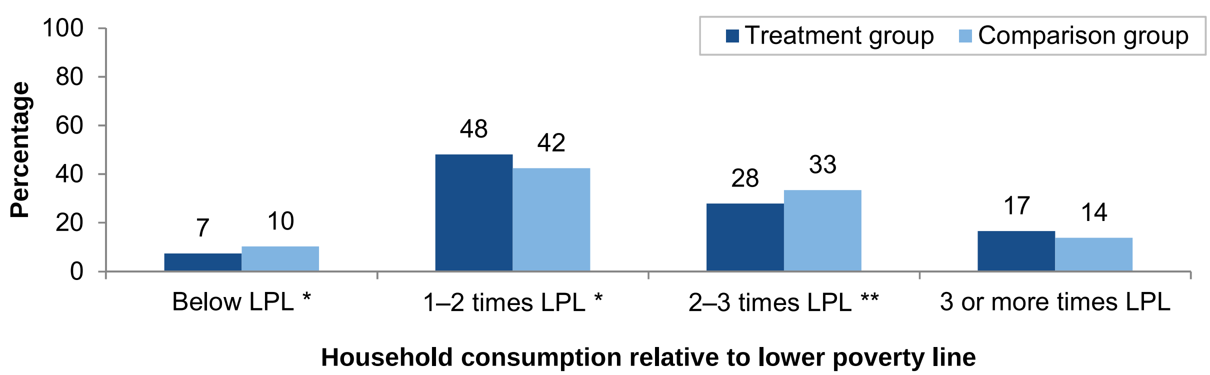
Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

In Figure IV.7, we show the distributions of consumption relative to the lower poverty line for farmers in the treatment and comparison groups. As in the tertiary canal sample, households in both the treatment and comparison groups are most likely to fall between one and two times the lower poverty line (48 and 42 percent, respectively). Although some of the comparisons here are marginally significant, they are not consistent with each other and may be due to chance in the distributions.

Figure IV.7. Consumption of respondent households relative to the lower poverty line (percentages)



Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

LPL = lower poverty line.

The differences in the distributions of consumption did not translate into any statistically significant impacts on the mean consumption relative to each of the poverty lines (Table IV.18). Overall, we conclude that there were no impacts on consumption.

Table IV.18. Impacts of large infrastructure on consumption relative to poverty lines (means)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value
Consumption relative to food poverty line	302	301	1	0.92
Consumption relative to lower poverty line	215	214	1	0.92
Consumption relative to upper poverty line	177	177	1	0.92
Sample size	825	523		

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from 0 at the .10/.05/.01 levels, respectively, two-tailed test.

To test more directly whether the tertiary canal rehabilitation had distributional effects, we calculated impacts on consumption of households relative to the lower poverty line by the size of the buffer that households had from the lower poverty line at baseline (Table IV.19). None of these impacts was significant.

Table IV.19. Impacts of large infrastructure on consumption of respondent households relative to the lower poverty line, by baseline consumption level (percentages)

	Treatment Group Mean	Comparison Group Mean	Impact	*p*-value	Sample Sizes (T; C)
Below LPL at baseline	176	176	0	0.98	144; 88
1–2 times LPL at baseline	200	211	-11	0.23	416; 252
2–3 times LPL at baseline	249	228	21	0.19	161; 128
3 or more times LPL at baseline	277	268	9	0.61	98; 53

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Treatment and comparison group percentages were estimated using regression adjustment. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from 0 at the .10/.05/.01 levels, respectively, two-tailed test.

LPL = lower poverty line.

Our findings from Chapter IV thus suggest that the rehabilitated large infrastructure did not improve households' economic well-being. Households in the treatment group did not report substantial improvements in their perceptions of their water supply, and there were no impacts on adoption of on-farm water management and high-value agriculture practices.

Although there were no impacts on total income or consumption, there was limited evidence that the rehabilitated large infrastructure decreased the diversity of crops cultivated by farmers, and this in turn decreased agricultural income. Although not statistically significant, the impact estimate on nonagricultural income is positive and appears to offset the decrease in agricultural income. One possibility is that the rehabilitated infrastructure induced some farmers to specialize their production and provide more nonagricultural labor.

V. OVERVIEW OF FINDINGS FOR THE IRRIGATION INFRASTRUCTURE ACTIVITY

A. Summary

The rehabilitation projects under MCC's Irrigation Infrastructure Activity were designed to improve agricultural production and reduce rural poverty in Armenia. By the end of the program in September 2011, 220 km of tertiary canals, 42 km of main canals, 17 pumping stations, 5 gravity schemes, and 13 drainage systems were rehabilitated, affecting around 300 communities and more than 420,000 beneficiaries. The final cost of the rehabilitation projects was about $122 million USD. The present report estimates impacts on agricultural production and household income two to three years after rehabilitation was completed and reports intermediate outcomes such as access to and reliability of water, water usage, and agricultural practices.

Using survey data that were collected to evaluate the rehabilitation of tertiary canals, we found some evidence that the rehabilitation of tertiary canals improved access to and reliability of irrigation water. Farmers in the treatment group were more likely to be water user association members and use network irrigation exclusively. They were also more likely to say that the timeliness and quantity of their water supply had improved since five years ago and since one year ago. Total hours of irrigation increased for arable land and kitchen plot land, compared to what farmers in the comparison group reported. However, these improvements in irrigation water use did not lead to a general increased adoption of agricultural practices. There was minimal evidence that farmers increased their agricultural production, income, economic profit, or consumption; in fact, there was weak evidence that the rehabilitated tertiary canals caused consumption to decrease.

The evaluation of rehabilitated large infrastructure utilized the same survey data for a subset of communities. However, there was no evidence that the rehabilitation of large infrastructure had similar positive impacts on most measures of irrigation water use, with the exception of spending more time irrigating orchards and vineyards. Farmers in the large infrastructure treatment group were actually more likely to report dissatisfaction with the timeliness and quantity of irrigation water than were farmers in the comparison group and were no more likely to rely exclusively on network irrigation water for their agricultural production. They were not substantially more likely to adopt key agricultural practices, and there was evidence that farmers cultivated fewer crop types. Market values of the treatment group's harvests were negative, leading to decreases in agricultural income, but there were no impacts on overall economic income because of a substantial but not statistically significant increase in nonagricultural income.

One of the key pathways through which rehabilitating irrigation systems was intended to improve farming households' wellbeing was by facilitating a shift away from grains and other lower-value crops to high-value crops such as fruits and vegetables, but this pathway was not realized. Many of the farmers whose irrigation supply should have been improved reported that irrigation was still not sufficient or reliable—the most commonly-reported reason for not cultivating high-value crops in their agricultural fields.[40] The next most common reason was a lack of interest in expanding agricultural production, which may be especially salient because many farmers only farm part-time and on a small scale due to outside employment.

A crucial assumption in our methods is that our models account for all variables that could lead the treatment and comparison groups to have different outcomes in the absence of the rehabilitation. Our methods establish that the treatment and comparison groups are similar on key outcome measures at baseline and many other characteristics, but some of the follow-up differences indicate the two groups may still have had a few underlying differences for which we cannot fully account. For instance, in the evaluation of rehabilitated large infrastructure, the treatment group was significantly more likely to report experiencing a natural disaster than the comparison group, which would bias our estimates toward understating positive effects. These weather patterns could bias the impact estimates for production and income-related outcomes in the negative direction and could possibly explain our null and negative estimates for some outcomes. However, they are unlikely to affect the irrigation and agricultural practices chosen before the harvest, so those estimated impacts should not be biased by differences in actual disasters experienced.

B. Benefit-cost analysis for the Infrastructure Activity

MCC estimated benefits and costs at the outset of the Compact to help determine whether the projected benefits of rehabilitating irrigation infrastructure were sufficiently large to justify the costs. Its estimates projected the benefits and costs expected for the activity over the 20-year time horizon that is standard for benefit-cost analyses in MCC Compacts, beginning with the first year of the Compact and ending 15 years after Compact close. MCC found that the *ex ante* estimated economic rate of return was 24 percent, meaning that the projected benefits substantially outweighed the projected costs (MCC 2011).[41]

Most of the costs contained in the economic rate of return model are for the construction work that was part of the project and were incurred in the second through fifth years of the Compact. They also factor in the costs of the Institutional Strengthening Subactivity that was designed to support the sustainability of the irrigation infrastructure investments.

The primary component of the benefits in MCC's *ex ante* model is households' increased agricultural income—which itself depends largely on increased area irrigated and greater yields per hectare—with energy savings for some types of rehabilitated infrastructure (such as gravity schemes) playing a small role. MCC projected immediate impacts of the irrigation rehabilitation

[40] Over half of the responses were that irrigation is not sufficient or reliable, and 30 percent were that there was no interest in expanding production. These tabulations are done among farmers who reside in a treatment group community for either the tertiary canal or the large infrastructure evaluation, and multiple responses are permitted from each farmer. The question was intended to be asked among those who did not cultivate fruits or vegetables in the field even if they did cultivate fruits or vegetables on their kitchen plots. However, some people who only cultivated on the kitchen plot were not asked these questions, erroneously.

[41] MCC previously referred to related analyses in the Compact and previous report as analyses of the economic rate of return but now characterizes these analyses as benefit-cost analyses. In the present report, what we call the economic rate of return is the calculated interest rate at which the discounted net benefits and discounted costs are equal, as was the case with MCC's *ex ante* benefit-cost analysis.

on households' agricultural income due to greater access to and reliability of irrigation water for land already under cultivation. MCC projected that the impacts on households' agricultural income would grow over time as farmers adapted further to the improved water supply by expanding the area under cultivation and shifting to more water-intensive but higher-value crops, such as orchards. The exact projected benefits vary somewhat for different types of irrigation infrastructure, but the broad pattern of benefits is shared across all types of irrigation infrastructure—immediate impacts after rehabilitation, with benefits doubling by six years after rehabilitation and tripling by the 10th year after rehabilitation.

As of two years after rehabilitation was complete, irrigated land was expected to increase by about nine percent, but by much more than that for specific types of projects. Income was expected to increase by a greater percentage because of the joint benefit streams of more irrigated land and greater yields per hectare. Two years after rehabilitation was completed, the projected effects of rehabilitating specific types of infrastructure were as follows:

- Canals (combined effects of main and tertiary): increase irrigated hectares by 29 percent and increase income by 50 percent. Some of the projected increase in irrigated land is relative to a counterfactual in which two percent less land can be irrigated each year due to deteriorating system functionality. About 33,000 and 39,000 farmers were expected to benefit from the main and tertiary canals, respectively.[42]
- Gravity schemes: increase irrigated hectares by 148 percent and increase income by 50 percent. As with canals, some of the projected increase in irrigated land stems from mitigating decreases in irrigated land. About 14,000 farmers were expected to benefit from these projects.
- Pumping stations: increase income by approximately 40 percent and save approximately $2 million in energy costs. About 55,000 farmers were expected to benefit from these projects.
- Ararat Valley drainage: increase income, but the projection for two years after rehabilitation this increase was modest, only $450,000 in total (compared to $11 million 15 years after rehabilitation, and to $34 million 2 years after rehabilitation for the Activity as a whole). About 64,000 farmers were expected to benefit from the associated projects.

The above projections encompass both the expanded area that could be irrigated as well as preventing the contraction of area irrigated that might happen if infrastructure breaks down. The *ex ante* projected benefits accounts for both aspects, but the assumptions about increases in irrigated land are larger in magnitude than the assumptions about preventing contractions in irrigated land.

In addition to the contributions of increased area irrigated and increased yields to increased income, the rescoping assessment (Braxein et al. 2008) also expected that more farmers would shift from lower-value to higher-value crops, but MCA-Armenia and MCC considered this more

[42] These beneficiary counts are based on estimates in Braxein et al. (2008). The projections for tertiary canals from Braxein et al. were 45,000, but this is probably too high because, subsequent to preparation of the rescoping report, some tertiary canals were removed because the communities did not provide the requisite copayment. The estimate of 39,000 assumes that the reduction in beneficiary farmers was proportional to the reduction in canals.

speculative and so did not assume that those shifts would happen in formulating the *ex ante* projected benefits.

We revisited the assumptions of the *ex ante* benefit-cost analysis in light of the impact estimates from the present report. The estimates reported herein are as of the 2013 agricultural season, which is two to three years after construction was completed in communities and seven years into the 20-year time horizon of the benefit-cost analysis. Unfortunately, the estimated impacts on household income for neither the rehabilitation of tertiary canals nor the rehabilitation of large infrastructure were not significantly different from zero. Thus, the early impacts that were expected have not materialized thus far.

Although MCC's projections predict that the earnings impacts are expected to grow beyond our evaluation time frame, the *ex ante* projected benefits are predicated on having already witnessed substantial increases in irrigated land, a result not found in the impact estimates. Nor do we find evidence that irrigated land has markedly contracted in the areas where infrastructure was not rehabilitated, based on their similar levels of irrigation at baseline and follow-up. The evidence from the other intermediate impacts examined in this report does not give great hope that large effects are near on the horizon—there is only evidence of modest changes in water use behavior, no significant evidence of adoption of new agricultural practices, and no significant evidence of adoption of new crops whose benefits could be seen in future years. Consequently, we do not expect that the economic rate of return will be as large as the *ex ante* prediction of 24 percent.

VI. COMPLEMENTARITIES BETWEEN THE INFRASTRUCTURE ACTIVITY AND WATER-TO-MARKET FARMER TRAINING

A. Research questions and data

As discussed in Chapter I, the Irrigated Infrastructure Activity was designed to work in tandem with the training of farmers that was conducted under the Water-to-Market Activity. The intention was that training would teach farmers new technologies and practices that could be deployed to leverage the improved irrigation supply. Consequently, in the evaluations of rehabilitated tertiary canals and large infrastructure, we controlled for the availability of training in communities in case households that had training responded differently to the rehabilitated infrastructure.

An important but disappointing finding from the Water-to-Market evaluation was that there was little evidence that Water-to-Market training had led to widespread adoption of new agricultural practices (Fortson et al. 2013). Two possible explanations for this disappointing result are (a) the follow-up period of two to three years after farmers were first trained was too short or (b) many farmers did not have access to reliable irrigation water at the time of training, which preceded completion of the Infrastructure Activity, and they could not effectively adopt new practices until the irrigation systems were rehabilitated.

In this chapter, we explore whether there has been an increase in the use of improved practices five to six years after training, focusing on communities with rehabilitated irrigation infrastructure of any kind, either because tertiary canals were rehabilitated or because other larger infrastructure was rehabilitated. We do not estimate impacts or use a comparison group design. This analysis of communities with rehabilitation and training was not originally planned, and so we did not initially draw a sample of communities with this research question in mind. Rather, the new research question was added after seeing the findings from the Water-to-Market evaluation.

Consequently, we draw on opportunistic data from the Tertiary Canal Survey. Specifically, we focused on 67 communities that were included in the Tertiary Canal Survey, were served by at least one type of irrigation infrastructure that was rehabilitated, and were one of the communities that received Water-to-Market training relatively early ("TCS-WtM sample"). We focused on the pilot communities (30 in our sample) and the communities randomly assigned to be offered training in the first full year of training implementation (37 in our sample) because these are the communities that have had the longest period to adopt new farming practices and, more importantly, because training was most intensive in these communities, with many communities being offered multiple opportunities to participate in training. In contrast, communities randomly assigned to be offered training near the end of the compact were much less likely to have multiple training sessions, so training participation was not as prevalent.

In the subsample of communities we include, about 68 percent of the households reported participating in on-farm water management or high-value agriculture training. Most of these farmers were likely through the Water-to-Market activity, but some were probably from other sources of training, though we have not been able to identify specific programs that were implemented after Water-to-Market. In communities that were not offered training through the

Water-to-Market activity, about 40 percent of households still reported that they had participated in training for on-farm water management or high-value agriculture. The communities that were offered Water-to-Market training were substantially more likely to report participating in training, but the difference between the two groups was not as large as we observed in the Water-to-Market evaluation. If there was another similar program that followed the Water-to-Market training and was implemented in these same communities, then the increase in adoption rates from before irrigation rehabilitation to after that we report in this section would be overstated, because they would reflect the combined effects of the Infrastructure Activity, farmer training from the Water-to-Market Activity, and training provided through other programs.

B. Analytical approach

We use simple descriptive comparisons to examine the extent to which practice adoption increased. We first used the Tertiary Canal Survey to tabulate agricultural practice adoption rates for households in the TCS-WtM sample. Many of the practices reported in the Tertiary Canal Survey were measured at follow-up but not at baseline for this survey, so we could not look at changes over time in the adoption rates. Instead, we report adoption rates at follow-up for these outcomes and refer to the Water-to-Market report to put into context whether these adoption rates are substantively different and seem to have increased over time. If Water-to-Market farmers were waiting for the irrigation infrastructure to be rehabilitated before they adopted these agricultural practices, then the Water-to-Market farmers we observed in 2013–2014 (five to six years after training) should have higher adoption rates than the Water-to-Market farmers we observed in 2010–2011 (three to four years after training). Thus, we compared the adoption rates observed in 2013–2014 through the follow-up Tertiary Canal Survey to the adoption rates observed in 2010–2011 for the Water-to-Market evaluation. However, because these are not directly comparable samples of communities or farmers within communities, we did not conduct tests for statistical significance.

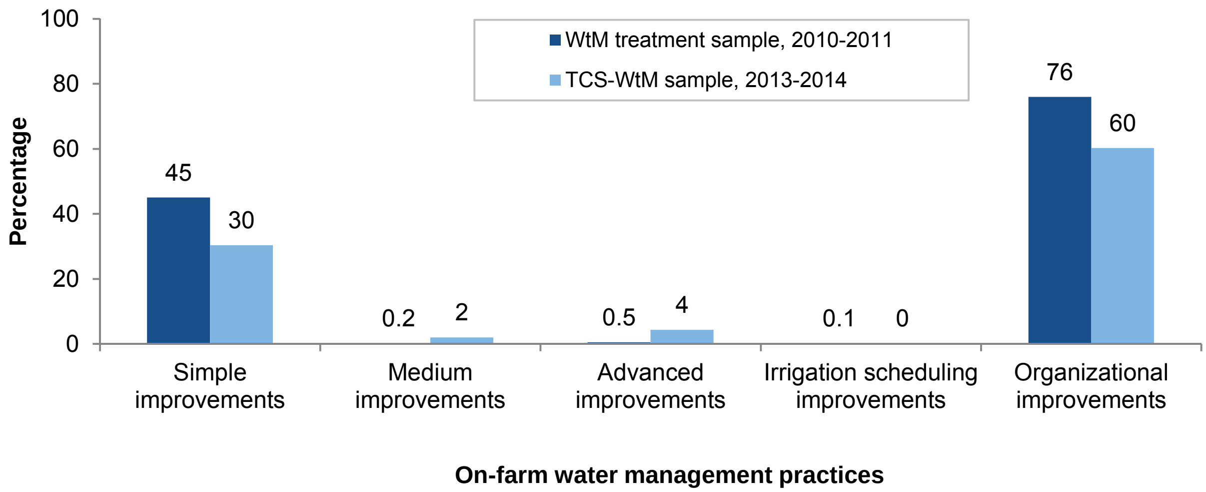
We emphasize that the TCS-WtM sample of communities was not selected randomly from the pool of communities that were selected for Water-to-Market training or included in the Water-to-Market evaluation, and households were sampled separately for the TCS and for the Water-to-Market evaluation. The 37 communities that were included in the TCS-WtM sample from year 2 of Water-to-Market training are a subset of the 112 communities in the Water-to-Market treatment sample. The TCS-WtM is an opportunistic sample of those communities based on the inclusion of the community in the Tertiary Canal Survey and being selected to receive rehabilitation of tertiary canals or large infrastructure. Still, examining the TCS-WtM sample provides a general sense of whether adoption greatly increased for communities that were offered training and whose irrigation infrastructure was later rehabilitated. Adoption rates were low enough in 2010 for most of the key practices that it would be evident if there had been widespread adoption in the years since the Water-to-Market evaluation was conducted.

The second hypothesis listed above, regarding whether farmers could not adopt practices until their irrigation infrastructure was rehabilitated, can be addressed more rigorously, though it is only meaningful if there is evidence of consequential increase in adoption rates since 2010. As described in Chapter III for evaluating rehabilitated tertiary canals, and analogously for larger rehabilitated infrastructure in Chapter IV, we first estimated separate impacts of tertiary canals and larger infrastructure on adoption of new agricultural practices. This first step identified that communities with newly reliable irrigation water did not adopt new agricultural practices. The second step was to distinguish whether the observed effects of infrastructure rehabilitation on adoption were enhanced by Water-to-Market training. For this second step, we used regressions within subgroups of the sample to determine the extent to which any observed impacts of the Infrastructure Activity on adoption of new practices were different in Water-to-Market communities versus non-Water-to-Market communities.

C. Findings

We did not observe that adoption of on-farm water management practices was substantially higher for the TCS-WtM sample (data collected in 2012–2013) than for the Water-to-Market treatment group (data collected in 2010; Figure VI.1).[43] In fact, fewer farmers in the TCS-WtM sample reported using simple improvements compared to farmers in the Water-to-Market treatment group. Adoption of medium improvements (such as gated pipes) or advanced improvements (such as drip irrigation) was still low for both groups, although slightly higher in the TCS-WtM sample. Organizational improvements, such as the preparation of irrigated land or having a copy of the farm's water user association water contract, were used by more than half of farmers in the TCS-WtM sample and more than three-quarters in the Water-to-Market treatment group. Overall, adoption rates of on-farm water management practices did not systematically increase over time.

Figure VI.1. Adoption of on-farm water management practices for Water-to-Market communities (percentages)



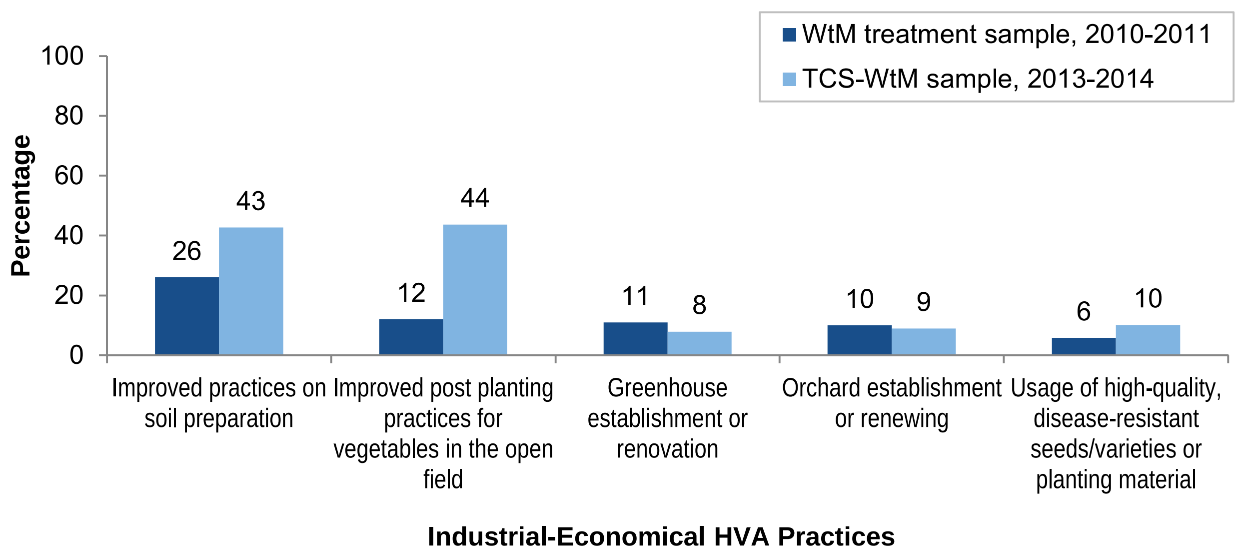
Sources: 2010–2011 Farming Practices Surveys and 2013–2014 Tertiary Canal Surveys.
OFWM = on-farm water management; WtM = Water-to-Market

[43] Had we observed any increases in adoption, our research protocol called for exploring whether these increases were attributable only to the Infrastructure Activity or to the interaction between the infrastructure rehabilitation and the Water-to-Market training provided earlier.

Next, we examined whether the adoption of high-value agriculture practices increased since 2010 (Figures VI.2 and VI.3). Specifically, we looked at industrial-economical practices such as fertilization or establishing a greenhouse that emphasize gains in efficiency or the value of production. We then turned to social-environmental practices, which focused on environmentally friendly, socially responsible practices that may not translate directly into gains in productivity or profits but could have long-term effects on farmers' health, consumers' health, or the environment.

We found evidence of higher adoption rates of the TCS-WtM sample than the Water-to-Market treatment group for the two high-value agriculture practices: improved soil preparation and improved post-planting procedures. More than 40 percent of farmers in the TCS-WtM sample reported implementing these practices. Other industrial-economical practices were much less common, with prevalence of 10 percent or less.

Figure VI.2. Adoption of industrial-economical HVA practices for Water-to-Market communities (percentages)

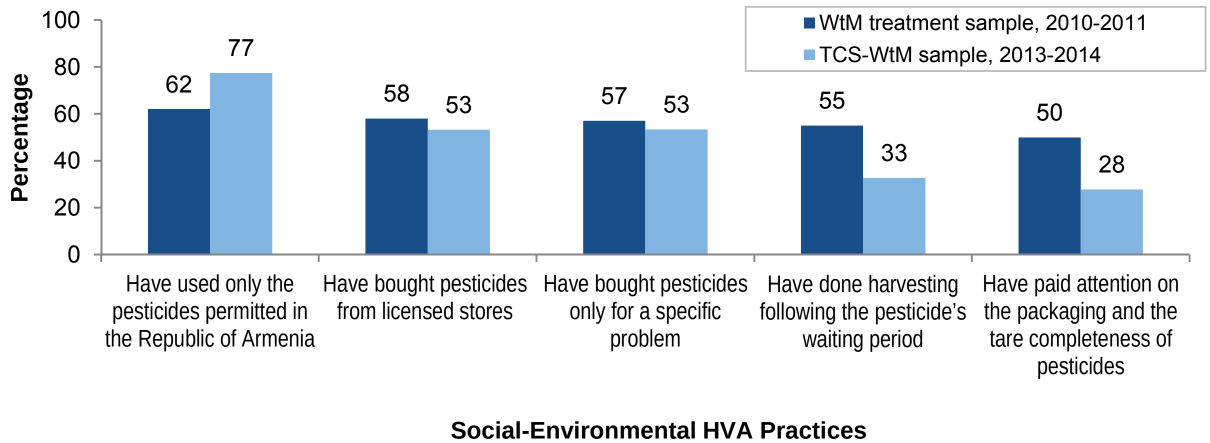


Sources: 2007–2008 and 2010–2011 Farming Practices Surveys and 2009–2010 and 2013–2014 Tertiary Canal Surveys.

HVA = high-value agriculture; WtM = Water-to-Market.

Examining social-environmental high-value agriculture practices, we found that the TCS-WtM sample was much more likely than was the Water-to-Market sample to exclusively use pesticides allowed in Armenia, but this was the exception. All other social-environmental practices had comparable rates of adoption between the two samples, or higher rates of adoption by the Water-to-Market treatment group than the TCS-WtM sample, suggesting that adoption rates were remaining constant or decreasing over time.

Figure VI.3. Adoption of social-environmental HVA practices for Water-to-Market communities (percentages)



Sources: 2007–2008 and 2010–2011 Farming Practices Surveys and 2009–2010 and 2013–2014 Tertiary Canal Surveys.

HVA = high-value agriculture; WtM = Water-to-Market.

To further explore whether the observed differences in select high-value agriculture practices resulted in more high-value agriculture crops being grown, we compared the types of crops cultivated by Water-to-Market communities where irrigation infrastructure was rehabilitated (Table VI.1). In general, rates of cultivation between the two samples were comparable for most crops. Overall, we did not find consistent evidence that farmers were waiting to experience improvements in their irrigation infrastructure before adopting the practices covered in training.

Table VI.1. Crop types cultivated by Water-to-Market communities (percentages)

	WtM Treatment Group	TCS Subsample of the WtM Treatment Group	Difference
HVA crops	94	95	-1
Grape	28	33	-5
Other fruits or nuts	67	68	-1
Tomato	35	35	0
Vegetables and herbs	43	43	0
Potato	28	19	9
Non-HVA crops	50	52	-2
Grain	34	31	3
Grass	26	29	-3

Sources: 2007–2008 and 2010–2011 Farming Practices Surveys and 2009–2010 and 2013–2014 Tertiary Canal Surveys.

WtM = Water-to-Market; HVA = high-value agriculture

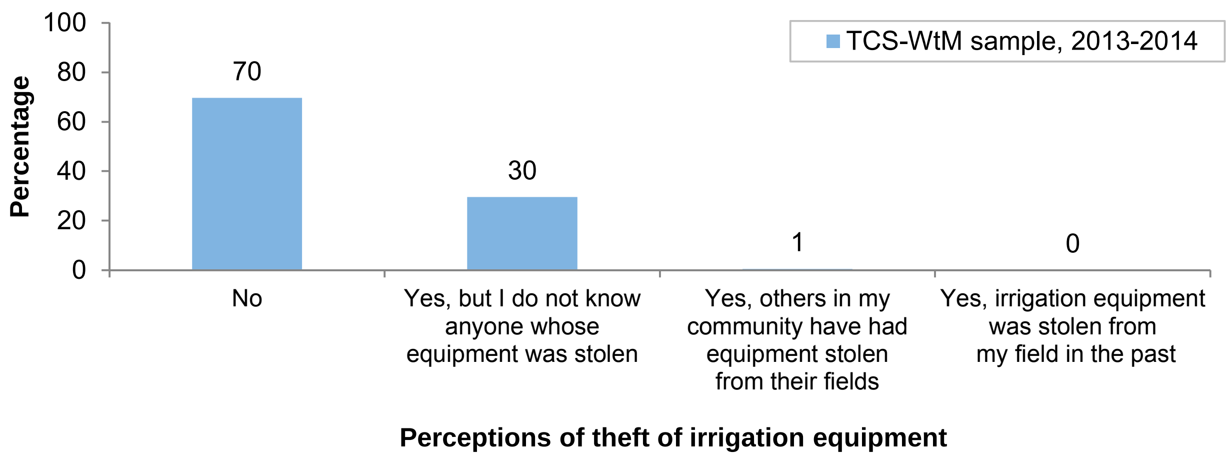
Based on these comparisons of the TCS-WtM sample and the Water-to-Market treatment group, there were few intermediate outcomes where the TCS-WtM sample outperformed the

Water-to-Market treatment group in terms of adoption rates of practices or crop types that were cultivated. Among the on-farm water management and high-value agriculture practices, the communities in the TCS-WtM sample were more likely than communities in the Water-to-Market treatment group to have improved soil preparation and improved post-planting practices for vegetables in the field (both industrial-economical high-value agriculture practices) as well as exclusive usage of pesticides allowed in Armenia (a social-environmental high-value agriculture practice). Communities in the Tertiary Canal Survey subsample also grew more grapes and fewer potatoes than the Water-to-Market treatment group, but overall cultivation patterns levels were similar.

Given that we did not detect evidence of significant impacts on these measures for either the evaluation of rehabilitated tertiary canals or large infrastructure, it is unlikely that there were strong interactions between the Water-to-Market and Infrastructure Activities. However, we cannot identify what the complementarities between the Infrastructure Activity and Water-to-Market training would have been if they had been implemented differently, and in particular, if the infrastructure rehabilitation had been completed prior to or shortly after training, it is possible that farmers would have been more motivated to adopt new practices.

Lastly, we used the Tertiary Canal Survey to explore one of the hypotheses from the Water-to-Market report for why adoption of certain technologies may have been low. In some interviews, farmers previously reported reluctance to invest in costly technologies that could be stolen, especially from their fields, which are usually far enough from farmers' houses that they cannot be easily monitored. This information was not collected in the Farming Practices Survey, however. In the Tertiary Canal Survey, we added some questions to investigate the prevalence of this belief and the extent to which it is grounded in firsthand or secondhand experience. We found that about 70 percent of farmers did not perceive theft of their irrigation equipment as a risk (Figure VI.4). Among the remaining 30 percent of farmers who perceived theft as a risk, the vast majority did not have any firsthand or secondhand experience of such theft occurring. Thus, theft seemed to be a concern of farmers but is not a strong explanation for our observation that farmers did not adopt new technologies.

Figure VI.4. Perceived risk of theft of irrigation equipment for Water-to-Market communities (percentages)



VII. THE INSTITUTIONAL STRENGTHENING SUBACTIVITY AND SUSTAINABILITY OF THE IRRIGATION INVESTMENTS

Water user associations (also called WUAs) are organizations established by water users to carry out the operation and maintenance of the country's rural irrigation systems.[44] Water user associations are nonprofit legal entities that operate in the public interest, often with large government subsidies to cover operational costs. Water supply agencies handle the operation and maintenance of irrigation dams, main canals, and pumping stations, and they supply water to water user associations. Water user associations pay water supply agencies based on their water usage and tariffs set by the Public Service Regulatory Commission of Armenia.

The primary objective of the Institutional Strengthening of Irrigation Management Entities Subactivity (ISSA) was to improve the managerial, technical, structural, and financial capacity of water user associations (and water supply agencies) operating in Armenia. In doing so, it was intended to help sustain the investments in rehabilitating irrigation infrastructure as part of the Infrastructure Activity. The design of ISSA assumed that water user associations' enhanced capacity would allow them to manage irrigation systems more efficiently and autonomously, and eventually reach financial sustainability. In addition, strengthened water user associations could more effectively operate and maintain Armenia's rural irrigation infrastructure, ensuring a reliable water supply and supporting long-term rural agricultural development.

To meet this objective, the component's implementing organizations—Mott MacDonald, Euroconsult, and VISTAA—provided technical assistance to staff from all 44 water user associations (as well as 3 water supply agencies) on irrigation water delivery services, water service fee collection practices, budgeting and accounting processes, irrigation infrastructure maintenance, and participatory management principles. ISSA's implementing organizations also provided material assistance to water user associations and water supply agencies in the form of office equipment, computer software, and heavy machinery. With a budget of approximately $4.9 million, this component was launched in September 2008 and completed in October 2011.

A. Research questions and data

The impacts of ISSA on water user associations and water users were previously estimated as part of the Water-to-Market evaluation (Fortson et al. 2013). In particular, the Water-to-Market evaluation analyzed changes in water user associations' financial standing and water users' membership rates before and during the course of ISSA implementation. Outcomes for water user associations were measured using administrative data from water user associations for the 2007-2010 fiscal years, and outcomes for water users were gathered from surveys of households in the geographic service area of water user associations for 2009 and 2010.[45] The administrative data and water user survey were gathered by AVAG Solutions.

[44] WUAs were formally created by Armenia beginning in 2003.

[45] A separate WUA administration survey was also administered in 2009 to obtain information on infrastructure and technical capacity, human resources, office space and equipment, water intake and delivery, finances, and institutional arrangements. Because ISSA began in late 2008, the 2008 WUA administration survey was considered baseline data.

Using these data, the Water-to-Market evaluation found that water user associations improved their financial standing from 2007 to 2010. Water user associations reduced expenditures on water payments, improved their membership fee collection, and improved their cost recovery rates. However, large annual deficits persisted, and water user associations did not appear to be approaching financial solvency in the near-term.

As outlined in Chapter I, the Irrigated Infrastructure Activity and ISSA were designed to complement each other, so outcomes for water user associations might have continued to improve after the Water-to-Market evaluation. The intent was that water user associations would use the technical assistance and equipment from ISSA to effectively manage the rehabilitated infrastructure and be financially sustainable.

This chapter uses administrative data from 2007-2013 and a survey of water user association directors in 2014 to update the analysis from the Water-to-Market evaluation. The availability of the data by year and the number of water user associations present in each year is shown in Table VII.1. The decrease in the number of water user associations is due to mergers between associations. The three additional years of administrative data (2011, 2012, and 2013) are used to extend the previous analysis of outcomes for water user associations (Section VII.C). The 2014 survey of water user association directors ("WUA director survey") was designed after the Water-to-Market evaluation to further explore water user associations' outcomes and to understand the sustainability of the irrigation rehabilitation investments (Section VII.D).

Table VII.1. Data sources and number of WUAs, 2007-2014

	2007	2008	2009	2010	2011	2012	2013	2014
WUA administrative data	✓	✓	✓	✓	✓	✓	✓	
WUA director survey								✓
Number of WUAs	52	52	44	44	44	44	42	42

The key research questions answered with the administrative data are whether the volume of irrigation water provided by water user associations has increased and whether their financial conditions have improved. Information from the water user association director survey is used to address questions about water user associations' perceptions of ISSA and the sustainability of its components. We examine challenges faced by water user associations in becoming financially self-sufficient, the continued use of equipment provided under ISSA, the use and coverage of business plans, and the use and helpfulness of management improvement plans. The findings in this chapter also complement the findings in Chapters III and IV by using administrative irrigation use data to cross-check the survey-based impact estimates.

B. Analytical approach

Our analysis approach compares water user associations' outcomes over time using the administrative data and describes tabulations of measures from the water user association director survey. As in the Water-to-Market evaluation, our ISSA analysis does not use an external comparison group. Because we do not have data measuring what would have happened over time in the absence of ISSA, we cannot be sure that these changes were causal impacts of the program. In particular, climatic, economic, and political developments between 2007 and

2014 likely affected most key water user association outcomes we examine below, complicating our ability to determine ISSA's contribution to these outcomes. For this reason, any observed changes in water user associations' practices and performance should be interpreted as merely suggestive that the program had true impacts. Given this concern, we do not report significance levels for these differences, as citing the statistical significance of differences over time would imply a true causal effect of the program. This is consistent with our approach for reporting changes over time in the Water-to-Market evaluation of ISSA (Fortson et al. 2013).

To increase the comparability of estimates over time, we adjusted the averages of measures from the administrative data to account for changes in the number of water user associations over time and for inflation (for monetary measures). As noted previously, the number of water user associations has declined over time because groups of water user associations merged in 2009 and 2013, reducing the number of water user associations in Armenia from 52 before 2009 to 42 in 2013. Even if there were no differences in the underlying measures, the raw averages over time would imply that water user associations are growing because the number of water user associations is decreasing. As in the Water-to-Market evaluation of ISSA, we account for these merges by using a base of 44 (the number of water user associations during most of the ISSA period) to calculate all averages. We also account for inflation by adjusting amounts in Armenian drams (AMD) to USD each year, and then adjusting the nominal amounts in USD to their inflation-adjusted USD equivalents in 2013.[46]

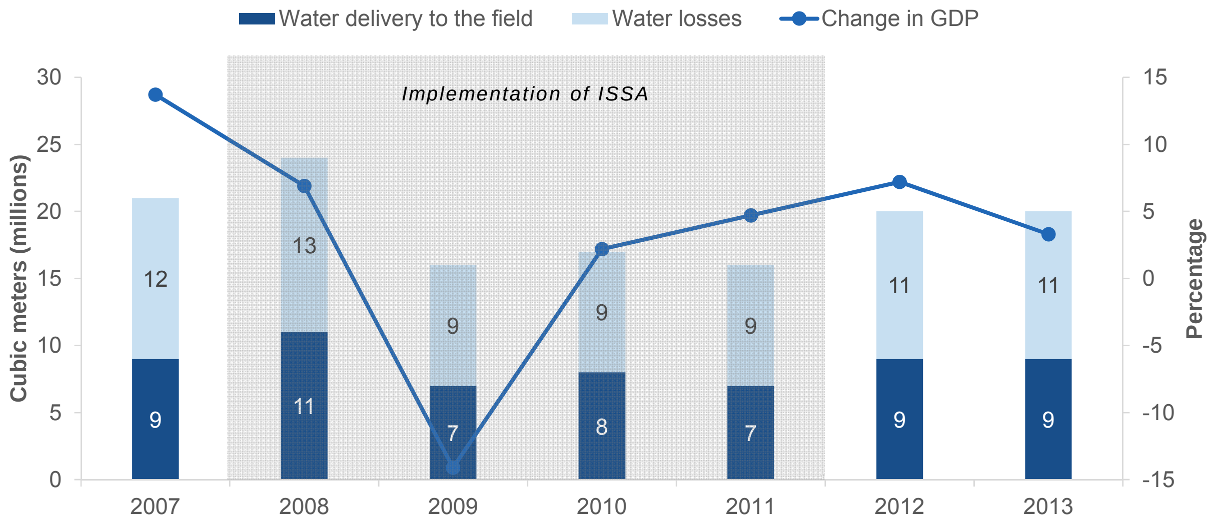
In the remainder of this chapter, we discuss changes in water user associations' revenues and costs (Section VII.C), the sustainability of the infrastructure investments (Section VII.D), and the sustainability of technical assistance provided under the Compact (Section VII.E). We summarize the findings in Section VII.F.

C. Changes in water user associations' revenues and costs

There are no large differences between 2007 and 2013 in water user association water deliveries (amount of water billed to farmers), estimated total water intake from water supply agencies, or water losses (calculated as estimated water intake minus deliveries) (Figure VII.1). This finding is consistent with the impact estimates reported in Chapters III and IV, which found minimal change in farmers' amount of land irrigated, frequency of irrigation, and duration of irrigation. Though there was little difference between the endpoints (2007 and 2013), there was variability in water deliveries, losses, and intake over this period. The average amount of water delivered by water user associations in 2009, 2010, and 2011 was dramatically lower than in earlier years, likely because of external factors such as heavy rains and perhaps also the unfavorable global economic conditions (see national growth rates in Figure VII.2). Since then, water deliveries and total water intake have increased, but by 2013, levels had not fully recovered to pre-ISSA (2007) levels.

[46] We converted AMD to USD on a yearly basis using currency exchange rates from OANDA on October 1 of each year. From 2008 to 2013, a time of substantial volatility in the value of the dram, the conversions for 1,000 AMD were $2.96886, $3.31214, $2.60227, $2.76771, $2.6875, $2.46579, and $2.46706 USD, respectively. As an alternative that is robust to exchange rate volatility, we converted nominal AMD into constant-year AMD based on Armenia's annual consumer price index and then converted constant-year AMD into USD, and the findings were substantively similar to those reported here.

Figure VII.1. Average WUA water delivery and losses for 2007-2013 (millions of cubic meters)



Sources: 2007-2013 WUA administrative data and National Statistical Service.

Notes: Estimates of water deliveries and water losses in each year were calculated by summing over all WUAs and dividing by 44, which is the number of WUAs present in 2009, 2010, and 2011.

GDP = gross domestic product.

There was also no evidence of large increases in water delivery based on measures of irrigated land area and the number of water users with signed contracts (Table VII.2), which is consistent with the findings in Chapters III and IV. This suggests that the null impacts of rehabilitated infrastructure on household well-being are not solely due to the coverage of the TCS. Based on water user association administrative data, irrigated land area has increased by 84 hectares, or 3 percent, from 2007 to 2013, and the number of water users with signed contrasts has decreased by 218 users, or 5 percent.

The financial condition of water user associations has improved since 2007. Expenditures decreased by an average of $112,000 from 2007 to 2013, largely due to a decrease in water payments to water supply agencies. This decrease is related to a decrease in the use of pumped water in favor of an increase in the use of water from gravity schemes. Energy costs increased sharply in 2013 after remaining stable from 2007 to 2012 because of an increase in energy tariffs assessed for WUAs, and this pattern was similar for the subset of WUAs served by rehabilitated gravity schemes, for which energy savings was an expected benefit. At the same time that overall expenditures decreased, revenues increased by $35,000, which was driven by a $31,000 increase in irrigation water payments from users. These patterns in expenditures and revenues are consistent with the patterns over the 2007 to 2010 period observed in the Water-to-Market evaluation. Because of the favorable changes in expenditures and revenues, the average water user association deficit (the amount by which expenditures exceed revenues) has become smaller. Since 2007, average water user association deficits have decreased by $147,000, or 35 percent. This is a substantial improvement and is suggestive that water user associations are getting closer to being financially self-sufficient. However, they are still not close: average expenditures in 2013 ($517,000) were still more than twice average revenues ($246,000).

Table VII.2. Average WUA water delivery, expenditures, and revenues, 2007 compared with 2011-2013

	2007	2011	2012	2013	Change from 2007 to 2013
Water Delivery					
Irrigated Land Area (hectares)	2,882	2,941	2,971	2,967	84
Number of Water Users with Signed Contracts	4,542	4,316	4,411	4,325	-218
Total Water Intake (1 million m^3)	21	17	20	20	2
Water Delivered (1 million m^3)	12	9	11	11	-1
Water Losses (1 million m^3)	9	7	9	9	-1
Expenditures ('000 USD)					
Total Cash Expenditures	628	541	492	517	-112
Wages and salaries	98	114	112	113	15
Water payments	174	80	42	38	-136
Repair and maintenance[a]	77	82	75	77	0
Energy costs	142	149	146	179	37
Other expenditures[b]	137	116	117	109	-27
Revenues ('000 USD)					
Total Cash Revenues	211	234	223	246	35
Membership fees	2	5	5	6	4
Irrigation water payments	209	229	219	240	31
Net Revenues (revenues - expenditures)	-417	-308	-268	-271	147
Sample Size	52	44	44	42	44

Sources: 2007 and 2011-2013 WUA administrative data.

Notes: Monetary values were adjusted to account for inflation and have been converted to 2013 dollars. The changes presented in the table may not be equal to the difference of the yearly values because of rounding. Estimates in each year were calculated by summing over all WUAs and dividing by 44, which is the number of WUAs present in 2009, 2010, and 2011.

USD = United States dollars.

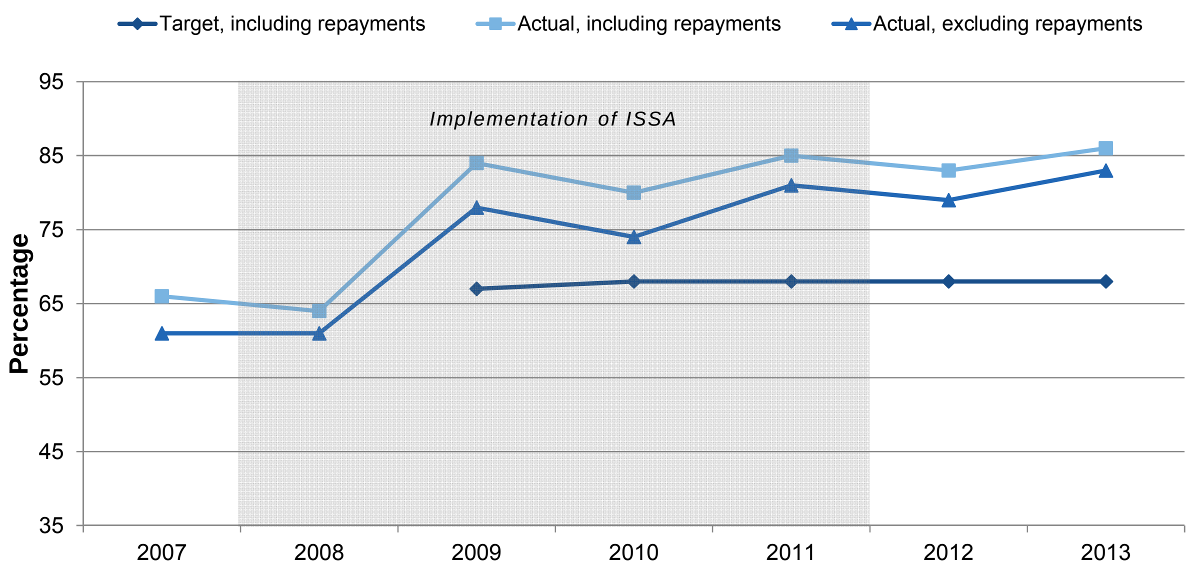
[a] Includes routine maintenance and repair prior to the agricultural season as well as repair during the season.

[b] Includes social security expenditures, transportation, banking, communication, trips, reserve fund, taxes, and other expenses.

Water user associations have increased their irrigation service fee collection rates, a key outcome that measures the proportion of irrigation charges that were collected from water users (Figure VII.2). This holds for irrigation service fee rates calculated while including and excluding repayments from previous years of service. Water user associations' service fee collection rates exceeded the MCA-Armenia targets since 2009, the first year that targets were available. As noted in the Water-to-Market evaluation, the sharp increases in service fee collection in 2009 and 2010 may have been linked to the Armenian government's decision to provide free irrigation water in April and May of 2009 and 2010 in an effort to alleviate agricultural hardship during those years. Because water users' service fee obligations were substantially lower during these years, the overall service fee collection rate increased despite an actual decrease in total revenues from water payments during this time period. However, the increase in service fee rates achieved after ISSA were sustained in

2011, 2012, and 2013. This suggests that water user associations have been able to increase irrigation service fee rates materially with improved administration, and the increases were not solely due to the government's decision to provide free irrigation water in some months.

Figure VII.2. Service fee collection rate over all WUAs, 2007-2013 (percentage of irrigation charges)

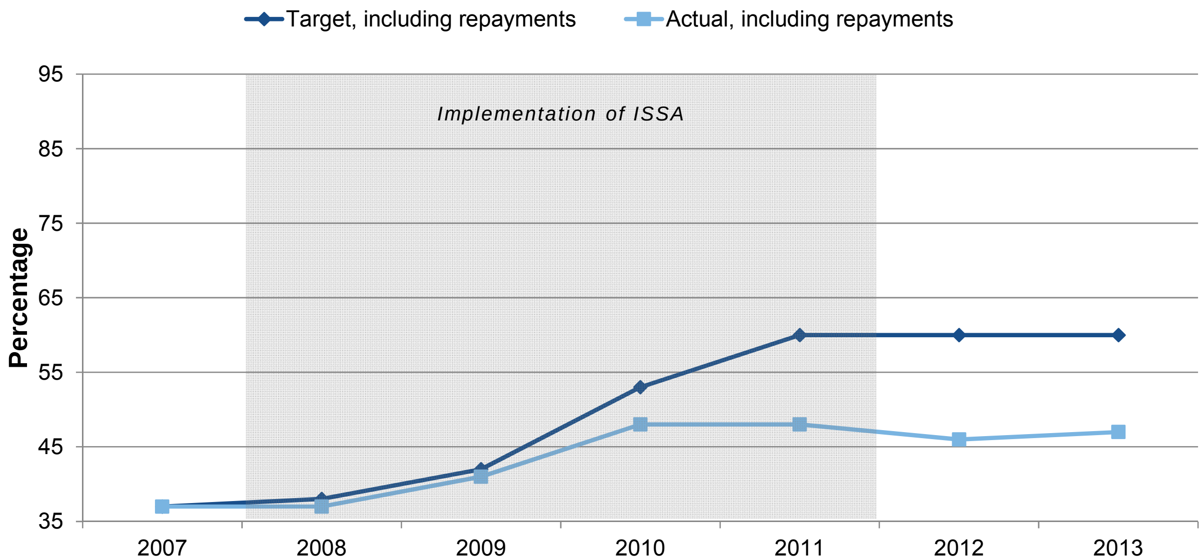


Sources: 2007-2013 WUA administrative data and Armenia post-Compact Monitoring and Evaluation Plan (Jan. 2013).

Notes: Service fee collection rates were calculated as irrigation water charges on a cash basis, including or excluding repayments from previously accumulated arrears, divided by irrigation water charges on a commitment basis. Target rates were reported in MCA-Armenia's Indicator Tracking Table (ITT) for 8 WUAs as 51, 53, and 55 percent for 2009, 2010, and 2011. A 2011 version of an ISSA-specific ITT reported a target rate of 71 percent for the other 34 WUAs. The target rate shown in the figure is the weighted average of these targets. A constant target rate was assumed from 2011 through 2013.

Another key outcome measure for ISSA is the cost recovery rate, or the proportion of operations and maintenance costs recovered by revenues from water charges. Water user associations have not met the targeted cost recovery rates in any year after ISSA, and the improvements in the cost recovery rates have leveled off since 2010. Given the flattened trend in cost recovery rates, it is unlikely that the cost recovery rates will improve enough to meet the target in the short-term without increasing water charges.

Figure VII.3. Cost recovery rate over all WUAs, 2007-2013 (percentage of operations and maintenance costs)



Sources: 2011, 2012, 2013 WUA administrative data, Water-to-Market evaluation report, and Armenia post-Compact Monitoring and Evaluation Plan (Jan. 2013).

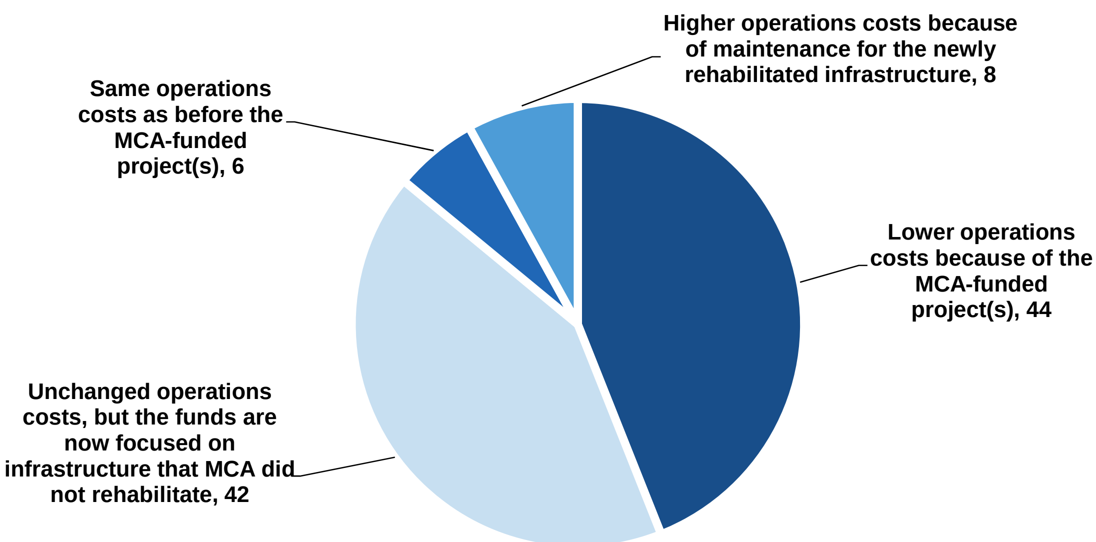
Notes: Estimates for each year are based on 44 WUAs except in 2013, when two pairs of WUAs merged. In 2013, we summed the measures over all WUAs and divided by 44 to impute averages as if the WUAs had remained separate. A constant target of 60 percent was assumed from 2011 through 2013.

Overall, our analysis of the time trends suggests that water user associations are unlikely to become financially self-sufficient in the near future without additional intervention. Revenues and expenditures have shown modest improvements since 2007, but the service fee collection rates and cost recovery rates appear to have plateaued after 2009. However, this analysis has been based on trends over time, and the improvements in water user associations' financial standing cannot be attributed solely to ISSA or to complementarities between ISSA and the Irrigation Infrastructure Activity. Climatic conditions and other changes to irrigation systems outside of the scope of ISSA and unrelated to the Irrigation Infrastructure Activity could have had some effect on irrigation and water user association outcomes.

We supplement the analysis of water user associations' outcomes in the administrative data with an analysis of data from the water user association director survey, which was conducted in 2014. The survey data were intended to help us understand water user association operations as well as to provide subjective assessments of the functionality of the rehabilitated infrastructure. As with the discussion of the administrative data, we first examine operations costs and then revenues. All tabulations with the survey data are based on the 42 water user associations as they existed in 2014.

Most water user association directors reported that MCA-funded infrastructure had favorable effects on their operations costs. Forty-four percent of water user association directors believed the MCA-funded project(s) lowered their operations costs. A slightly smaller fraction (42 percent) of water user association directors thought their total operations costs were unchanged, but that the MCA-funded project allowed them to increase expenditures on other, non-MCA-funded infrastructure. We do not have data on the amount or type of investments made by water user associations, but it is possible that the increased expenditures on non-MCA-funded infrastructure benefitted the communities in the comparison group. Eight percent of water user association directors reported that there were higher operations costs due to maintenance of the rehabilitated infrastructure, but no water user association directors reported that there were higher operations costs because of additional repairs (apart from regular maintenance) to the MCA-funded infrastructure.

Figure VII.4. WUA directors' subjective assessments of changes in operations costs following rehabilitated infrastructure (percentage of WUA directors)

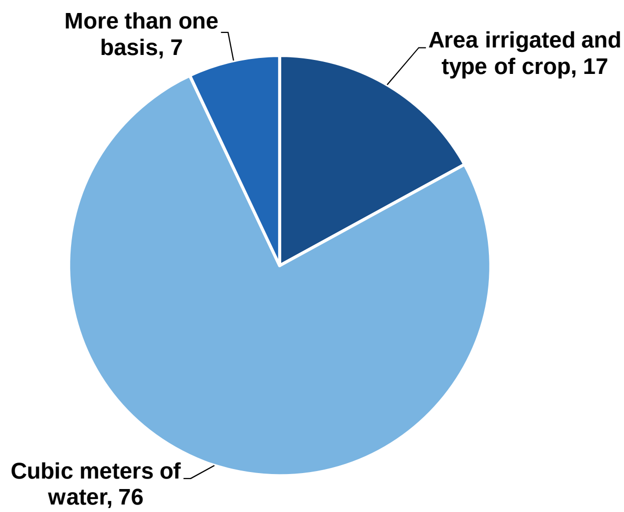


Source: 2014 WUA director survey.

Notes: Estimates are based on 42 WUAs in place as of 2014.

To understand water user associations' revenues from water payments, water user association directors were asked about their process for determining water usage fees and their techniques for addressing delinquent payments. Water user associations were asked whether they determined water usage fees based on the land area irrigated and the type of crop cultivated, cubic meters of water according to a water meter, the duration of time that water was provided, or another basis. Over three quarters of the beneficiary water user associations based their fees for water users on cubic meters of water (Figure VII.5), which potentially provides the most accurate estimates and also incentivizes farmers to conserve water. The most common use of water meters by WUAs is to measure cubic meters of water for a large land area containing multiple farms, charging farmers proportionately based on their land within the larger area. Most of the remainder of WUAs based their fees on the land area and type of crop being irrigated by the farmer, which was the standard practice prior to ISSA. The other three water user associations used more than one basis to determine water usage fees. Two of these water user associations considered both the cubic meters of water provided as well as the area irrigated and type of crop cultivated by the farmer. The third water user association considered the cubic meters of water provided, the area irrigated and type of crop cultivated in case of gravity irrigation, and the duration of time that water was provided for pumped water.

Figure VII.5. Basis of water usage fees for individual farmers (percentage of WUAs)

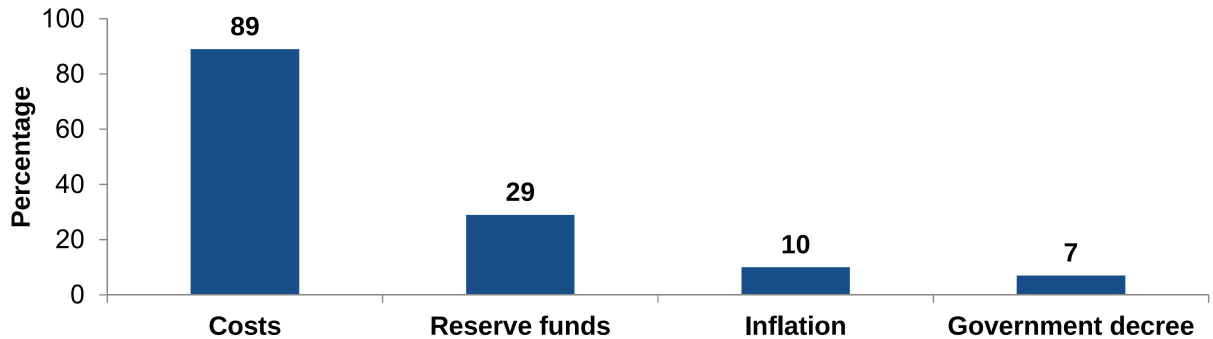


Sources: 2014 WUA director survey.

Notes: Estimates are based on 42 WUAs. Three WUAs used more than one basis to determine water usage fees. Two of these WUAs considered both the cubic meters of water provided as well as the area irrigated and type of crop cultivated by the farmer. The third WUA considered the cubic meters of water provided and the duration of time that water was provided.

Second, the per-unit rate is most frequently influenced by costs or reserve funds (Figure VII.6). All but five water user associations indicated that costs were a factor in selecting the per-unit rate, and nearly a third of water user associations stated that reserve funds were a factor. Factors external to water user association operations, such as inflation and government decree, were less commonly considered when water user associations determine water users' fees.

Figure VII.6. Factors WUAs consider when determining per-unit rates to charge farmers (percentage of WUAs)

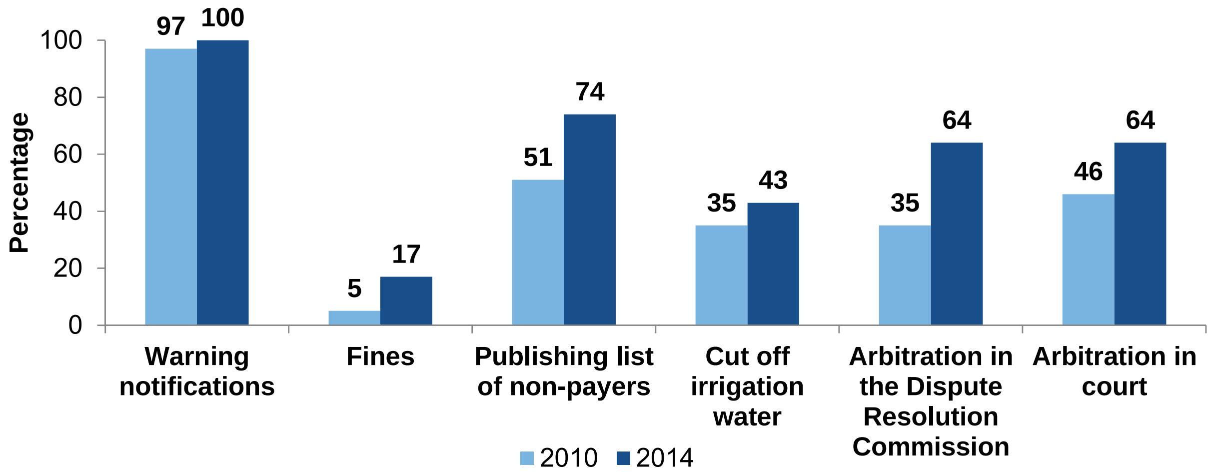


Source: 2014 WUA director survey.

Notes: Estimates are based on 42 WUAs in place as of 2014. Multiple responses were permitted from each WUA.

Water user associations often used multiple approaches to address delinquent payments for water (Figure VII.7). All water user associations gave delinquent farmers warning notifications, and over half of water user associations published lists of non-payers and pursued arbitration. Sixty-four percent of water user associations pursued arbitration in the Dispute Resolution Commission or in court, and 45 percent of water user associations used both channels for arbitration. No water user association directors reported addressing delinquent payments for water by terminating memberships of farmers, but 43 percent reported cutting off irrigation water. This information was also requested from water user associations in 2010, when there were 37 out of 44 water user associations that responded rather than the 42 water user associations in 2014. The distribution of methods overall looks similar. Water user associations appear to have become more likely to publish lists of non-payers and pursue arbitration and are less likely to terminate memberships; in 2010, 10 percent of water user associations reported terminating memberships of farmers who had not paid for water (not shown).

Figure VII.7. Approaches for addressing delinquent payments for water (percentage of WUAs)



Sources: 2010 and 2014 WUA director surveys.

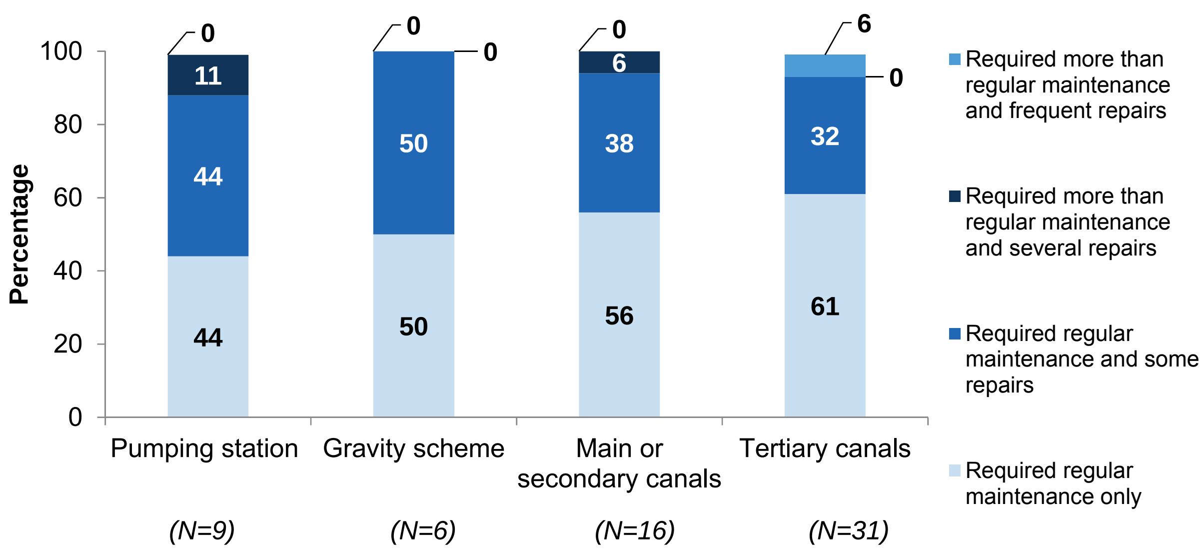
Notes: The 2010 and 2014 WUA director surveys were administered to 37 WUAs and 42 WUAs, respectively. In 2010, 10 percent of WUAs reported terminating membership in 2010 for farmers who did not pay for water, and no WUAs reported terminating membership in 2014 for farmers who did not pay for water.

D. Sustainability of infrastructure investments

The sustainability of MCA-Armenia's infrastructure investments depends not only on the financial stability of water user associations but also on their ability to perform regular maintenance and any additional repairs. Earlier interviews with water user associations had revealed that farmers sometimes accessed water illegally and damaged the irrigation infrastructure. To assess the sustainability of the infrastructure investments, we asked water user association directors about the functionality and condition of the pumping stations, gravity schemes, main or secondary canals, and tertiary canals since the rehabilitation, how water user associations handle repairs, and the extent to which farmers accessing water illegally was perceived to be a problem by the water user association. We did not ask water user association directors about the functionality of drainage systems because individual water user associations are not responsible for maintaining them.

Nearly all water user associations reported that their rehabilitated infrastructure does not require more than regular maintenance or frequent repairs (Figure VII.8). Only one water user association out of nine with a rehabilitated pumping station reported that the pumping stations required more than regular maintenance and several repairs. For all other types of infrastructure (gravity schemes, main or secondary canals, and tertiary canals), 93 percent or more of water user associations agreed that only regular maintenance or regular maintenance with some repairs was typically needed. Among those that reported their rehabilitated infrastructure required more than regular maintenance: one water user association reported that their rehabilitated pumping station required several repairs, one water user association reported that their rehabilitated main or secondary canals required several repairs, and one water user association reported that their rehabilitated tertiary canals required frequent repairs. Thus, it appears that most rehabilitated infrastructure was operating as planned.

Figure VII.8. Perceived functionality of rehabilitated pumping stations, gravity schemes, main or secondary canals, and tertiary canals (percentage of WUAs with that type of rehabilitated infrastructure)



Source: 2014 WUA director survey.

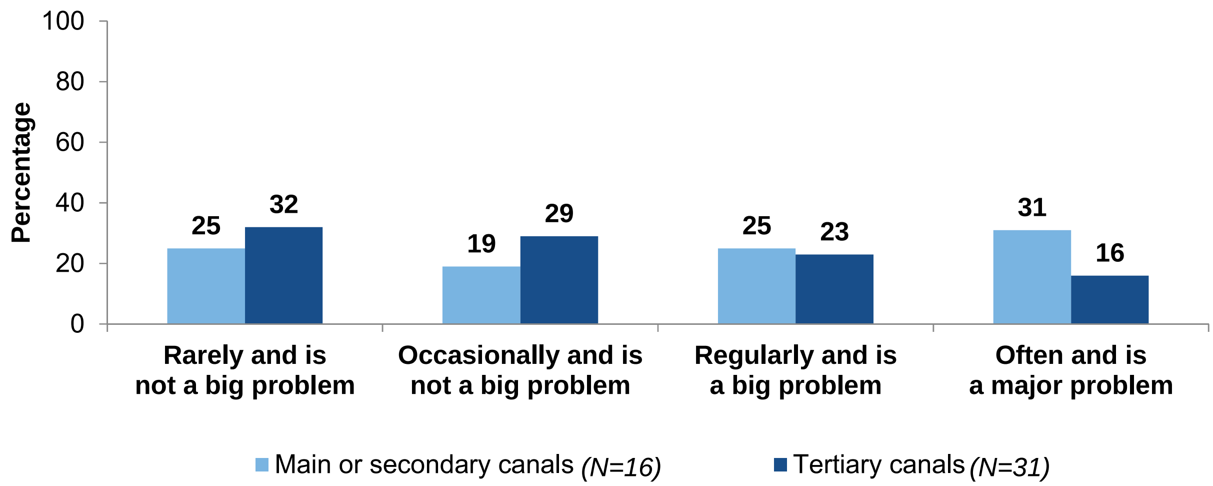
Notes: Estimates are conditional on the WUA director reporting that the WUA had each type of rehabilitated infrastructure.

The water user association director survey also inquired about the primary source of information that was used by water user associations for operating and maintaining rehabilitated pumping stations. Of the nine water user associations with rehabilitated pumping stations, most reported that their primary source of information was water user association staff (six water user associations). This source has limited sustainability because of staff turnover. Two water user associations reported that their primary source of information was an unofficial manual, and only one water user association reported that its primary source was an official manual. No water user associations reported primarily using information from colleagues that were not in the water user association or the internet. Despite the differences in the sources of information that were used, all of these water user associations except one said they believed they had sufficient information to successfully operate and maintain the rehabilitated pumping station. The single water user association that did not believe it had sufficient information primarily relied on an unofficial manual.

Other challenges to sustainability include unintentional damage to the infrastructure from farmers disposing of trash in canals and farmers connecting to the infrastructure illegally. Farmers dispose of trash in canals out of convenience but also in part to raise the water levels, and farmers connect to the infrastructure illegally to access water. These behaviors can lead to damage that requires more costly repairs.

We found that water user associations commonly cite trash disposal in canals as a challenge (Figure VII.10). Over half of water user associations with rehabilitated main or secondary canals and nearly 40 percent of water user associations with rehabilitated tertiary canals characterized trash disposal as a “big” or “major” problem. Trash disposal in rehabilitated canals happened regularly or often in these water user associations. However, it happened “rarely” for nearly a third of water user associations with rehabilitated tertiary canals and a fourth of water user associations with rehabilitated main or secondary canals.

Figure VII.10. Whether farmers disposing of trash in canals continues to be a problem (percentage of WUAs with rehabilitated canals)

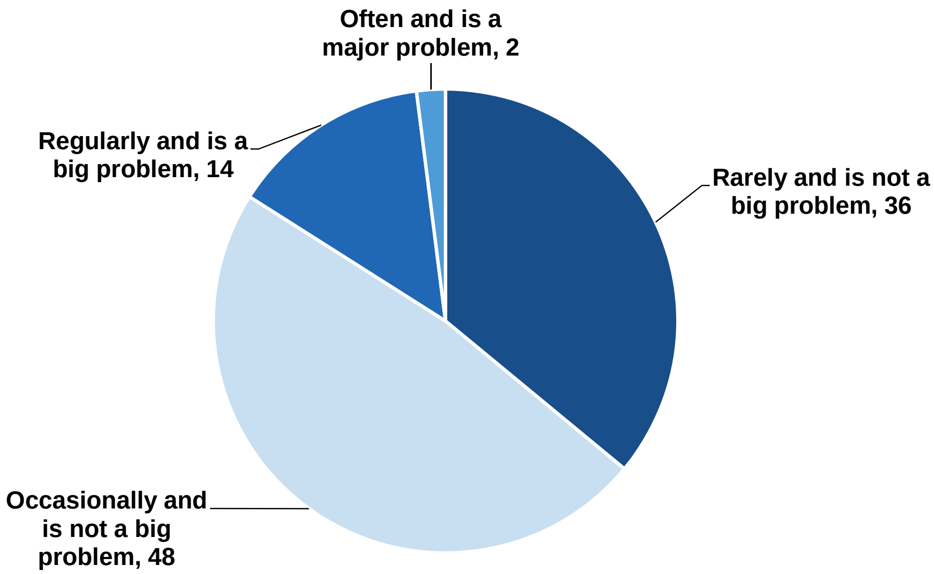


Sources: 2014 WUA director survey.

Notes: Estimates are conditional on the WUA director reporting that the WUA had each type of rehabilitated infrastructure.

Some water user associations also consider illegal connections to the infrastructure to be a substantial problem, but most water user associations did not think illegal connections were a big problem because they happened only occasionally or rarely (Figure VII.11). Fourteen percent of water user associations reported that illegal connections happened regularly and were a big problem, and one water user association reported they happened often and were a major problem.

Figure VII.11. Frequency with which farmers illegally connect to the system to steal water, damaging the infrastructure (percentage of WUAs)

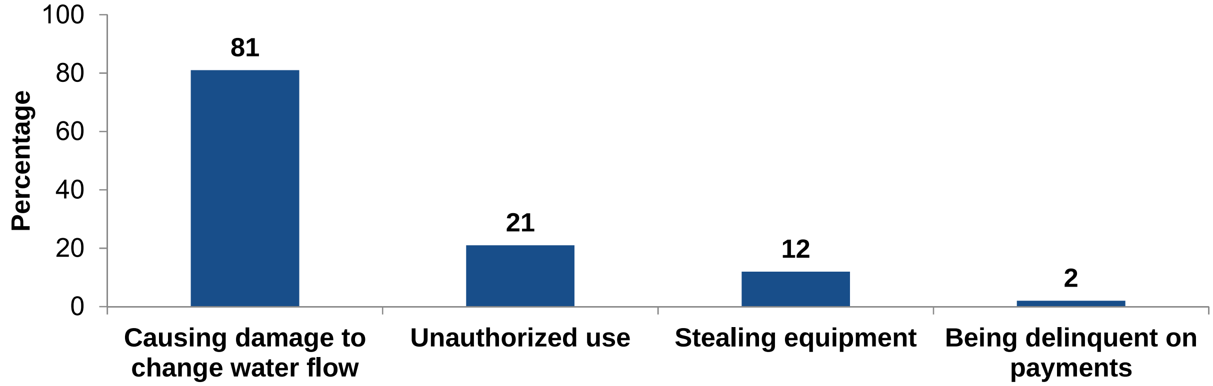


Sources: 2014 WUA survey.

Notes: Estimates are based on 42 WUAs in place as of 2014.

The survey asked water user association directors to list up to three additional actions that farmers take that cause damage to the functionality of the system. We categorized the reasons into four groups, and the frequencies of these reasons are shown in Figure VII.12. The most common type of damaging action was by farmers who were trying to change the water flow; over 80 percent of water user associations reported that farmers caused damage to the system to change the water flow. These actions included breaking or damaging locks or pipes, clogging canals, or creating artificial barriers in canals. The next most common type of response was that farmers caused damage in trying to gain unauthorized use. These actions included stealing water or violating the water delivery schedule. Being delinquent on payments was only reported by one water user association. The last class of actions reported by water user associations was stealing equipment, including stealing equipment from electricity substations or oil from energy substations, which was reported by 12 percent of water user association directors.

Figure VII.12. Prevalence of actions that damage the functionality of the system (percentage of WUAs)

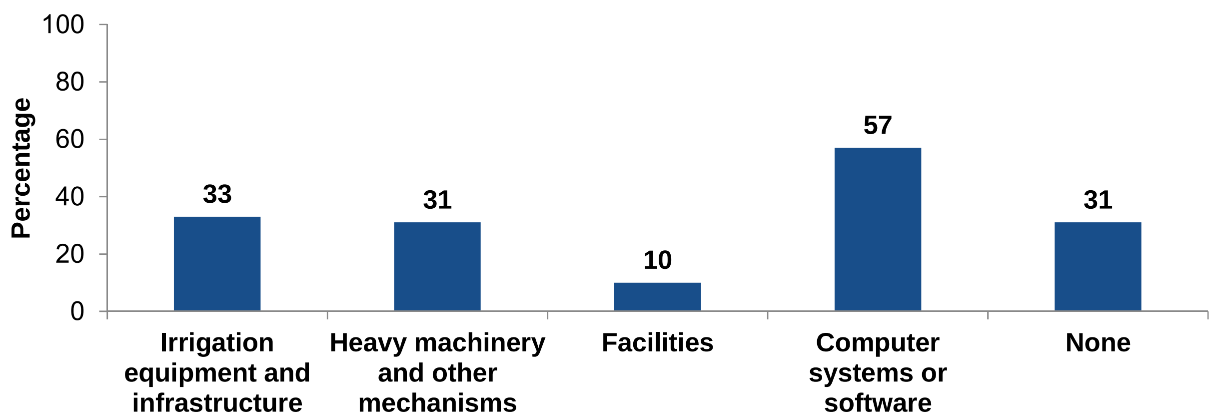


Sources: 2014 WUA director survey.

Notes: Estimates are based on 42 WUAs in place as of 2014. Multiple responses were permitted from each WUA.

Despite these continued challenges, many water user associations have invested in upgrades to their systems since the infrastructure rehabilitation funded by MCA-Armenia was completed (Figure VII.13). Most water user associations (57 percent) updated their computer systems or software, and nearly a third of water user associations updated their irrigation equipment and infrastructure or heavy machinery. Forty percent of water user associations implemented a combination of updates (not shown). Computer systems or software might be a more common upgrade in part because it is less costly than irrigation infrastructure and heavy machinery. However, a third of water user associations did not make any investments in post-Compact upgrades beyond regular repairs and maintenance; we cannot identify whether these water user associations felt they did not need more post-Compact upgrades or whether they needed but were unable to make these upgrades.

Figure VII.13. Investments in post-Compact upgrades beyond regular repairs and maintenance (percentage of WUAs)

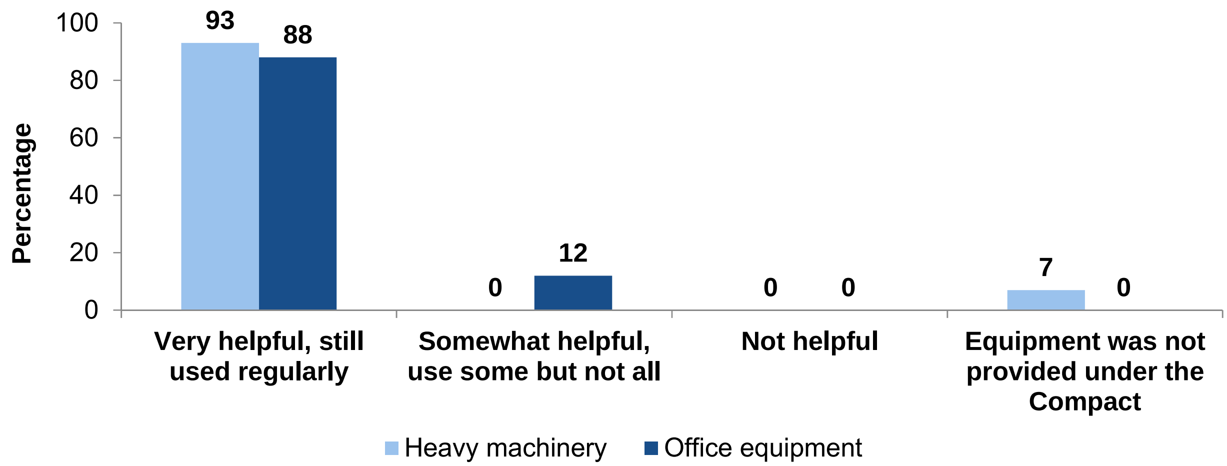


Sources: 2014 WUA survey.

Notes: Estimates are based on 42 WUAs in place as of 2014. Multiple responses were permitted from each WUA.

The post-Compact upgrades to heavy machinery and computer systems or software seem to have complemented MCA-Armenia's equipment instead of replacing them (Figure VII.14). MCA-Armenia provided water user associations with heavy machinery and office equipment under the Compact to help with modernization. Nearly all water user associations said that the heavy machinery and office equipment was very helpful and still used regularly. The other water user associations indicated that the office equipment provided under the Compact was "somewhat helpful; we use some but not all of it" (12 percent), or they thought that equipment was not provided to the water user association under the Compact (7 percent). No water user associations said that equipment provided under the Compact was not helpful.

Figure VII.14. Helpfulness of heavy machinery and office equipment provided under the Compact (percentage of WUAs)



Sources: 2014 WUA director survey.

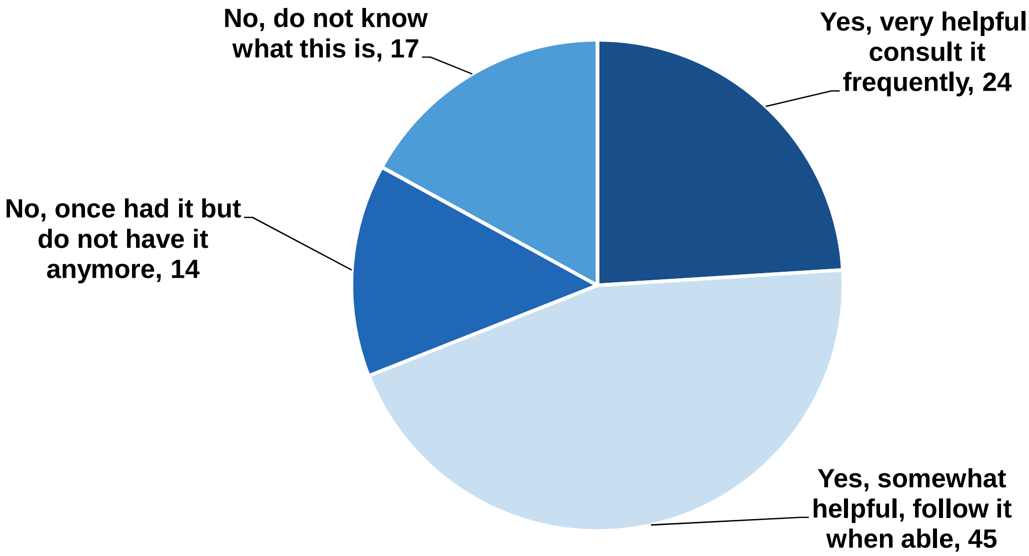
Notes: Estimates are based on 42 WUAs in place as of 2014.

E. Sustainability of technical assistance

Under the Compact, specialists worked with each water user association to develop a management improvement plan. The management improvement plan for each water user association outlined the water user association's strengths, weaknesses, and specific milestones to help reach technical, managerial, and financial self-sustainability. Based on qualitative interviews with several water user associations, the Water-to-Market report concluded that water user association staff generally did not consider the consultations particularly helpful or relevant to their daily operations. However, interviews were not conducted with all water user associations, so we revisited this question in the water user association director survey for a longer-term measure.

The management improvement plans developed with MCA-Armenia were still used by 69 percent of water user associations. Most of these water user associations found the management improvement plans somewhat (but not very) helpful and followed it when able to do so (Figure VII.15). One quarter of all water user associations found the management improvement plan to be very helpful and consulted it frequently. No water user associations reported having a management improvement plan but finding it unhelpful. This was unexpected given that the water user associations interviewed by Socioscope did not find the management improvement plans to be particularly useful. However, the remaining 31 percent of water user associations do not use the management improvement plans anymore, either because they did not have them or because they did not know what the survey was referencing. The latter group is likely due to water user association staff turnover.

Figure VII.15. WUAs' use and perceived helpfulness of management improvement plans developed with MCA-Armenia (percentage of WUAs)

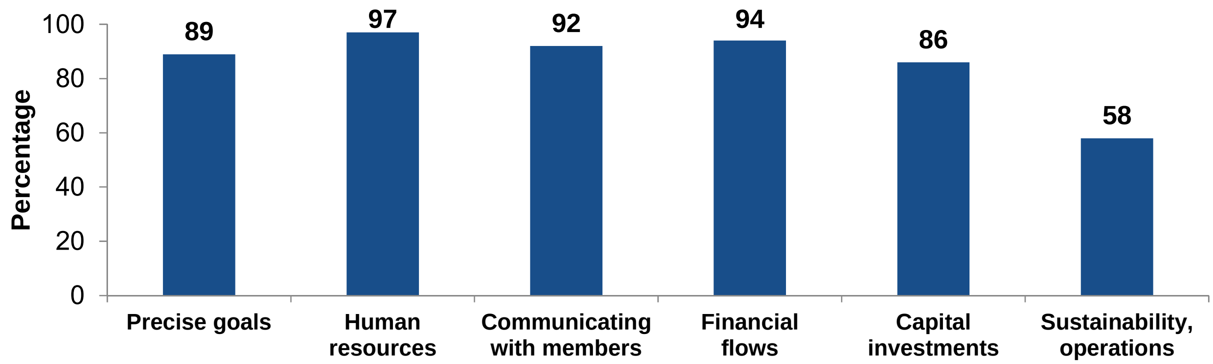


Source: 2014 WUA director survey.

Notes: Estimates are based on 42 WUAs.

As part of the technical consultations, water user associations that did not have business plans, or who had them but had not updated them recently, were encouraged to create them and provided guidance to do so. This was not a major point of emphasis under ISSA, but it is another indicator of longer-term sustainability of the associations. In 2014, 37 of the 42 water user associations still had a business plan. The survey requested that the 37 water user associations with business plans identify which of the following were covered in their business plans: precise goals and targets; human resources management; communication, information, and education for their members; financial flows; capital investment plans; and sustainability and operational efficiency. The vast majority (86 to 97 percent) of business plans covered the first five topics, but substantially fewer (58 percent) covered sustainability and operational efficiency (Figure VII.15).

Figure VII.16. Topics covered in WUAs' business plans (percentage of WUAs with a business plan)

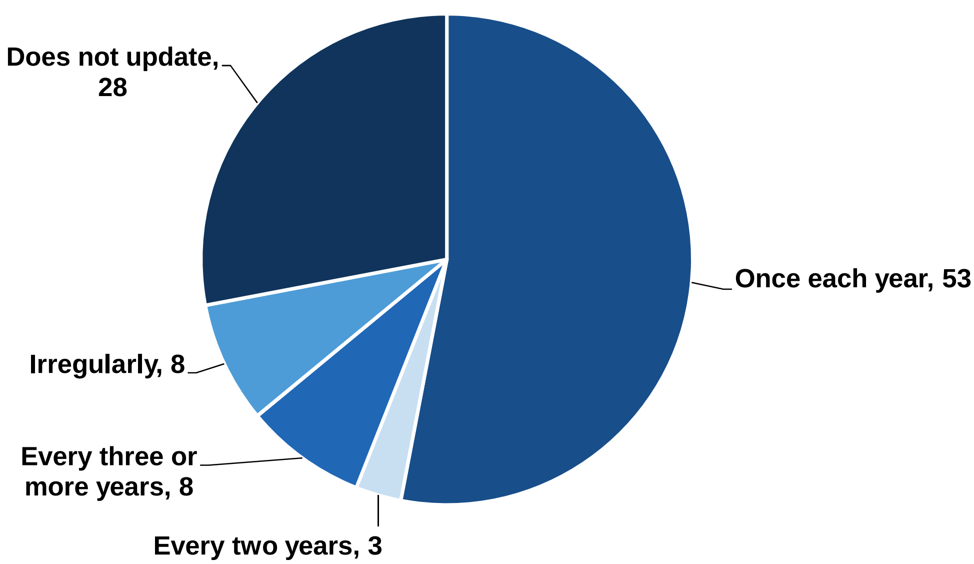


Source: 2014 WUA director survey.

Notes: The percentages are based on 37 WUAs that reported having a business plan.

We also found that most water user associations (53 percent) updated their business plans yearly, but a sizeable minority of water user associations do not update their business plans regularly (Figure VII.16). Twenty-eight percent of water user associations reported that they do not update their business plans at all, and an additional 8 percent of water user associations reported updating their business plans irregularly. Eleven percent of water user associations updated their business plans every two years or every three or more years.

Figure VII.17. Frequency of updates to WUAs' business plans (percentage of WUAs that have a business plan)



Source: 2014 WUA director survey.

Notes: The percentages are based on 37 WUAs that reported having a business plan.

F. Summary

Overall, our analysis of the time trends suggests that water user associations are unlikely to become financially self-sufficient in the near future without additional intervention, though there have been many improvements that followed the implementation of ISSA. Revenues and expenditures have shown modest improvements since 2007, but the service fee collection rates and cost recovery rates appear to have plateaued after 2009. Only a quarter of the water user associations perceived the management improvement plans to be very useful plans that they continued to use, but most water user associations had business plans that they used and update regularly. Some water user associations have also transitioned to using water meters to determine water fees, more so for large areas of land than small, rather than estimating the amount of water needed based on hectares and type of crop, though this change appears to have happened independently from ISSA.

Water user association directors reported that the rehabilitated irrigation infrastructure is mostly operating as planned and required little more than regular maintenance and repair. They also reported that the heavy machinery and office equipment provided under the Compact have been very helpful. The longer-term sustainability of the infrastructure investments is uncertain, however. One specific concern about sustainability was that farmers sometimes accessed water illegally and damaged the irrigation infrastructure. We found that most WUAs have observed this problem. About four in five reported that farmers damage the system in order to change the flow of water, and nearly half of those with rehabilitated canals reported that farmers disposing of trash in canals is a problem. Yet, most directors reported that farmers illegally connecting to the irrigation system was only an occasional or rare problem, so it seems unlikely that damage from illegal access to water will be a major threat to sustainability.

VIII. CONCLUSIONS

A. Overview

MCC and MCA aimed to increase economic well-being in Armenia by rehabilitating substantial portions of Armenia's canals and other irrigation infrastructure. Over 420,000 beneficiaries are estimated to be influenced by improvements in tertiary canals, main canals, pumping stations, gravity schemes, and drainage systems through the Irrigation Infrastructure Activity. Total costs of the Activity, for which rehabilitation efforts were completed in 2011, were about $122 million USD. This study examined whether the Irrigation Infrastructure Activity increased agricultural production and economic well-being in Armenia approximately two to three years after rehabilitation was completed in communities.

We examined the impacts of the rehabilitation of tertiary canals and the rehabilitation of larger infrastructure separately using matched comparison methods. Although the research questions are similar for each of them, the evaluations were conducted separately because the impacts of the larger infrastructure projects could theoretically differ from those of the more localized tertiary canals. Moreover, our survey sample and design for our main data source, the Tertiary Canal Survey, were originally tailored to facilitate a rigorous evaluation of rehabilitated tertiary canals. The evaluation of rehabilitated large infrastructure was designed after the baseline Tertiary Canal Survey had been fielded, and there was no possibility of gathering pre-intervention data specifically for the evaluation of large infrastructure. As a result, even though we use the same dataset and similar quantitative methods, we consider the evaluation of rehabilitated tertiary canals to be more rigorous than the evaluation of rehabilitated large infrastructure, for which the data can only be considered an opportunistic sample.

We also revisited the findings for the Water-to-Market training and Institutional Strengthening Subactivity that were originally assessed as part of the Water-to-Market evaluation (Fortson et al. 2013) and were thought to have important linkages with the Infrastructure Activity. The present report examined those initiatives with a longer timeframe than was possible for the Water-to-Market evaluation.

B. Summary of findings

Based on the program logic model for the Infrastructure Activity, we expected impacts of rehabilitated tertiary canals and large infrastructure on a range of outcomes, from the immediate- to the long-term. In Table VIII.1, we have summarized the strength of the evidence for these impacts.

Table VIII.1. Summary of evidence for the logic model of the Infrastructure activity

Expected outcomes in logic model	Evidence for communities with rehabilitated tertiary canals	Evidence for communities with rehabilitated large infrastructure
Immediate		
Improvements in irrigation infrastructure	Strong evidence: farmers perceived improvements in the timeliness and reliability of irrigation water.	Weak evidence: farmers were more likely to report dissatisfaction with the timeliness and quantity of irrigation water, but WUAs reported the infrastructure was generally functioning well as planned. The expected (but modest) energy savings for gravity schemes did not materialize.
Short-term		
More efficient irrigation	Limited evidence that may be anomalous: farmers did not systematically adopt improved irrigation technologies or increase the adoption of higher-value but more irrigation-intensive crops.	
Increased area of irrigated land	Limited evidence that may be anomalous: farmers did not irrigate more of their land or more frequently overall, but farmers increased the total hours of irrigation on some portions of their land.	
Medium-term		
Increased production of high-value crops and total crop yields	No evidence.	
Lower production costs	No evidence.	
Long-term		
Increased and more diversified production	No evidence.	
Increased sales and agricultural profits	No evidence.	
Increased household income/consumption	No evidence.	
Reduced rural poverty	No evidence.	

Beneficiaries of tertiary canals perceived improvements in the accessibility and reliability of irrigation water, but beneficiaries of larger infrastructure improvements did not. In the evaluation of rehabilitated tertiary canals, communities with rehabilitated tertiary canals reported improvements with the timeliness and reliability of irrigation water following rehabilitation. In contrast, farmers in the large infrastructure treatment group did not perceive that their accessibility and reliability of irrigation water had improved. They were more likely to report dissatisfaction with the timeliness and quantity of irrigation water than farmers in the comparison group.

Beneficiaries made few changes to their irrigation practices. Neither the beneficiaries of tertiary canals nor beneficiaries of other large infrastructure irrigated more of their land or more frequently. Farmers may have irrigated some crops more intensively: tertiary canal beneficiaries irrigated arable land and kitchen plots for more total hours, and beneficiaries of other large infrastructure irrigated vineyards for more total hours. There were few significant changes in adoption of improved irrigation technologies or increased adoption of higher-value but more irrigation-intensive crops like fruits and vegetables. Likewise, the time series of water user association data corroborate the impact estimates: according to the water user association administrative data, the area irrigated and amount of water distributed reveals little change from before infrastructure rehabilitation to two years after all rehabilitation had been completed.

Two to three years after rehabilitation of the irrigation infrastructure, there is no evidence of improvements in household income. There were no significant impacts of tertiary canal rehabilitation on agricultural production, economic profit from agricultural, household income, or consumption. For other large infrastructure, farmers in the treatment group cultivated fewer crop types, and agricultural income decreased. However, there were no impacts on overall economic income because of a substantial increase in nonagricultural income. We also do not anticipate large positive impacts on agricultural income in future years because there is no evidence of systematic positive impacts on intermediate outcomes such as irrigation behavior, adoption of agricultural practices, or crop cultivation.

Our analysis of linkages between infrastructure rehabilitation and other MCC investments had mixed findings. We did not find evidence of complementarities between infrastructure rehabilitation and Water-to-Market training. However, WUAs have sustained the improvements in their financial standing after the Institutional Strengthening Subactivity, and they report that MCC's investments in infrastructure are mostly functioning as expected.

There was no evidence of longer-term adoption of new agricultural practices in communities that received Water-to-Market training. The evaluation of Water-to-Market training found that the farmer training program did not increase adoption of agricultural practices. One hypothesis was that farmers might begin adopting more agricultural practices once the irrigation infrastructure to be rehabilitated. While the Infrastructure Activity and Water-to-Market training had been envisioned as being linked, rehabilitation was not fully completed before farmers received training, and targets for the two programs were in fact revised separately. In this study, we found no evidence of systematic increases in the adoption rates of agricultural practices within communities that had farmer training and now had greater access to reliable irrigation. This suggests that farmers who participated in training were not waiting for the irrigation infrastructure to be rehabilitated before changing their agricultural practices. However, had the Infrastructure Activity been completed before or shortly after Water-to-Market training was provided, it remains possible that farmers could have had more motivation to adopt the practices they learned in training. It is also possible that the practices covered in training would have been more salient to farmers if the Infrastructure Activity had been completed closer to the training. We did not attempt to assess how well farmers remembered the practices covered in training.

Water user associations' financial statuses have leveled off since 2010, with little further progress toward financial self-sustainability. The Water-to-Market evaluation found that water user associations improved their financial standings from 2007 to 2010. WUAs reduced expenditures on water payments, improved their membership fee collection, and improved their cost recovery rates. However, large annual deficits persisted, and water user associations did not appear to be approaching financial solvency in the near-term. The present evaluation updates those estimates for 2011 to 2013, but the water user associations' cash expenditures, revenues, and net revenues have changed little over this period.

Water user associations report that the irrigation infrastructure rehabilitated under the Compact has mostly operated as planned, requiring little more than regular maintenance. In addition to the financial conditions of water user associations, the sustainability of MCA-Armenia's infrastructure investments depends on the challenges faced by water user associations to perform regular maintenance and any additional repairs. Nearly all WUAs reported that their rehabilitated infrastructure either required regular maintenance only or with some repairs (Figure 12).

C. Possible explanations for the null impact estimates

Farmers have behavioral inertia. Many of these farmers only farm part-time and possibly only for household consumption. Even among farmers who cultivate crops to sell, many are also employed or migrate to Russia parts of the year for work. On average, farming households earn about 40 percent more from nonagricultural work compared to the value of their harvests. They earn more than twice as much from nonagricultural work compared to agricultural net profits after subtracting agricultural costs. Those farmers are less likely to be attentive to opportunities to increase profits, and changing crops or investing in new technologies is also a bigger behavioral change because it entails deciding to place greater emphasis on farming as a main activity. The growing behavioral economics literature hypothesizes that there could be non-rational or even subconscious reasons people do not change behavior. For example, even in the absence of other constraints, farmers might not have changed their behaviors because they stick to what they are comfortable with or it takes mental effort and time to reassess the benefits and costs of change, and this is especially salient if farming is one of two or three sources of income for the household.

Farmers lacked funds to invest in new crops or new agricultural technologies. Farmers may have lacked personal funds or access to affordable agricultural credit to pay for irrigation water that would have been needed to expand cultivation or change crops. Alternatively, farmers may have lacked funds and credit to purchase inputs that would be complementary to irrigation water such as supplies needed for new crops or equipment for new agricultural practices. Although our evidence on these is limited, what we have observed did not support this hypothesis. For the subset of farmers who were asked, few farmers reported that agricultural inputs were not affordable. Most reported that they still did not perceive irrigation water as reliable or were not interested in expanding their cultivation.

Farmers viewed investments in new crops or new agricultural technologies as too risky. Most of the higher-value crops as well as new agricultural technologies entail higher upfront costs but much higher profit margins. Farmers may have been reluctant to make these investments because they did not know what markets would buy their produce, feared price volatility, or feared the risk of a failed harvest.

System functionality did not improve as much as was expected. Rehabilitation might not have repaired the targeted problems as well as was hoped for farmers. Alternatively, rehabilitation may have targeted the wrong issues with the irrigation systems or an incomplete set of issues—for example, perhaps a main canal was rehabilitated, but many of the tertiary canals that deliver water to the fields are still in poor repair. It is also conceivable that the tertiary canals were operating fine before rehabilitation, and the repairs had more of a cosmetic effect without affecting the canals' capacity for water delivery. There unfortunately are not good measures of the functionality of infrastructure. Farmers report in the Tertiary Canal Survey that irrigation functionality remains a constraint for them, but they may not have the expertise to assess functionality accurately, so we do not know if their reports are accurate. One way to measure the impact of complete rehabilitation would be to compare communities that were influenced by rehabilitation of tertiary canals and at least one large type of infrastructure to communities that were not influenced by any infrastructure rehabilitation. Unfortunately, we cannot conduct this comparison because of sample size limitations; only 30 treatment and 17 comparison communities would be in the sample with the bare minimum of matching.

Other less likely explanations. The follow-up period of two to three years after rehabilitation was too short. The impact evaluation is based on survey data collected approximately two to three years after irrigation rehabilitation was complete. Impacts on some outcomes, such as agricultural production and household income, may not be fully realized in three years. However, there are not impacts on intermediate outcomes that could foretell future impacts, such as substantially increasing irrigation use, cultivating higher-value crops, or adopting new agricultural practices, so we are skeptical that future impacts are likely. But it could be that farmers were slow to realize that their irrigation systems had been rehabilitated, in which case even these intermediate impacts could be delayed. Another possibility is that farmers were slow to respond to improvements in their irrigation systems because of reasons related to the global financial crisis in 2008, such as having difficulty accessing agricultural credit or weakened markets for agricultural production. The global economic conditions would affect post-harvest outcomes similarly for the two groups, but we cannot definitively say whether treatment and comparison farmers would have reacted differently without the recession. The impacts of the program could have been different in the absence of the financial crisis if it suppressed farmers' willingness to take advantage of the newly rehabilitated infrastructure with increased production.

Many of the above explanations focus on smaller-scale farmers, and conceivably, larger-scale farm operations could have been better poised to change their operations. The survey on which the impact evaluation was based included smaller-scale farm operations—nearly all survey respondents cultivated 15 hectares or less at baseline (and few even cultivated more than 10). Consequently, the household-level impact estimates do not reflect impacts that accrued to larger-scale farms, which might have had more resources to adopt new agricultural practices and grow high-value crops. However, the WUA administrative data cover both small and large-scale farms, and we do not find evidence that total water deliveries increase after the rehabilitation was completed.

D. Suggestions for future irrigation evaluations

Well-executed random assignment could be used to learn about different types of irrigation infrastructure and different groups of beneficiaries. A crucial assumption in our empirical methods is that our models account for all variables that could lead the treatment and comparison groups to have different outcomes in the absence of the rehabilitation. Our methods establish that the treatment and comparison groups are similar on key outcome measures at baseline and many other characteristics, but we cannot prove that the groups are equivalent for factors that cannot be measured. Future programs could use a well-executed randomized controlled trial to generate intervention and control groups that are equivalent on average, and randomization can be structured so that impacts can be rigorously estimated for subgroups of beneficiaries that receive different types of infrastructure rehabilitation. We note instances where there are many units that are considered for rehabilitation, and a significant subset actually are rehabilitated, such as with tertiary canals, would be especially conducive to a randomized-controlled trial.

Engineering experts could inspect irrigation functionality. Although other data sources have measures of irrigation functionality, having an irrigation expert assess functionality would be a more reliable way to explore this possible explanation. It could be that the systems are actually functioning well but farmers do not yet realize it and/or use perceived irrigation limitations to justify behavioral inertia. The key question for the engineer would be whether irrigation water is flowing as it is supposed to, particularly downstream (in the tertiary canals). This could be done by examining the rehabilitated infrastructure itself and/or water at the tertiary canals even if the tertiary canals themselves were not rehabilitated.

MCC could consider investing in water meters or other monitoring tools that would help water user associations while also providing better measurement of outcomes. Improved water delivery and reduced losses were fundamental expected outcomes of the Infrastructure Activity, but the existing data have not been validated, and there are not accurate measures of water delivery to farmers. This makes it more difficult to know whether water availability has actually improved for individual farmers. Creating the means for WUAs to more precisely measure water delivery would also potentially help them manage their resources more effectively and could possibly be of greater benefit to them than other types of technical and material assistance, beyond the benefits it would have for monitoring purposes.

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APPENDIX A

TECHNICAL APPENDIX

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This appendix provides additional information about the analytic samples for the evaluations of rehabilitated tertiary canals and rehabilitated large infrastructure, including the processes for addressing missing data and outliers, the distributions of propensity scores across communities, the geographic distributions of sampled households and respondents, and the baseline characteristics of the analytic samples. Section A.1 describes how we addressed missing data and outliers in both the evaluation of rehabilitated tertiary canals and the evaluation of rehabilitated large infrastructure. Section A.2 focuses on the analytic sample in the evaluation of rehabilitated tertiary canals, and Section A.3 focuses on the analytic sample in the evaluation of rehabilitated large infrastructure.

1. Addressing missing data and outliers

We used the same process throughout the study to address missing data and outliers in the Tertiary Canal Survey and the Village Mayor Survey. Our focus for reducing missing data was on key outcome measures that we constructed from aggregating crop-level data: amount produced, amount sold, and revenues. We used a sequential process to impute missing values in these items. First, if a respondent had some but not all of this information for a specific crop, then we imputed the missing items using median crop prices within the community, water users association (if a community-level mean was not available), zone (if a water users association-level mean was not available), or full sample (if a zone-level mean was not available). For example, if we had data on the volume sold but not the revenue for a particular crop, we used the median crop price to convert the volume into crop-specific revenue, and vice versa. In a handful of other cases missing crop-specific variables at follow-up, we imputed based on a predicted value from the corresponding baseline measure.

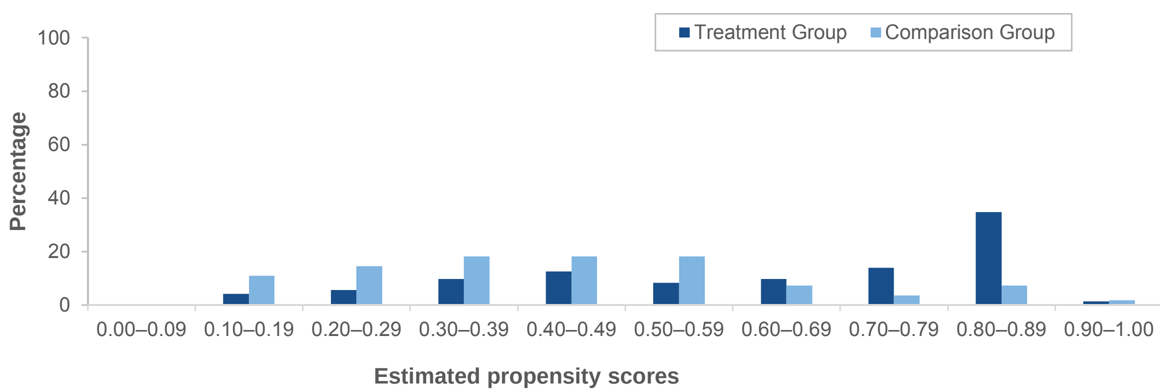
To account for outliers that could skew our estimates away from impacts on a typical farmer, we censored each continuous covariate and outcome measure from the Tertiary Canal Survey either at the 98th percentile or at both the 2nd and 98th percentiles. Income variables, including total market value of harvest, nonagricultural income, agricultural profit, total economic income, and consumption relative to the poverty line, and the head of household’s age were both top- and bottom-censored. All other continuous variables from the Tertiary Canal Survey were top-censored only because there was no risk of outlying values. We did not censor variables from the Village Mayor Survey because it did not have as much variation in the continuous variables. Item nonresponse was also much more limited in the Village Mayor Survey than in the Tertiary Canal Survey, which contains many more, and more detailed, questions. After censoring as described above, we also imputed propensity score model covariates for the analyses in Chapters III and IV by either the community-level average (for the Tertiary Canal Survey) or by the overall sample median (Village Mayor Survey).

2. Analytic sample and sensitivity analyses for the evaluation of rehabilitated tertiary canals

As discussed in Section III.C, we anticipated that communities in the treatment and comparison groups would have differences on key characteristics because they were not randomly assigned to have rehabilitated tertiary canals. This was confirmed in the baseline data, though the differences were not extensive (Fortson et al. 2010). As a result, we used a series of steps to select a subset of communities in the treatment and comparison groups that were more similar than the full treatment and comparison groups: (1) identifying characteristics that might be related to each community's probability of having rehabilitated tertiary canals; (2) using a logistic regression to estimate this probability, called a propensity score, for each community; and (3) comparing the distributions of the propensity scores for communities who did and did not have rehabilitated tertiary canals. Restricting the analytic sample to the set of communities with the same range of estimated propensity scores—the common support of the propensity score distributions—reduces the imbalance in the propensity scores of the treatment and comparison groups substantially.

Restricting the analysis sample to the common support serves two purposes. First, it means our regression estimates are not dependent on out-of-sample predictions, which can yield misleading findings when the treatment and comparison groups are fundamentally different from each other. Second, it means the pre-intervention outcomes are, on average, more similar for the treatment and comparison groups. We defined the common support for this evaluation as communities with propensity scores that were higher than or equal to the minimum propensity score in the treatment group but lower than or equal to the maximum propensity score in the comparison group. The common support contains 72 communities in the treatment group and 55 communities in the comparison group, for a total of 127 communities from the 173 communities where the Tertiary Canal Survey was fielded (73 percent). The distribution of propensity scores among communities in the common support is shown in Figure A.1.

Figure A.1. Distribution of community-level propensity scores in the analytic sample for the evaluation of rehabilitated tertiary canals



Propensity score analyses normally employ further adjustments based on the propensity score, such as weighting or matching, but in our sample, restricting the sample to the common support sufficed to achieve balance on baseline outcomes. To assess the baseline equivalence of the analytic sample, we tested whether households in the treatment and comparison groups had similar household-level characteristics, including baseline measures of the outcome measures, using the Tertiary Canal Survey and similar village characteristics using the Village Mayor Survey. None of the differences were statistically significant (Table A.1). We also note that the baseline means for the treatment group are very similar to the corresponding values at follow-up reported in Chapter III if the outcomes measured in dollars are deflated to be consistent across years, further confirming the unfortunate conclusion that there were not meaningful impacts.

Table A.1. Baseline differences between the treatment and comparison groups in the analytic sample for the evaluation of rehabilitated tertiary canals (percentages except where indicated)

	Treatment Group	Comparison Group	Difference	*p*-value
Key Outcome Measures				
Adopted any OFWM practice	59	59	0	0.93
Arable land owned or rented (hectares)	1.2	1.1	0.1	0.77
Arable land irrigated (hectares)	0.4	0.4	0.0	0.92
Cultivated crops				
Grape	28	26	2	0.71
Other fruits or nuts	62	62	0	0.94
Tomato	36	37	-1	0.80
Vegetables and herbs	46	44	2	0.68
Potato	39	38	1	0.91
Grain	43	35	8	0.14
Grass	23	27	-5	0.31
Total agricultural production (tons)	7.7	8.5	-0.8	0.60
Total revenues from crops (USD)	1,132	1,055	77	0.73
Market value of harvests (USD)	1,850	1,788	62	0.83
Total agricultural expenditures (USD)	711	677	34	0.73
Economic income (USD)	3,707	3,680	26	0.93
Household Characteristics				
Head of household's age (years)	50	49	1	0.39
Female-headed household	12	13	0	0.85
Head of household's education				
Less than secondary	9	8	2	0.29
Full secondary	38	42	-4	0.18
Secondary vocational	29	26	3	0.11
More than secondary	23	25	-2	0.50
Total people in household	5.2	5.1	0.1	0.20
Number of children in household	1.2	1.2	0.0	0.44
Orchards owned or rented (hectares)	0.1	0.1	0.0	0.75
Vineyards owned or rented (hectares)	0.1	0.1	0.0	0.53
Village Characteristics				
Number of households	640	712	-72	0.49
Households that farm as their main occupation	80	82	-2	0.45
Total land cultivated (hectares)				
Arable land	534	438	96	0.22
Orchards	38	46	-8	0.49
Vineyards	37	42	-5	0.68
Kitchen plot	98	88	10	0.55
Village has a water users association	100	98	2	0.32
Village has irrigation network	100	98	2	0.32
Village has rehabilitated large infrastructure	65	58	7	0.43
Sample size	901	901		

Source: 2009–2010 Tertiary Canal Survey and 2009–2010 Village Mayor Survey.

Note: Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

OFWM = on-farm water management; HVA = high-value agriculture; USD = United States dollars.

We conducted several sensitivity analyses and found that our estimates were robust to alternative specifications (Table A.2). Using regression adjustment only without restricting to the common support did not substantively affect the estimates, nor did defining a narrower analytic sample. This narrower sample was defined as ranging from the second-lowest estimated propensity score in the treatment group to the third-highest estimated propensity score in the comparison group, a range over which the distributions of estimated propensity scores were more similar for the treatment and comparison groups.

Table A.2. Impact estimates of rehabilitated tertiary canals on measures of income estimated with different models (USD)

	Difference	*p*-value
Nonagricultural Income		
Main model (regression adjustment with a common support)	-247	0.23
Regression adjustment only	-150	0.43
Smaller common support	-193	0.40
Inverse propensity score weights	-275	0.18
Inverse propensity score weights with bootstrapped standard errors	-275	0.96
Market Value of Harvests		
Main model (regression adjustment with a common support)	-154	0.62
Regression adjustment only	16	0.95
Smaller common support	-231	0.45
Inverse propensity score weights	-578	0.10
Inverse propensity score weights with bootstrapped standard errors	-578	0.92
Agricultural Expenditures		
Main model (regression adjustment with a common support)	-7	0.93
Regression adjustment only	0	1.00
Smaller common support	-24	0.76
Inverse propensity score weights	-14	0.85
Inverse propensity score weights with bootstrapped standard errors	-14	0.99
Economic Income		
Main model (regression adjustment with a common support)	-395	0.32
Regression adjustment only	-89	0.80
Smaller common support	-363	0.37
Inverse propensity score weights	-796	0.06
Inverse propensity score weights with bootstrapped standard errors	-796	0.52
Sample size (T; C)	901; 901	

Source: 2009–2010 Tertiary Canal Survey.

Note: Reported differences may not equal the difference in reported treatment and comparison means because of rounding. The bootstrapped estimates are based on 500 draws with replacement from the pool of communities where the TCS was fielded, of which 361 (72 percent) resulted in a data structure where the initial logistic regression to estimate propensity scores was estimable. Sample sizes are based on the estimates for the main model and the regression adjustment only.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

USD = United States dollars; TCS = Tertiary Canal Survey.

As noted above, propensity score analyses typically first restrict the analysis sample to the common support and then use further adjustment to shape the treatment and comparison groups so that they have similar pre-intervention averages. Our original research protocol called for using weighting based on the inverse of the estimated propensity scores to achieve this, and this was another key sensitivity test. However, given that the baseline characteristics were similar for the treatment and comparison groups after restricting to the common support, it is not surprising that using the estimated propensity score to construct weights made little difference in the estimated impacts.

For the sensitivity analyses with weighting based on the propensity score, we report p-values both with and without bootstrapped standard errors. Bootstrapping is a method for correcting the impact estimates' standard errors to account for variability in the propensity score estimates. Bootstrapping in this context involved, for each outcome, taking many iterations of selecting a number of communities from the analytic sample, then estimating a propensity score model to derive the common support, and finally calculating an impact estimate with that set of communities. Each draw was done with replacement, so the same community could be drawn multiple times in a single draw (or not at all). Bootstrapping allowed us to measure how much noise is in the propensity score weights, which are themselves estimates. The standard deviation of the impacts from each bootstrap sample represents the impact estimate's standard error. When we bootstrapped, we found that some distributions of impacts had very large outliers, leading to implausibly large standard errors. For instance, the impact estimate on nonagricultural income had a standard error that was more than 10 times as large as the unadjusted standard error, and the impact estimates implausibly ranged from less than -$400,000 to greater than $300,000. This was due to chance exclusions of certain communities in a sample or a particularly skewed distribution of propensity scores in a sample—particularly low propensity scores could lead to very large weights for a single community in a sample.

In each community in the analytic sample, more than 70 percent of households that responded to the baseline Tertiary Canal Survey also responded to the follow-up Tertiary Canal Survey. The response rates from baseline to follow-up and the number of respondents in the follow-up Tertiary Canal Survey are shown by water users association and research group (treatment and comparison) in Table A.3. Overall, the treatment and comparison groups had similar response rates from baseline to follow-up (83 percent in the treatment group, 82 percent in the comparison group). By chance, the analytic sample contained the same number of households in the treatment and comparison groups. Some analyses in Chapter III, however, have fewer than 1,802 households because of item nonresponse or because the information was presented conditionally.

Table A.3. Response rates and numbers of households in the analytic sample for the evaluation of rehabilitated tertiary canals, by water users association

Water Users Association	Treatment Group Response Rate	Treatment Group Sample Size	Comparison Group Response Rate	Comparison Group Sample Size
Aknalich	78.3%	47	80.0%	48
Aparan-Aragats	86.7%	91	83.8%	67
Aragats Vorogum	88.3%	53	80.0%	32
Ararat	86.7%	26	78.3%	47
Armavir	84.4%	38	82.5%	66
Azat	86.7%	26	82.5%	33
Eghegnadzor	80.0%	48	86.7%	52
Eghvard	86.7%	26	82.5%	33
Gavar	93.3%	14	90.0%	36
Idjevan	82.2%	37	80.0%	48
Karakert	86.7%	13	-	0
Khoi	85.0%	102	90.0%	18
Kotayq	66.7%	20	82.5%	33
Loru Jrantsk	75.6%	34	90.0%	18
Martuni	86.7%	13	80.0%	16
Masis	73.3%	11	80.0%	32
Merdzapnya	80.0%	12	85.0%	17
Noyamberyan	86.7%	26	75.0%	30
Parpi	84.4%	38	77.5%	31
Sevjur-Akhtamar	83.3%	25	82.5%	33
Shenik	-	0	78.9%	15
Shirvorogum	93.3%	14	82.5%	33
Vagharshapat	90.0%	27	90.0%	36
Vardenis	83.3%	75	81.3%	61
Vedi	81.0%	85	82.5%	66
Total	83.4%	901	82.4%	901

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Nonresponse rates are calculated over all households served by each water users association after restricting the sample to the common support. Communities that were not in the analytic sample are excluded. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Table A.4 provides empirical estimates of the minimum detectable impacts for key outcomes in the tertiary canal analysis. A minimum detectable impact is the smallest true impact for which we are likely to estimate a statistically significant impact. These estimates assume a 5 percent significance level and 80 percent power and are based on the standard errors for the estimated impact on each of the outcomes listed. We also report our ex ante estimated minimum detectable impacts from our design report, which are about half the size of our ex post minimum detectable impacts. This is because restricting the sample to the common support trimmed more communities from the analysis than we expected, and the outcome measures were also much more variable than we expected. That the estimates are less precise than was expected does not, in the end, affect our interpretation of the findings, but had we seen large but insignificant estimates, it would have made drawing firm conclusions challenging. This also serves as a cautionary lesson for designing other nonexperimental studies, for which it is much harder to estimate minimum detectable impacts than for randomized controlled trials.

Table A.4. Minimum detectable impacts of tertiary canal rehabilitation on key outcomes

	Ex ante Minimum Detectable Impact	*Ex post* Minimum Detectable Impact	Baseline Average
Irrigated land (hectares)	0.14	0.39	0.77
Land under cultivation for HVA crops (hectares)	0.09	0.18	0.61
Agricultural profits (USD)	314	650	1,286
Economic income (USD)	482	1,098	4,684
Households below the lower poverty line (%)	6.0	3.7	16.0

Source: *Ex post* estimates based on Tertiary Canal Survey. *Ex ante* estimates based on authors' calculations drawing on Fortson et al. (2013), which used the Farming Practices Survey, a survey with outcomes and a sample that are closely related to the Tertiary Canal Survey used for the present analysis.

Note: The minimum detectable impacts assume a confidence level of 95 percent, two-tailed tests, and 80 percent power, resulting in a factor of 2.8.

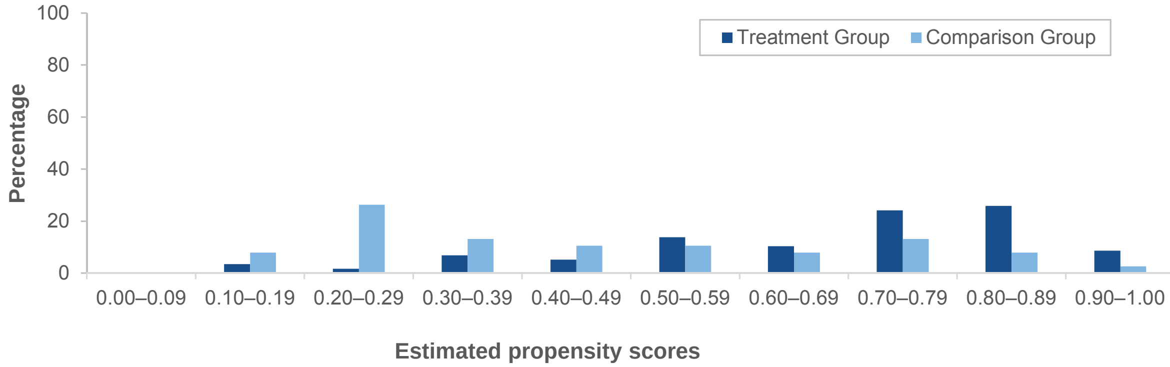
HVA = high-value agriculture; USD = United States dollars.

3. Analytic sample and sensitivity analyses for the evaluation of rehabilitated large infrastructure

As with the evaluation of rehabilitated tertiary canals, restricting the analysis sample to the common support means our regression estimates are not dependent on out-of-sample predictions, and it also means the pre-intervention outcomes are, on average, more similar for the treatment and comparison groups. We defined the common support for the large infrastructure analysis in a more restrictive manner than for the tertiary canal analysis, using communities with propensity scores that were higher than or equal to the second lowest propensity score in the treatment group but lower than or equal to the second highest maximum propensity score in the comparison group. We selected a more stringent definition for the common support than in the tertiary canal evaluation because there was one community in the treatment group with a very low propensity score and one community in the comparison group with a very high propensity score; the more stringent definition results in these outliers being out of the common support.

The analytic sample for the large infrastructure evaluation contains households from 96 communities, 58 in the treatment group and 38 in the comparison group. This is 55 percent of the communities where the Tertiary Canal Survey was fielded. The distribution of propensity scores among communities in the common support is shown in Figure A.2.

Figure A.2. Distribution of community-level propensity scores in the analytic sample for the evaluation of rehabilitated large infrastructure



Once we limited the sample to the common support, we assessed baseline differences on household and village characteristics for the treatment and comparison groups (Table A.5). Households in the treatment and comparison group irrigated similar amounts of land at baseline and did not have statistically significant differences on other baseline measures of agricultural production. However, there were a few significant differences; relative to households in the comparison group, households in the treatment group owned 0.4 fewer hectares of arable land, were 7 percent less likely to have more education than secondary school, and had slightly more children. As discussed in Section IV.C, we account for these differences by controlling for these variables in our impact regressions.

We also note that, as with the tertiary canal analysis, the baseline means for the treatment group are very similar to the corresponding values at follow-up reported in Chapter IV if the outcomes measured in dollars are deflated to be consistent across years, further confirming the unfortunate conclusion that there were not meaningful impacts.

Table A.5. Baseline differences between the treatment and comparison groups in the analytic sample for the evaluation of rehabilitated large infrastructure (percentages except where indicated)

	Treatment Group	Comparison Group	Difference	*p*-value
Key Outcome Measures				
Adopted any OFWM practice	51	50	1	0.90
Total land owned or rented (hectares)	1.3	1.6	-0.3	0.14
Arable land owned or rented (hectares)	0.9	1.3	-0.4*	0.05
Arable land irrigated (hectares)	0.4	0.4	0.0	0.81
Cultivated crops				
Grape	25	20	6	0.36
Other fruits or nuts	56	67	-12	0.09
Tomato	34	41	-7	0.27
Vegetables and herbs	44	49	-5	0.50
Potato	34	40	-7	0.38
Grain	30	38	-8	0.16
Grass	30	28	2	0.75
Total agricultural production (tons)	7.7	6.6	1.1	0.49
Total revenues from crops (USD)	1,218	813	406	0.16

	Treatment Group	Comparison Group	Difference	*p*-value
Market value of harvests (USD)	1,750	1,463	287	0.37
Total agricultural expenditures (USD)				
Economic income (USD)	3,660	3,394	266	0.46
Household Characteristics				
Head of household's age (years)	50	50	1	0.45
Female-headed household	14	15	-1	0.64
Head of household's education				
Less than secondary	10	8	2	0.25
Full secondary	41	38	4	0.30
Secondary vocational	28	27	1	0.70
More than secondary	21	28	-7**	0.01
Total people in household	5.2	5.1	0.1	0.40
Number of children in household	1.2	1.1	0.1**	0.05
Orchards owned or rented (hectares)	0.1	0.1	0.0	0.12
Vineyards owned or rented (hectares)	0.1	0.1	0.0	0.45
Village Characteristics				
Number of households	626	662	-36	0.78
Households that farm as their main occupation	78	82	-3	0.25
Total land cultivated (hectares)				
Arable land	479	505	-25	0.72
Orchards	46	29	17	0.28
Vineyards	34	16	17	0.10
Kitchen plot	115	96	18	0.37
Village is a water users association member	98	97	1	0.76
Village has irrigation network	100	100	0	-
Village has rehabilitated tertiary canal	46	49	-3	0.79
Sample size	825	523		

Source: 2009–2010 Tertiary Canal Survey and 2009–2010 Village Mayor Survey.

Note: Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

OFWM = on-farm water management; HVA = high-value agriculture; USD = United States dollars.

We conducted the same series of sensitivity analyses for the large infrastructure analysis as for the tertiary canal analysis and again found that our estimates were robust to alternative specifications (Table A.6).

Table A.6. Impact estimates of rehabilitated large infrastructure on measures of income estimated with different models

	Difference	*p*-value
Nonagricultural Income		
Main model (regression adjustment with a common support)	389	0.11
Regression adjustment only	356	0.07*
Smaller common support	419	0.10*
Inverse propensity score weights	393	0.09*
Inverse propensity score weights with bootstrapped standard errors	393	0.92
Market Value of Harvests		
Main model (regression adjustment with a common support)	-406	0.08
Regression adjustment only	-303	0.29
Smaller common support	-388	0.10
Inverse propensity score weights	-766	0.01***
Inverse propensity score weights with bootstrapped standard errors	-766	0.90
Agricultural Expenditures		
Main model (regression adjustment with a common support)	30	0.69
Regression adjustment only	-9	0.92
Smaller common support	44	0.57
Inverse propensity score weights	-17	0.83
Inverse propensity score weights with bootstrapped standard errors	-17	0.94
Economic Income		
Main model (regression adjustment with a common support)	68	0.83
Regression adjustment only	163	0.58
Smaller common support	118	0.72
Inverse propensity score weights	-254	0.38
Inverse propensity score weights with bootstrapped standard errors	-254	0.95
Sample size (T; C)	825; 523	

Source: 2009–2010 Tertiary Canal Survey.

Note: Reported differences may not equal the difference in reported treatment and comparison means because of rounding. The bootstrapped estimates are based on 500 draws with replacement from the pool of communities where the TCS was fielded, of which 229 (46 percent) resulted in a data structure where the initial logistic regression to estimate propensity scores was estimable. Sample sizes are based on the estimates for the main model and the regression adjustment only.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

TCS = Tertiary Canal Survey.

In the analytic sample, more than 82 percent of households that responded to the baseline Tertiary Canal Survey also responded to the follow-up Tertiary Canal Survey. The response rates from baseline to follow-up and the number of respondents in the follow-up Tertiary Canal Survey are shown by water users association and research group (treatment and control) in Table A.7. Overall, the treatment and comparison groups had similar response rates from baseline to follow-up (83 percent in the treatment group, 82 percent in the comparison group), but there were substantially more households in the treatment group (825) than in the comparison group (523). The lowest response rate in a water users association was 74 percent.

Table A.7. Response rates and numbers of households in the analytic sample for the evaluation of rehabilitated large infrastructure, by water users association

Water Users Association	Treatment Group Response Rate	Treatment Group Sample Size	Comparison Group Response Rate	Comparison Group Sample Size
Aknalich	79.1%	87	86.7%	13
Aparan-Aragats	86.0%	86	84.3%	59
Aragats Vorogum	83.3%	100	80.0%	16
Ararat	82.9%	29	-	-
Armavir	85.7%	30	80.0%	28
Azat	86.0%	43	-	-
Eghegnadzor	-	-	84.2%	101
Eghvard	82.9%	87	-	-
Gavar	-	-	88.6%	31
Idjevan	80.0%	12	86.7%	13
Karakert	-	-	-	-
Khoi	86.0%	43	93.3%	14
Kotayq	80.0%	12	75.3%	64
Loru Jrantsk	-	-	80.0%	24
Martuni	80.0%	16	86.7%	13
Masis	77.1%	54	-	-
Merdzapnya	-	-	82.9%	29
Noyamberyan	74.0%	37	93.3%	14
Parpi	82.9%	29	80.0%	24
Sevjur-Akhtamar	80.0%	12	85.0%	17
Shenik	80.0%	28	-	-
Shirvorogum	-	-	80.0%	12
Vagharshapat	92.7%	51	66.7%	10
Vardenis	93.3%	14	80.0%	12
Vedi	84.6%	55	82.9%	29
Total	82.9%	825	82.4%	523

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys.

Note: Nonresponse rates are calculated from the baseline to the follow-up Tertiary Canal Survey, over all households served by each water users association and after restricting the sample to the common support. Communities that were not in the analytic sample are excluded. Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Table A.8 provides empirical estimates of the minimum detectable impacts for key outcomes in the large infrastructure analysis. A minimum detectable impact is the smallest true impact for which we are likely to estimate a statistically significant impact. These estimates assume a 5 percent significance level and 80 percent power and are based on the standard errors for the estimated impact on each of the outcomes listed. We also report our ex ante estimated minimum detectable impacts from our design report, which are about half the size of our ex post minimum detectable impacts. Similar to what we found with the tertiary canal analysis, restricting the sample to the common support trimmed more communities from the analysis than we expected, and the outcome measures were also much more variable than we expected.

Table A.8. Minimum detectable impacts of other large infrastructure rehabilitation on key outcomes

	Ex ante Minimum Detectable Impact	*Ex post* Minimum Detectable Impact	Baseline Average
Irrigated land (hectares)	0.15	0.41	0.77
Land under cultivation for HVA crops (hectares)	0.10	0.16	0.61
Agricultural profits (USD)	345	546	1,286
Economic income (USD)	530	854	4,684
Households below the lower poverty line (%)	6.6	5.4	16.0

Source: *Ex post* estimates based on Tertiary Canal Survey. *Ex ante* estimates based on authors' calculations drawing on Fortson et al. (2013), which used the Farming Practices Survey, a survey with outcomes and sample that are closely related to the Tertiary Canal Survey used for the present analysis.

Note: The minimum detectable impacts assume a confidence level of 95 percent, two-tailed tests, and 80 percent power, resulting in a factor of 2.8.

HVA = high-value agriculture; USD = United States dollars.

APPENDIX B

SUPPLEMENTAL TABLES

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Table B.1. Impacts of rehabilitated tertiary canals on production of crops (metric tons)

	Treatment Group Mean	Control Group Mean	Impact	p-value
High-Value Agriculture				
Grape	0.88	0.72	0.16	0.35
Apple	0.12	0.12	0.00	0.94
Peach	0.17	0.13	0.03	0.46
Apricot	0.23	0.27	-0.04	0.41
Pear	0.01	0.01	0.00	0.89
Prunes	0.00	0.00	0.00	0.88
Plum	0.01	0.01	0.00	0.75
Fig	0.01	0.00	0.00	0.25
Pomegranate	0.00	0.00	0.00	0.21
Sweet cherry	0.00	0.00	0.00	0.73
Cherry	0.00	0.00	0.00	0.43
Cornel	0.00	0.00	0.00	0.25
Quince	0.00	0.01	0.00	0.14
Watermelon	0.06	0.13	-0.08	0.10
Melon	0.00	0.00	0.00	0.91
Lemon	0.00	0.00	0.00	.
Malta orange	0.00	0.00	0.00	0.81
Walnut, hazelnut	0.01	0.01	0.00	0.82
Strawberry	0.02	0.01	0.01	0.66
Other fruits	0.00	0.01	-0.01	0.16
Tomato	0.57	0.53	0.04	0.73
Pumpkin	0.00	0.00	0.00	0.30
Cucumber	0.21	0.24	-0.03	0.72
Eggplant	0.09	0.10	-0.01	0.78
Pepper	0.08	0.09	-0.02	0.61
Cabbage	0.03	0.03	-0.01	0.77
Carrot	0.02	0.04	-0.02	0.27
Squash	0.00	0.00	0.00	0.55
Onion	0.04	0.02	0.02	0.29
Garlic	0.00	0.00	0.00	0.64
Red beet	0.13	0.02	0.11	0.18
Other vegetables	0.01	0.01	0.00	0.97
Potato	1.29	1.74	-0.46	0.26
Sunflower	0.01	0.01	0.01	0.39
Haricot	0.02	0.01	0.01*	0.06
Tobacco	0.01	0.00	0.01	0.14
Non-High-Value Agriculture				
Wheat	0.80	0.82	-0.01	0.94
Barley	0.19	0.23	-0.04	0.46
Maize	0.03	0.03	0.00	0.99
Emmer wheat	0.01	0.01	0.00	0.97
Natural grass	0.34	0.42	-0.08	0.54
Gramma or other feed	0.70	0.62	0.08	0.64
Sample size	901	901		

Source: 2009–2010 Tertiary Canal Survey.

Note: Reported differences may not equal the difference in reported treatment and comparison means because of rounding. Because of difficulties measuring the amount of sorgo, greens, planting stock, and flower production in a way that is comparable to other crops, we omit these crops from this table.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Table B.2. Impacts of rehabilitated tertiary canals on the market value of harvests (USD)

	Treatment Group Mean	Control Group Mean	Impact	*p*-value
High-Value Agriculture				
Grape	331	266	65	0.33
Apple	44	46	-2	0.81
Peach	64	54	10	0.57
Apricot	92	143	-51**	0.03
Pear	8	7	1	0.63
Prunes	1	1	0	0.77
Plum	3	4	-1	0.56
Fig	3	1	2	0.23
Pomegranate	0	1	0	0.23
Sweet cherry	3	3	0	0.70
Cherry	1	1	0	0.53
Cornel	2	0	1	0.28
Quince	1	3	-2	0.12
Watermelon	11	26	-15*	0.09
Melon	1	1	0	0.91
Lemon	0	0	0	.
Malta orange	0	0	0	0.76
Walnut, hazelnut	14	13	1	0.86
Strawberry	28	17	11	0.57
Other fruits	0	10	-9	0.14
Tomato	176	161	15	0.66
Pumpkin	0	0	0	.
Cucumber	77	79	-2	0.93
Eggplant	22	25	-3	0.72
Pepper	34	37	-3	0.81
Cabbage	8	10	-2	0.62
Carrot	3	6	-3	0.30
Squash	0	1	0	0.59
Onion	13	6	8	0.17
Garlic	1	1	0	0.75
Red beet	5	4	1	0.63
Other vegetables	10	7	3	0.83
Greens	36	14	22*	0.07
Potato	301	403	-102	0.26
Sunflower	22	19	3	0.85
Haricot	12	5	7**	0.03
Tobacco	2	0	2	0.14
Sorgo	21	1	20	0.28
Planting stock	0	0	0	.
Flowers	20	25	-5	0.76
Non-High-Value Agriculture				
Wheat	256	266	-10	0.84
Barley	67	83	-16	0.36
Maize	9	9	0	0.93
Emmer wheat	10	10	0	0.97
Natural grass	42	55	-13	0.45
Gramma or other feed	88	69	19	0.41
Sample size	901	901		

Source: 2009–2010 Tertiary Canal Survey.

Note: Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

USD = United States dollars.

Table B.3. Impacts of rehabilitated large infrastructure on production of crops (metric tons)

	Treatment Group Mean	Control Group Mean	Impact	*p*-value
High-Value Agriculture				
Grape	0.62	0.47	0.15	0.35
Apple	0.12	0.18	-0.06*	0.06
Peach	0.08	0.10	-0.02	0.61
Apricot	0.28	0.24	0.04	0.72
Pear	0.01	0.02	-0.01	0.13
Prunes	0.00	0.00	0.00	0.13
Plum	0.01	0.00	0.00	0.46
Fig	0.00	0.00	0.00	0.95
Pomegranate	0.00	0.00	0.00	0.13
Sweet cherry	0.00	0.00	0.00	0.85
Cherry	0.00	0.00	0.00	0.34
Cornel	0.00	0.00	0.00	0.33
Quince	0.01	0.00	0.01	0.19
Watermelon	0.11	0.15	-0.04	0.48
Melon	0.00	0.00	0.00	0.70
Lemon	0.00	0.00	0.00	.
Malta orange	0.00	0.00	0.00*	0.09
Walnut, hazelnut	0.00	0.01	-0.01***	0.00
Strawberry	0.01	0.01	0.01	0.54
Other fruits	0.01	0.00	0.01*	0.09
Tomato	0.46	0.60	-0.14	0.30
Pumpkin	0.00	0.00	0.00	.
Cucumber	0.24	0.33	-0.09	0.39
Eggplant	0.10	0.10	0.00	0.94
Pepper	0.11	0.16	-0.05	0.28
Cabbage	0.04	0.05	-0.01	0.78
Carrot	0.04	0.04	0.00	0.88
Squash	0.00	0.00	0.00	0.82
Onion	0.05	0.04	0.01	0.79
Garlic	0.00	0.00	0.00	0.11
Red beet	0.14	0.00	0.15	0.18
Other vegetables	0.01	0.00	0.00	0.67
Potato	0.67	1.25	-0.58	0.18
Sunflower	0.01	0.01	0.00	0.96
Haricot	0.01	0.01	0.01	0.23
Tobacco	0.00	0.00	0.00	.
Non-High-Value Agriculture				
Wheat	0.54	0.69	-0.15	0.32
Barley	0.18	0.18	0.00	0.98
Maize	0.02	0.03	-0.01	0.75
Emmer wheat	0.01	0.03	-0.02	0.30
Natural grass	0.34	0.75	-0.41**	0.02
Gramma or other feed	1.03	0.44	0.59**	0.02
Sample size	825	523		

Source: 2009–2010 Tertiary Canal Survey.

Note: Reported differences may not equal the difference in reported treatment and comparison means because of rounding. Because of difficulties measuring the amount of sorgo, greens, planting stock, and flower production in a way that is comparable to other crops, we omit these crops from this table.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

Table B.4. Impacts of rehabilitated large infrastructure on the market value of harvests (USD)

	Treatment Group Mean	Control Group Mean	Impact	*p*-value
High-Value Agriculture				
Grape	229	204	25	0.67
Apple	44	71	-27**	0.04
Peach	32	38	-7	0.59
Apricot	115	116	-1	0.98
Pear	7	10	-3	0.26
Prunes	1	1	0	0.11
Plum	3	2	1	0.15
Fig	2	1	0	0.97
Pomegranate	0	0	1	0.13
Sweet cherry	3	3	0	0.80
Cherry	2	1	0	0.35
Cornel	0	2	-1	0.29
Quince	2	0	3	0.15
Watermelon	21	30	-9	0.41
Melon	1	1	0	0.69
Lemon	0	0	0	.
Malta orange	0	0	0*	0.09
Walnut, hazelnut	11	27	-16***	0.01
Strawberry	21	10	11	0.58
Other fruits	11	-2	13	0.17
Tomato	171	223	-51	0.28
Pumpkin	0	0	0	.
Cucumber	93	115	-22	0.61
Eggplant	27	24	3	0.78
Pepper	48	67	-18	0.34
Cabbage	11	15	-3	0.61
Carrot	6	7	-1	0.86
Squash	1	1	0	0.87
Onion	15	14	1	0.92
Garlic	1	-1	2	0.11
Red beet	7	1	6	0.12
Other vegetables	2	3	-1	0.74
Greens	40	10	30*	0.08
Potato	172	315	-143	0.14
Sunflower	8	18	-9	0.46
Haricot	10	5	5*	0.09
Tobacco	0	0	0	.
Sorgo	0	0	0	0.31
Planting stock	0	0	0	.
Flowers	26	19	7	0.80
Non-High-Value Agriculture				
Wheat	176	242	-67	0.18
Barley	62	63	-1	0.95
Maize	8	9	0	0.94
Emmer wheat	10	23	-13	0.49
Natural grass	47	106	-59**	0.03
Gramma or other feed	130	51	79**	0.03
Sample size	825	523		

Source: 2009–2010 Tertiary Canal Survey.

Note: Reported differences may not equal the difference in reported treatment and comparison means because of rounding.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

USD = United States dollars.

Table B.5. Adoption of OFWM practices of WtM communities, detailed practices

	TCS sample	WtM report
Simple Improvements	30	45
Modification of furrow sizes	29	44
Plastic cover for ditch	2	3.3
Siphons	0	0.5
Spiles	0	0.5
Dams	1	0.1
Medium Improvements	2	0.2
Movable gated pipes	1	0.1
Hydrants	1	0.0
Advanced Improvements	4	0.5
Sprinkler irrigation	1	0.1
Micro-sprinkler irrigation	0	0.1
Drip irrigation	3	0.2
Irrigation Scheduling Improvements	0	0.1
Soil moisture meter	0	0.1
Evapotranspiration gauge	0	0.0
Organizational Improvements	60	76
Preparation of irrigated land	52	60
Water measurement at farm gate	0	0.0
Have copy of water supply contract from WUA	25	45
Updated the annex to the water supply contract	15	10
Presented water order to the WUA about cultivated crops	20	19
Placed written water order	11	0.4
Sample size	923	2,133

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys and 2007–2008 and 2010–2011 Farming Practices Surveys.

OFWM = on-farm water management; WtM = Water-to-Market; TCS = Tertiary Canal Survey; WUA = water users association.

Table B.6. Adoption of industrial-economical HVA practices of WtM communities, detailed practices

	TCS Sample	WtM Report
Produced high-value crops for budget reasons	1	2.8
Produced nontraditional crops	0	0.1
Changed crop or variety based on demand	1	3.7
Mixed crops	1	1.8
Produced multiple yields	6	2.3
Established or renewed an orchard	9	10
Established or renewed a greenhouse	8	11
Improved soil preparation activities (plowing, cultivation, etc.)	43	26
Used high-quality, disease-resistant seeds or planting material	10	5.8
Improved post-planting practices (weeding, fertilization, pest control, etc.)	44	12
Shifted time of harvest by using plastic tunnels or planting seedlings	1	1.4
Sample size	923	2,133

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys and 2007–2008 and 2010–2011 Farming Practices Surveys.

HVA = high-value agriculture; WtM = Water-to-Market.

Table B.7. Adoption of social-environmental HVA practices of WtM communities

	TCS sample	WtM report
Used nonchemical methods of pest and disease management	7	0.3
Used only pesticides permitted in Armenia	77	62
Purchased pesticide from licensed stores	53	58
Did not purchase pesticides in damaged packaging	28	50
Used safety equipment when working with pesticides	30	49
Bought pesticides for a specific problem (disease, insects), avoiding residuals	53	57
Harvested crops after the pesticide’s waiting period	33	55
Did not burn or discard residual pesticide into the ditch or mudflow conduits	20	45
Did not use excessive amounts of chemical fertilizer(s)	23	23
Did not burn organic waste remaining after harvesting crops	2	0.0
Prepared compost and used it as organic fertilizer	1	0.1
Used organic fertilizers with appropriate methods	29	12
Sample size	923	2,133

Sources: 2009–2010 and 2013–2014 Tertiary Canal Surveys and 2007–2008 and 2010–2011 Farming Practices Surveys.

HVA = high-value agriculture; WtM = Water-to-Market.

Table B.8. Estimates and targets for key monitoring and evaluation indicators for the Irrigation Infrastructure Activity

	Estimate as of Year 7	M&E Target for Year 5
Additional land irrigated under project (hectares)[a]	-784	1,767
Annual energy savings under project (thousand kWh)	-9,189	1,375
Share of beneficiaries satisfied with irrigation services	22.5	--
Recovery of WUA operations and maintenance cost by water charges (percentage)	48	60
Increased collection of irrigation service fee for the water used (percentage)	84	55

Sources: Targets taken from the Monitoring and Evaluation Plan for the Armenia Compact. Estimates based on authors' calculations based on analyses of the Tertiary Canal Survey and water users association administrative data.

[a] We estimated the additional land irrigated under the project by using our impact estimates to calculate the estimated percentage change in irrigated land, and then applied this percentage to the baseline number of irrigated hectares covered by the targeted infrastructure projects.

*/**/*** Significantly different from zero at the .10/.05/.01 levels, respectively, two-tailed test.

M&E = Monitoring and Evaluation; USD = United States dollars; kWh = kilowatt-hour; WUA = water users association.

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APPENDIX C

COMMENTS ON IRRIGATION EVALUATION

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This appendix compiles comments provided by MCC staff, former staff of MCA-Armenia, and other relevant stakeholders. All comments are presented unedited except for our notes on comments provided orally, which have been edited for clarity (with follow-up from the relevant parties to ensure we have maintained their intent).

We greatly appreciate input from the following individuals who provided comments:

Ester Hakobyan, former MCA-Armenia M&E officer
Lusine Kharatyan, former MCA-Armenia M&E officer
Lusine Yeremyan, former MCA-Armenia M&E officer
Shushan Kurkchiyan, former MCA-Armenia M&E specialist
Anahit Petrosyan, former MCA-Armenia agriculture officer
Tigran Kalantaryan, former MCA-Armenia Irrigation officer
Ara Hovsepyan, former MCA-Armenia CEO
Onno Schaap, water management consultant
Melik Gasparyan, AVAG Solutions CEO
Marycel Tuazon, MCC infrastructure
Sarah Bishop, MCC economist
Rebecca Goldsmith, MCC M&E
Kathy Farley, MCC agriculture

- In the Executive Summary, the “Summary and Lessons Learned” section is really repetitive of the “Summary of findings.” Any way to reduce the redundancy in the Exec Sum? Could you include a similar table to the one included in the road report where it walked through the logic and gave the results for each stage of the logic?
- For the “Possible Explanations for the Null Impact Estimates”…
    - Is the follow-up 2 or 3 years? (Exec Sum says 3 years, page 39 of pdf says approx. 2 years) Pls make this clear and consistent throughout. If it was 2 years for some areas and 3 for others, pls show that. Is there any evidence from other studies that 2 or 3 years is sufficient or not sufficient? Did MCC expect it to be sufficient based on the ERR?
    - If large farmers were benefitting, wouldn’t we see WUAs providing more water? I don’t understand how this adds up.
    - One theory that was discussed during the EMC was whether or not the tertiary canals were actually in bad shape to begin with. It never occurred to me that they wouldn’t be in need of rehab, but do we have any evidence of what shape they were in? Would it help to know what works were done in which communities? Perhaps that would show the level of rehab that was necessary?
    - Is there any way to start to narrow this list down and rule out some potential explanations or rank it in order of likeliness?
- Page 39 of the pdf – the road report is now released in MCC’s eval catalog if you want to update that

- Tables showing targets for WTM seem to ignore the fact that WTM was re-scoped as well as Infra
- A map and table early on showing where the different types of infra was rehabbed and where training took place would be helpful
- Page 52 of pdf, could you explain in the description of each type of infra what the benefit streams were in the ERR. I think this could help differentiate between the expected types of benefits.
- Page 59 of the pdf, comparison areas were selected based on similar condition of tertiary canals, do you know how this was determined?
- Do you know how many of the comparison communities submitted an application for tertiary rehab, but didn't get it?
- When describing sample sizes and communities, tables would help to make it clearer (along with the text). For both tertiary and large infra.
- Page 68, it says that the community counterpart contribution was 18%, I thought it was 15%. Am I remembering wrong?
- Page 69, it says "We expected water user association membership rates at follow-up to be higher in the treatment group relative to the comparison group since the rehabilitated tertiary canals could provide more households with access to water." In the document, there is no real information about baseline levels of access to water. It might be helpful to provide this to give people a sense of whether or not farmers didn't have access to water or just didn't have enough at the right times. For tertiary and large infra.
- Page 70, treatment farmers are more likely to use network irrigation exclusively, but page 73, there's no difference in the use of personal alternatives. How do you explain this?
- Page 75, there is a statistically significant result for kitchen plots, but tertiary canals didn't reach kitchen plots, right? Can this be explained in the text? In fact, I don't think that there is any discussion of kitchen plots vs. field plots and it may be worth describing the relationship between the activity investments and the kitchen plot (or lack thereof).

Starting page 77 (practices), do we know how many farmers in the TCS treatment sample actually attended WTM training? If not (or if it's really low), that could be a reason for poor results and a limitation of this analysis. Same for large infra. (Now that I've read the whole report, I realize that this section may not have meant to analyze training, but it would still be interesting to know).

- Page 87 in pdf, Table III.18. Not clear what this table is showing and how it relates to Figure III.8.
- Why is there so much analysis on consumption when we've found no meaningful effects on earlier parts of the program logic? What makes us think it would have distributional impacts at this point in the analysis? (page 88) How do you explain the results? Same for large infra.
- There needs to be a clearer explanation of why the tertiary canals and large infra were evaluated separately. Perhaps include in the timeline when the tertiary eval was designed and when large infra eval was designed? Also important to note that the communities didn't

all overlap, i.e. that even though schemes were envisioned in the beginning, they were not implemented as schemes and were approved in re-scoping as individual investments.

- Could the report be clearer on how many pieces of the large infra are covered by the evaluation? Are many of them not included at all? If so, could this be biasing results?
- Page 96, this sentence reads oddly "Again, these percentages seem to reflect a lack of awareness about the large infrastructure rehabilitation efforts by MCC that might not difference is driven by comparison communities being 17 percentage points more likely to report the rehabilitation of a tertiary canal."
- Are we pretty confident that the farmers sampled in the TCS had tertiary canals that were connected to the large infrastructure being evaluated?
- Reading through the WTM section, I became confused about what was being analyzed under the irrigation chapters vs. the WTM section. Is it just irrigation alone under the irrigation chapter and training is controlled for? Then in the WTM section, it compares training alone vs. training plus irrigation? Maybe this can all be made clearer.
    - Also I wonder if the tables and figures should be different from the previous sections? It seems odd to me that as you read the figure, you're going back in time. That 2013 comes before 2010. I know this is consistent with the treatment-comparison order in previous tables, but it's confusing (also not consistent with time-order for ISSA chapter).
- Page 129 and 130, it may help to show rain levels and economic growth rates for Armenia over the same time period of 2007 to 2013, and possibly the exchange rate, which could potentially impact investment in crops?
- How are water delivery and water losses measured?
- Is "delivered" the same as billed?
- Do you have confidence in these numbers?
- Table VII.2 – energy costs went up?!? Would be good to know if this was for all WUAs or a certain few since the gravity systems were really supposed to reduce energy costs. Do the WUAs with the new gravity systems have decreased energy costs?
- It would be helpful to include a line in the graphs over time for when the compact started and ended.
- Page 134, if WUAs are using funds to improve non-MCA infra more then could this be having an impact on the comparison groups?
- Page 134, I didn't think WUAs had water meters at the farm gate, so how do they know the cubic meters of water provided? Something seems off here.
- Figure VII.8. Any reason drainage systems aren't included here? Do we know how much upkeep they require and if it's being done?
- Page 145, Section B on Lessons Learned. These don't look like lessons learned, they look like a summary of findings.
- Thanks for Table B.8!

- Is there any data in the WUA admin data about land under irrigation? Does it show any increases in irrigation across the WUAs over the last 2 years? Just curious! If there are large increases, then that might mean we're missing something, but if not, that supports the conclusions of the eval. OK just saw this data in the ISSA chapter. This seems like important information that would help to clear up a lot of questions. Could you reference this finding earlier in the report and in the Exec Summ?
- Do you think it would be worthwhile to look at comparing communities that received all types of infra improvements compared to ones that received nothing? Just wondering if the piecemeal nature of investments is the problem and if there are examples where it wasn't piecemeal, was there more of an impact? I know, sample size is probably an issue.
- Mentioned by Ag below, I just want to re-emphasize how useful it would be to include MDIs in the discussion for key indicators like irrigated land and cultivation of HVA for both tertiary and large infra. It would also be useful to discuss the expected changes to put the results in context.
- As discussed during the EMC, by Year 7, how much additional land was expected to be under irrigation and for which pieces of infra and do we have sample covering those pieces of infra? (the re-scoping document may help)
- Similar to a comment by Ag below, could you include the estimated number of farmers that each type of infra was meant to benefit in addition to the community numbers that are already included in the report?
- Given the comments included here (and your answers) plus the discussion with the EMC, would you still recommend an engineering inspection and a survey of farmers to try to learn more about why there was no impact (and if so, in what order)?
- Please include a summary of comments received on the report in an Annex, including stakeholder comments and MCC comments (no need to identify the commenters).

Summary of Findings:

Overall, to what degree do the analysts think that the significant findings among the tertiary canals is attributable to a better research design, and perhaps better statistical power, than for the 'other large infra'?

- Difference between the communities that are reached by tertiary canals and 'other large infra' – type of land or communities?
- Overall these are both a sample of convenience, not a representative sample – this is part of the project design and the research design is left to create or apply methods to obtain useful results given this limitation.
- Tertiary canal comparison, but may have benefitted from a main canal or other large infra (n=31 of n=75 communities) – nearly half. Control for this within the econometric analysis? Yes, control if they had received any other large infra for the tertiary canal analysis – and

vice versa, use control for tertiary when looking at 'other large infra'. Does the variable used to control for this appear to be significant?

- We examined the statistical significance of these explanatory variables for the outcomes of nonagricultural income, agricultural income, and total economic income. We found they did not tend to be statistically significant. That is, the covariates representing different types of rehabilitated large infrastructure were not generally statistically significant in the analysis of rehabilitated tertiary canals, and the covariate representing rehabilitated tertiary canals were not statistically significant in the analysis of rehabilitated large infrastructure.
- Who was ultimately selected for treatment and comparison? What was used as criteria?
  - Use propensity score matching

Infra condition:

- Perception: This is still seems relatively low - less than 1/3 of the treatment sample. Do we think that this could be affecting the other results – why we are not seeing the later stage results occurring?
- Agree that some type of engineering evaluation to determine the true efficiency and quality of the system would be beneficial, since all of the other results depend on knowing this result.
- Pg. xxii. Right before Figure 3. This sentence, as written, sounds a bit like the results are similar to that reported in the sentence directly before it, but the results actually appear to be the opposite, where the comparison group is about 12 percentage points greater. The numbers seem to be written correctly based on the graph below, but the wording is a bit misleading about the actual situation.
- If there are meters, as noted, then can these be used to see if more water is being used?
- It seems like some additional thought should be put into a statement that is included in the paper and would affect this greatly:
  - *"Although most directors reported that farmers illegally connecting to the irrigation system was only an occasional or rare problem, about four in five reported that farmers damage the system in order to change the flow of water, and nearly half of those with rehabilitated canals reported that farmers disposing of trash in canals is a problem."*
- Rehabilitating irrigation infrastructure did not lead to increased production.
- Is there any sense that price fluctuations are feeding into decisions on how much to produce and of what products?
- Is there a question at the BL that gives indication that there was even much room for expanding irrigation to additional land in the first place? This would have been an indicator of a poorly designed project from the offset - that was weakly identified as an area for potential gains, and would change the assumptions in the CBA model.

Water-to-Market Activity

- It needs to be clearer upfront on who is being compared to whom and how. Were TCS-WtM sample in both the 2010 and 2013 survey, and included in both the graph bars or you are comparing both the treatment groups based on 2013 survey? Both groups received training at the same time?
- It seems like perhaps the data could be used to get a comparing groups, but I cannot tell for sure because I am not entirely clear on who is being compared here.
- Do the results of this activity indicate that there was learning that occurred from this training? Basically, was there a typical pre- and post-survey/test completed, as done with trainings of all levels and across fields, to simply determine (1) Did they know this info before coming?; (2) Did they leave with new knowledge?; (3) Are you sure that they actually learned?; (4) How likely did they think they were to apply this knowledge?
    - I know there is a separate report on this activity, but I think that summarizing these results is helpful for understanding why there may not be results at this later stage in the process – applying it to improve production.
- Should highlight that potential issue of not detecting effects is that the training occurred so far in advance of the improved irrigation access that this would reduce the likelihood of applying the training, especially if they were waiting for these improvements. Recently spoke with a training expert who told me that trainees usually leave with about 20% of the knowledge shared, but this decreases over time without constant interaction with the similar materials.

Potential Explanations for Results (beyond a few noted above):

- Would be good to see a breakdown of the question on if they did not invest, then why. Lack of funds is noted, but I would think that the surveys would capture this element and clarify whether this was in fact perceived as a constraint to their investment.
- Note a follow-up survey to get a behaviors. Given that one of the underlying goals of the project was to change behaviors I would have thought that this was speckled throughout the surveys that were already completed. Is this not the case or were they deemed unusual in supporting the analysis?

CBA Work

The description of an updated ERR is limited and needs to be expanded. I would not suggest working through the actual spreadsheet and attempting to update the entire model, each data point, etc. – I don't think that would be a good use of resources. Instead, I would suggest creating perhaps some tables or clear way of showing the following:

- What were the estimated costs (initial, rescoping, and closeout) vs. the actual costs (post-compact)?
    - You can see in the spreadsheet how MCC defines this – funds from MCC, but also the country, administrative costs, etc. This would include a breakdown of the costs, and how those individual costs, as well as the overall costs changed in each of the 4 points.

- Provide a brief analysis on what this comparison tells us – i.e. how they changed over time and why

- What were the estimated benefits (initial, rescoping, and closeout) vs. the actual benefits (post-compact)?
  - Again, the various categories, their anticipated trends, and the numbers tied to them should be in the spreadsheets provided.
  - Provide a brief analysis on how these factors compare across the 4 points in time and why the changes occurred. This would require some slight expansion of what is already written on whether benefits materialized. One question that stands out is: What level of certainty can we place in the current results at this time given the strength of the research design (which was clearly limited by the implementation strategy)? How comfortable are we in expanding those results to project future results?

- What were the assumptions? How did these change across time? Does this evaluation indicate that these assumptions were proven, disproven, unable to shed light on their validity, etc.? What does that tell us for developing future CBA models in irrigation?
  - Again, refer to the models at the 3 periods in time to see the outlined assumptions.
  - Based on the results I hope there is something around (1) expanding area of land irrigated – connection with above question on whether a BL and/or follow-up surveys gave us a better indication of how much land was even available to expand to these practices; and (2) how benefits would accrue to small and large farmers.

- Of course the costs and benefits are discounted and therefore linked to a specific period in time. What does the review of implementation indicate about potential differences in when the project was anticipated to be completed and when the benefits or costs would accrue?
  - As written in the report I wasn't clear on where we were on this aspect. Perhaps including the actual year, not just a number to reflect initiation, etc. would be helpful in explain this aspect – or a time series graph showing differences with these estimates and what actually happened.

- MCC's versions of the ERRs are also being sent along with these comments to ensure that we all have the same versions
  - Note that the closeout ERR should not be shared as it was never considered final and published. I would use it for reference and inform the analysis, but not provide the actual estimates.
  - Documents:
    - First page of spreadsheet will indicate whether it is the original or the rescoped ERR – have these both for WtM and Infra
    - Closeout ERR is just for infra and it's the file that is over 1MB.
    - For naming purposes online they all have the same name.
  - Note that Sarah Bishop will be going on maternity leave in about a month, so if you have any questions for her, please ask sooner rather than later. Thanks!

- Could we see a chart of rainfall data over the past several years – just so we know how 2013 and the year of the baseline survey compare to average rainfall? This should be answerable more scientifically than asking farmers whether there was a natural disaster.
- Could we see some basic summary statistics about the breakdown of small vs. large farmers – what percent of farmers were small enough to be part of the survey and what percent of the land do they farm?
- Could we see some discussion of whether land consolidation has taken place – if the survey follows the farmer and not the parcel, it might be hard to capture land that has been consolidated and put to more valuable use. The WUA presidents should be able to tell us this.
- We really do need to understand what improvements were happening in those comparison communities to make half the people say there had been improvements.
- It would be nice if there was more before/after comparison as well as the difference-in-difference comparisons. I would want to know whether both the treatment and comparison areas saw benefits, they were just similar, or if there were really no changes for either group.
- It would be good to see some discussion on whether the economic problems in Armenia over that time period might be one potential explanation
- I appreciate that they included a table of MDIs in an annex, but those could be discussed throughout the report as part of the presentation of results.
- A chart at the beginning showing the overlap between communities with both tertiary and large infrastructure would be helpful, so we can clearly see who got what interventions, and which groups were compared against which other groups and visually see the complexity of trying to tease out differences when different communities got different combinations of interventions. With number of hectares in each of these different combination groups just so we can all better understand the situation.
- Better document and understand why communities did or did not get tertiary but got the larger infrastructure; how was the infrastructure selected and then when re-scoping took place, how was it decided what stayed in and what was left out?
- It would be interesting to see the year-on-year prices charged for water use and membership fees. Was this a deterrent for the control group?
- Role of market/demand – is there any other way to look at this issue other than the farmer survey? Can we look at overall production numbers – imports and exports to try to understand what happened? Are there national statistics we can access to help understand what might or might not have been going on in the market?
- On the new proposed farm survey – worried if we only survey farmers that did not grow HVA before 2013 that we will miss understanding full picture on adoption and objective of improving productivity. There was lots of training targeted to improve productivity not just transition.

General comments:

The Irrigation Infrastructure Activity rehabilitated sections of the network, expanded capacity and extended the lifetime of the systems. The drainage project reduced flooding significantly. This should have increased arable land.

The large infrastructure focused on rehabilitating existing systems. Any plan for expansion of irrigated land would likely have required the construction of new tertiary canals, which was not included within the project.

It seems that many questions that were asked to farmers regarding the large infrastructure may have been more appropriate for WUA management and/or technical staff. Some farmers may or may not be members of WUAs. The farmers may not have thorough knowledge of the functionality of the main canals, or pumping stations.

Armenia has largely subsistence or small farmers; there are limited large commercial farmers who would more likely have the resources to try high value crops

Detailed comments:

Executive Section,

D. Summary of Findings:

1. ***PDF p22 "Rehabilitating tertiary canals increased farmers' perceptions of the condition of their irrigation systems, but rehabilitating other infrastructure did not."***

   What are the land sizes of the farmers interviewed? Farmers with smaller plots are in close proximity to tertiary canals; the large infrastructure – main canals, pumping stations, gravity canals, and drainage systems may not be so close to the farmers' locations. The WUAs management and technical staff are more appropriate to ask the condition of the large infrastructure.

2. ***PDF p30 "Water user associations report that the irrigation infrastructure rehabilitated under the Compact has mostly operated as planned, requiring little more than regular maintenance.*** *In addition to the financial conditions of water user associations, the sustainability of MCA-Armenia's infrastructure investments depends on the challenges faced by water user associations to perform regular maintenance and any additional repairs. Nearly all water user associations reported that their rehabilitated infrastructure either required regular maintenance only or with some repairs (Figure 12)."*

   This statement does not seem to support the hypothesis below on PDF P35 (see also page PDF p137)

   "System functionality was not as good as was expected. Rehabilitation might not have repaired the targeted problems as well as was hoped, or the repaired infrastructure could have deteriorated faster than was expected. Alternatively, rehabilitation may have targeted the wrong issues with the irrigation systems or an incomplete set of issues—for example, perhaps a main canal was rehabilitated, but many of the tertiary canals that deliver water to

the fields are still in poor repair. Farmers report in the Tertiary Canal Survey that irrigation functionality remains a constraint for them, but they may not have the expertise to assess functionality accurately, so we do not know if their reports are accurate. "

Section III. Evaluation of Rehabilitated Tertiary Canals

Timeliness and Quantity:

1. PDF P71 Figure III.2 Except for "Could not pay for irrigation" these reasons seem like they could also be water management issues that should be addressed to the local WUA managing the delivery of the water.

2. Each WUA (that we worked with) should have a water management plan which states the command area, canal flows, inflow from each water source, any plan for expansion of irrigable lands, the possibility of using other water sources, and how water would be regulated (using meters, regulators and impounding structures, etc). Do we have a sense from the water users association how much they follow the water management plan?

Section IV. Evaluation of Rehabilitated Large Infrastructure

1. ***Table IV.3. Farmer knowledge of rehabilitation of irrigation infrastructure in past 5 years (percentages)***

   Table IV.4. Farmers' perception of main irrigation problems (percentages)

   Table IV.5. Infrastructure reported by village mayors to have been rehabilitated since 2009 (percentages)

   The rehabilitated pumping stations, main canals and/or drainage systems could very well have been miles away from the farmers included in this survey.

   Were the survey participants WUA members? WUA members may have more knowledge of issues related to the network.

2. ***E. Impacts of rehabilitated large infrastructure on water use***

   PDF p99 Figure IV.2. Figure IV.2. Reasons for not using network irrigation water exclusively (treatment group only, percentages)

   "…most farmers said they had no water access due to technical reasons (44 percent)…"

Do we have a sense what these 'technical reasons' are?

- Q: How are water delivery and water losses measured?
  - To the best of my knowledge, there is water measurement performed at water intake from WSA (at main canals). Also, measurement is performed on major structures on secondary canals (within WUA). Then, upon request by water user a measurement of water delivery may be performed at the field. However, in most of the cases water delivery is calculated based e.g. on the diameter and water flow in the pipe and/or type of crop planted. One of problems may occur with water intake from local source (which probably is not measured properly).

- Q: Is “delivered” the same as billed?
  - Yes, delivered is the same as billed. However, you have take into account collection ratio to speak about collected revenue.

- Q: Do you have confidence in these [WUA water delivery] numbers?
  - This is only source of data and as far as I know there is no any specific (comprehensive) study to disuses this issue. Please note that under the current project funded by the WB there is a component to deal with water measurement issue through using new technologies (e.g. introduction of SCADA systems)

This is a professionally made and well documented research and conclusions look reasonable. Although I would like to bring to your attention the following arguments to be considered and possibly incorporated mostly in the Section H of the Executive Summary and/or to be used to reward conclusions regarding the impact of the project related to the infrastructure. Below are my arguments:

- The global economic crisis and recession, which in Armenia continues since 2009 to present, has significantly impacted on all sectors of economy including agriculture. Foreign transfers which form significant part of the purchasing power of population have been twice reduced. In my opinion less than expected expansion of cultivated areas or transfer to high value agriculture has direct link to these macroeconomic issues and is generally caused by the limited demand in the market.
- As you mention, the research was carried out among small farmers who in fact were the target of MCA Project. However it should be noted that in Armenia (I assume this is valid also for other countries) first beneficiaries are the big viable farmers who can further invest and benefit from similar projects. This is already visible in Moldova as well. In fact training of the so called farmers and providing access to funds isn’t enough to ensure broad adoption. The major issue in Armenia is that these small land owners are not real farmers who by definition should get their income from agriculture. Cultivating the small plot of lands they just survive and have no means to grow and adopt benefits of the project.
- All large infrastructure rehabilitated was implemented with good quality and will serve its purpose for decades, I have no doubts in that. However if there is possibility will be good to have the infrastructure audited, any positive or negative results will be useful. There might

be few exceptions among the pump stations which might not provide the full expected performance because of the known quality issues with the Contractor (Farmex). Anyways I don't believe that these investments have had null impact. These were the highest priority structures subject for rehabilitation and maybe other research criteria would be appropriate to be applied to evaluate the efficiency. For example could be analyzed scenario "without project" for the main infrastructure. The reduced water supply and hence reduced cultivated lands could form the idea why these works were important.

- Adoption of advanced (water saving) technologies in my opinion has had less adoption rate because it was not supported with economic/financial incentives to save water. I think the farmers who had benefitted from demonstrated farms had to be requested to pay the full cost for water and these projects had to be implemented not where it was easier to implement, but where the cost of water is high. Low water cost is a global issue in the country. It is heavily and evenly subsidized and farmers are not really interested in water savings. For example in Moldova water costs 6-10 times more and farmers pay full cost without hesitation. It is true that in Moldova farmers can get some harvest without irrigation and irrigation is less intensive than in Armenia. However farmers value the water and possibly save it.
- The Stagnated level of the self-recovery rate in the sector during the last few years first of all is because of the unchanged water tariffs which has more political reasons than economic. This has nothing to do with the project and it's results. I think this should be somehow noted.

- Actually, just on the intuitive level, I would not expect increased use of HVA practices or significant increases on HH income, but i would expect increase in the cultivated land area and possibly productivity (though the new land may have been used for orchards and in this case it takes years to see some yields).
- Actually, I remember from the last year of MCA how some village mayors were pointing out to new cultivated areas under the tertiary canals. On the observation level, I can see more lands being cultivated, at least in the Ararat valley. But definitely, your explanation that larger farmers may have benefited is very likely since what we see is much larger lands under cultivation. It would be interesting to know whether WUAs report changes in cultivated land in their areas.
- Hail was really a big issue a few (two?) seasons ago, mostly in Ararat valley, but in other regions as well. So, if not for the differences in reporting about natural disaster in treatment and comparision groups, it might have been interesting to do some further research related to oucomes in hail struck areas (at that time there were lots of lists of the communities that suffered and the Government provided support to them).
- I think job migration could be another issue. More and more of rural farmers are leaving their land to go to Russia for seasonal work.I do not know whether the survey has a question on this, but this could be a problem.
- With respect to project implementation, one aspect is important (and you touch on it)-the linkages between larger infra rehab and tertiary canals. I remember the time when MCC/Himesh and Alex insisted that at least for some gravity schemes there should be

interrelated rehabilitation of connected tertiary canals (even if these were commuities that initally did not apply and did not provide cofunding) and there were some changes to accomodate this. However, I am not really sure how effectively and correctly these interconnected canals were identified and rehabed, I am not also sure about similar linkages with respect to other larger infra-main canals and pumps-which was more difficult to achieve.

- I know this is not very helpful, but this is what my modest contribution is

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- I went through this small document and have no comments.
- The comparisons I could see are not the best, but the economy of Armenia is in general in free “sky” fall, so with all that it is good that we have ANY movements expressed in the report.

- Q: The rescoping documents suggest infrastructure components were separable, unlike the original plan to rehabilitate schemes. Was this consistent with your observations during implementation?
  - Initial scope of the Infrastructure Activity as part of the Compact had separate components (dams, main canals, gravity schemes, pump stations, drainage and tertiary canals). Feasibility studies revealed that only 40% of the scope can be implemented with allocated funds and there came the need to rescope the project. Initial approach was to integrate the project components in hydrological schemes (overall 23) and to identify the most efficient ones to keep in the project. This approach was later rejected (by the Government and ultimately by MCC) as it was significantly limiting the project area and finally was decided to focus on the most severe infrastructure concerns/emergency situations throughout Armenia. Because the condition of the rehabilitated infrastructure was so bad, it is a positive finding that farmers and WUAs didn’t decline over the study period.
- Q: What was the condition of the tertiary canals? Were there specific records about the relative conditions of tertiary canals before rehabilitation?
  - Most of the tertiary system was debilitated. Previously, there were large water losses. It would be very difficult to compare conditions of canals, and that’s partly why the community financing approach was used (so communities would identify portions of tertiary canals most in need). It was easier to identify the conditions of potential large infrastructure projects, and the large infrastructure projects that were chosen were the ones that most needed rehabilitation.
- Q: To what extent was the rehabilitation intended to maintain versus improve infrastructure?
  - When rescoping the project and focusing on reducing costs, the main idea was to keep the system operational rather than expanding to new canals and irrigation infrastructure.

- Q: The ERR seems clear that the land under irrigation was expected to increase. Was the economic analysis done separately and more optimistically than the expectations of the implementation?
  - There are a range of models with different assumptions. Because we chose the most deteriorated large infrastructure, it could be that the infrastructure would completely fail in a few years without rehabilitation, so the status of the land would be non-irrigated land.
  - ERR included both the expectation that land would stop being irrigated without rehabilitation and the expectation that land under irrigation would increase. The projected declines in the ERRs were smaller than what was indicated.
- Q: Why do we not see evidence of deterioration for comparison communities?
  - This is possibly because the analysis is not based on the population that would most benefit. The core issue is that many households we called farmers are doing it on a very small scale and are not really farmers. But people I talked with have all said that the rehabilitated infrastructure is functioning well after rehabilitation. (More on the issue of farmers' perceptions in h.)
- Q: On gravity schemes, which are more energy-intensive, we expected to see an increase in irrigated land and savings in energy costs. Is that correct?
  - Yes, because (for example) the gravity schemes dealt with non-functioning pump stations, canals and canals with large water losses. These are working well, although maybe there was not as much improvement as we had expected. With the rehabilitated gravity schemes, they could irrigate much more and without pumping. Energy parameters were included in the analysis.
- Q: Did you have any formal discussions with farmers about their perceptions of the irrigation water supply changes, and do they have plans to change behaviors in the future?
  - No, unfortunately there has been no contact with farmers since the project.
- Q: Some stakeholders have indicated that farmers are unlikely to know the condition of the irrigation infrastructure. Would a farmer know if a pumping station or main canal was rehabilitated?
  - It's likely that they would know for tertiary canals, but it's unlikely as farmers get further away from large infrastructure. It's difficult to get accurate information from farmers about water, and there are many complaints about the costs of irrigation water. People who farm on a small level are not appreciative of improvements in infrastructure because they are not really farmers who need water, and they do not react to the changes in infrastructure. In Moldova, small "farmers" do not actually farm -- they rent out their land, and the farmers who do farm are much more in need of improved water supply. In Armenia, the core assumption was that the general condition of the water supply would improve so much that even small farmers who cultivate 1 hectare of land would be able to take advantage of the improved water supply. This assumption may have been a mistake. We also thought there would be land consolidation, but there were psychological issues with that for these farmers. The economic crisis also played a

factor—it weakened markets, so there was less incentive for them to expand their cultivation. Because of these reasons, I am skeptical that these results reflect the true impacts of rehabilitation.

- Q: Is your expectation that we would not see impacts for small farmers (e.g. farmers cultivating 1 or 2 hectares of land) because those types of farmers wouldn't be motivated to use those improvements, or is it that the farms are too small for the improvements in infrastructure to affect their water use?
  - Yes, that's exactly right. Even if we did the best for those farmers, the farmer would not have big gains in income from just one hectare.
- Q: We thought that rehabilitating the Ararat drainage system would increase irrigated hectares and agricultural land. Did that happen?
  - I don't have that information. Previously (during Soviet years), drained water was pumped to the river. We deepened the Ararat valley main and secondary drains so pumping would not be necessary, and the improvements were obvious even during construction. There were some flooded lands that could now be used for irrigation. The government is regularly paying for the maintenance now. I talked to one person about this several years ago, and he said the condition of the drainage system was much better.

- Q: What is your sense of outcomes like yields that were considered in the ERRs?
  - Different types of irrigation infrastructure would impact not necessarily yields but the final outcomes. The tertiary canals would lead to improved irrigation and better yields. My recollection is that we thought that a plot that got the full amount of water would have a higher yield of ~15%. Energy costs could be reduced in the case of other infrastructure improvements too.
  - The ERRs don't have specific lines that say "increase in yields" as a benefit stream, but I believe that increased yields are included in the benefit streams if you look at the worksheets that are used to calculate the benefit streams.
  - Some marzes like Ararat marz have improved water supply, but there is still some issue with the supply of water in other marzes. Job migration, particularly from rural areas, could also be a big issue.
  - An associate perceived definite increases in greenhouse establishment, but perhaps it is through potable water and perhaps by medium to larger farmers (5 to 10 hectares, or more). The larger farmers have also installed drip irrigation. There is also a continued interest in and need for support by WUAs.
- Q: What support did WUAs think were useful or would be more interested to get?
  - I think they would still be interested in infrastructure improvements. As the MCC project was being completed, there was a big investment by the World Bank in main canals, but it's unclear how important that is for the evaluation. The World Bank's efforts seemed to

be a continuation of MCC's rehabilitation. I think (but I am not sure) I saw it in 2011 in Aragatsotn.

- There are budget line items for the World Bank in 2013, 2014, and 2015, and the World Bank is working with communities to improve tertiary canals. The government has also started to work on construction of reservoirs with different donors because of concerns about climate change. For example, for 2016, there is a line item in the budget for construction of a reservoir.
- On the topic of the rescoping for irrigation and training, I remember that a couple of tertiary canal communities made a request to be included in Water-to-Market training. Both of the irrigation rescoping and the revisions for training were because of the exchange rate.

- Q: What drove how communities were selected to be included after the rescoping? Or was the rescoping mainly to reduce the numbers of people influenced within the original set of communities?
  - The [training] rescoping was focused on the numbers of people, and most communities were still covered. There were definitely some efforts to align the infrastructure and training, and we can talk to the irrigation team about it.

- Q: Did the reservoir construction mainly occur after 2013? Could you send documentation of other projects (particularly World Bank) going on at the time of the irrigation infrastructure rehabilitation?
  - OK, I will talk to World Bank peers tomorrow.

- Q: Were any comparison communities in areas where the World Bank made improvements to main canals? Can we identify them?
  - My recollection is that either the timing or the location of the communities influenced by the World Bank improvements meant it was not a concern for our evaluation. [Follow-up: We checked our notes and confirmed that, at least for the projects of which we are aware, they were later than our evaluation timeframe and/or in different communities. It would still be helpful to have access to what was mentioned in case there are other projects we missed.]

- Q: Returning to the earlier observation about greenhouses being built, it seems unlikely that greenhouses would be built in the field plots, which were the focus of our evaluation. Is that correct?
  - The point was that greenhouses would use potable water because irrigation water would need a lot of filtering and pressure adjustment. There is another issue with high-value agriculture. For example, this year had very big production of apples and grapes, and prices dropped. Farmers relied more on greenhouse produce than orchards and vineyards because greenhouse production helps maintain stable prices, whereas orchard and vineyard production is susceptible to price decreases.

- Q: Our sample focused on small farmers, but are there many medium to large farmers in Armenia?
  - I can't say with statistical certainty or confidence, but I see many bigger farms emerging in Armenia. There are definitely people who are buying plots. There is some level of consolidation at least on a small scale.
- Q: How does consolidation affect our results?
  - Just to clarify, I think we didn't see a lot of consolidation in the follow-up survey in 2013, but the prevalence of consolidation could have changed in the last three years.
  - The potential issue is that we didn't include large farmers in the evaluation sample.
- Q: Could small farmers be reporting that they're not irrigating because they've sold the land?
  - That wasn't happening, at least in 2013.
  - The most viable explanation for the evaluation results is job migration. Farmers might not be reporting land use and irrigation in ways that reflect this. Most farmers who leave families have small plots of land nearby. Men are more likely to do migrant work, and their wives aren't able to keep up with the added work of managing a farm when they also have families to take care of.
  - Respondents also might not be reporting accurately, and they might not really know if land is irrigated or not in the case of migrant workers who normally do most of the farming not being available during the survey period.
- Q: One of our general ideas for a possible explanation of the findings is that we have mostly small farmers, and we expected they would benefit from the infrastructure rehabilitation. However, most of them are not as focused on agriculture as we thought. Has that focus on agriculture changed over time?
  - My sense is that the migration mostly happens during the active farming season. Drip irrigation has become really popular among bigger farmers.
  - We've also observed a recent tendency in the media for farmers with land to throw away crops like apples and grapes and not utilize their land because there is no support for food processing.
  - All of these factors also became more intense after 2013 – hail really damaged a lot of yields.
  - Another factor that may influence the market is access to the Russian market. There might be a transportation issue given the distance between Armenia and Russia, but it could be an incentive for the big farmers to cultivate more land.

- Q: Is there a sense among farmers or in the media that the irrigation supply has improved?
  - I suggest you get the statistical service social snapshot report, which was written during the Armenia study period. It includes perceptions of the road rehabilitation and agriculture conditions.
  - Regarding post-Compact monitoring, in September 2012 in Aragatsotn (possibly), we observed some new land under irrigation. We had some discussion with farmers about their experiences with irrigation, and they thought the improved gravity scheme was working well.

- Q: Someone said that agricultural land had not increased, and we should be happy it didn’t go down. Is that correct?
  - The agricultural land has not increased except for a few fluctuations.
  - Part of the puzzle is that the ERRs said agricultural land would increase, so we might have had unrealistic expectations.
  - If our improvements kept the irrigated land stable, then why didn’t the land in the comparison communities decrease? Either there were other improvements in the comparison communities or our improvements didn’t do much.