What makes rural water systems sustainable?

Meta-analysis, determinants, and the empirical impacts of a large-scale WASH program in Nicaragua

Christian Borja-Vega

Submitted in accordance with the requirements for the degree of

Doctor of Philosophy

The University of Leeds

Faculty of Engineering

School of Civil Engineering

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The candidate confirms that the work submitted is his original and his own, except where work which has formed part of four jointly authored publications, all included in this thesis. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others. This thesis is by publication and follows the University's guidelines.

Four chapters contain jointly authored papers which have been published in peer-reviewed publications:

- Chapter 2. A Meta-Analysis of Water Supply and Sanitation Impact Evaluation Studies [*Citation: Andres, Luis Albert; Borja-Vega, Christian; Fenwick, Crystal; De Jesus Filho, Jaime; Gomez-Suarez, Ronald. Overview and Meta-Analysis of Global Water, Sanitation, and Hygiene (WASH) Impact Evaluations (May 15, 2018*). *World Bank Policy Research Working Paper No. 8444. Available at SSRN: https://ssrn.com/abstract=3179267]*. A meta-analysis of water supply, sanitation and hygiene (WASH) impact evaluations study began during the first days of my PhD program with the aim of understanding the knowledge gaps of the WASH impacts explored in developing countries. My involvement in this research was as a co-lead author: from collecting the information and building the meta-analysis papers' database, to analysing and contributing with the draft versions of the report, to providing final edits and addressing peer-review comments. This research provided a first overall global picture of the focus areas and effects of WASH impact evaluations that are based on experimental and quasi-experimental designs. The research was published in 2018 along with brief summary for policy makers. The results of this analysis show that evaluations of WASH interventions continue to focus predominantly on reducing diarrheal disease and there is a strong need for larger, more rigorously designed studies covering a broader scope of outcome effects. Similarly, there is a need for greater geographical representation and finally, well-trained implementing agencies to achieve the desired results. Those conclusions reaffirm the need to focus on impact evaluations in WASH that measure the effect of enhancing institutional, management and technical capacities of local WASH entities to make these services sustainable.

Confirmation of Lead-Coauthor of this published paper:

RE: confirmation co-authorship

From: Luis Alberto Andres <landres@worldbank.org>
Sent: Tuesday, March 17, 2020 4:28 PM
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Cc: Christian Borja-Vega <cncbv@leeds.ac.uk>
Subject: RE: confirmation co-authorship

Dear Christian,

This email is to confirm your contributions in our joint paper "Overview and meta-analysis of global water, sanitation, and hygiene (WASH) impact evaluations" as stated in your thesis consisted on a) building the initial database of impact evaluations; b) compilation of literature, and outline; c) production of graphs, tables, estimates; as well final writing inputs throughout the paper, and d) conclusions and overall edits to the document. I am also confirming that you had a co-leading role in this publication.

I will be available for any other query.

Regards,

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- Chapter 3. Innovations in Water Supply, Sanitation and Hygiene Impact Measures. *[Citation: Thomas, Evan; Luis Alberto Andrés; Christian Borja-Vega, and Germán Sturzenegger, eds. 2018. Innovations in WASH Impact Measures: Water and Sanitation Measurement Technologies and Practices to Inform the Sustainable Development Goals. Directions in Development. Washington, DC: World Bank. doi:10.1596/978-1-4648-1197-5. License: Creative Commons Attribution CC BY 3.0 IGO].* I contributed one of the co-editors of this book. This publication was published in the prestigious series of "Directions in Development" of the World Bank, with peer review and forewords of leaders in the sector. The main aim of the publication was to obtain a comprehensive picture of the best possible means of collecting monitoring indicators of WASH interventions. This publication also reviewed the cost-effective options for collecting data on the field. In fact, the impact evaluation endline survey data utilized electronic applications using cell phones and tablets to improve the efficiency and accuracy of data collection. The impact evaluation endline survey also followed some of the recommendations of this publication regarding water quality tests and training procedures. The relevant pieces of this book are included in this thesis as published. Other chapters that are not relevant to the aim of the thesis, nor provided knowledge to inform the chapters presented in this thesis were omitted. Specifically, this Book publication identified some of the shortcomings of traditional monitoring and evaluation methods. While household surveys and censuses still have a role to play, they can be most useful when integrated with other sources such as water quality testing and earth observations. The book does not recommend one technology above another. Their application should always be context-specific. In the case of this thesis, it help also utilise efficiently the impact evaluation surveys combined with the Rural Water and Sanitation Monitoring System of Nicaragua (SIASAR).

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As co-authors of the publication I confirm the contribution of the candidate as stated in the thesis and publications lists. The research contribution of the referred book consisted on a) initial review; b) outline; c) production of tables; as well final writing inputs throughout the paper, and c) conclusions and overall edits to the document.

Christian Borja-Vega contributed to the edit of this compilation, considered, hence, a co-editor. As a Lead co-author of the publication I confirm the contribution of the candidate as stated in the thesis consisted on a) building the initial database of impact evaluations; b) compilation of papers, and outline; as well final writing inputs throughout the paper, and c) conclusions and overall edits to the document. Christian Borja-Vega had a co-editor role in this publication.

Sincerely,

Evan Thomas, PhD, PE, MPH | Associate Professor
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- Chapter 4. Sustainability of rural water systems: quantitative analysis of Nicaragua's monitoring data. *[Citation: Borja-Vega, C., Pena, L., & Stip, C. (2017). Sustainability of rural water systems: quantitative analysis of Nicaragua's monitoring data. Waterlines, 36(1), 40-70. http://dx.doi.org/10.3362/1756-3488.2017.003] This paper was published in 2017 in the Journal Waterlines.* The main purpose of this paper was to contextualize and describe those factors that strongly explain changes in rural water systems' sustainability in Nicaragua. The findings provide supportive evidence that institutional and governance factors of local entities, in charge of managing and maintaining the functionality of these systems, are deterministic of good performance outcomes and uninterrupted water and sanitation service delivery. The paper uses data from 6,863 communities, 4,792 water systems, 2,585 service providers, and 154 technical assistance (TA) providers contained in the Rural Water and Sanitation Monitoring System (SIASAR) of Nicaragua. Statistical and econometric analysis presented in this peer-reviewed published paper provided evidence to support the hypothesis – widespread among rural WSS practitioners – that 'soft' measures in the provision of WSS are effective in fostering sustainability or 'functionality' of those systems. Such 'soft' measures include management capacity building of WSS community boards in charge of WSS oversight; demand-responsive approaches for developing, operating, managing, maintaining, rural water infrastructure; cost recovery mechanisms; community participation in the management of WSS systems. Such evidence also confirms some of the conclusions presented in the meta-analysis and call for the need to rigorously evaluate interventions that aim at enhancing rural water and sanitation institutions at the local level.

Confirmation of co-lead author of the published paper:

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March 18, 2020

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Re : Confirmation of co-authorship

I confirm Christian Borja-Vega's involvement and co-authorship in the publication described below.

The work described here was reported in the publication (*Borja-Vega, C., Pena, L., & Stip, C. (2017). Sustainability of rural water systems: quantitative analysis of Nicaragua's monitoring data. Waterlines, 36(1), 40-70. http://dx.doi.org/10.3362/1756-3488.2017.003*). Co-authors of the publication confirm the contribution of the candidate as stated in the thesis consisted on a) Literature review; b) outline; c) production of graphs, tables, estimates; as well final writing inputs throughout the paper, and c) conclusions and overall edits to the document. Christian Borja-Vega had a co-leading role in this publication.

Sincerely,

Clementine Stip
Program Analyst
World Bank Water Practice

- Chapter 6. Impact Evaluation Baseline Results. The impact evaluation of a large-scale Rural Water Supply and Sanitation Project (PROSASR) in Nicaragua was proposed as the core element of this research. The impact evaluation was design to test the causal attribution of a large-scale training program to enhance institutional, managerial and technical capabilities of municipal entities in charge of delivering social and public services (UMAS) and maintaining rural water supply and sanitation community water boards (CAPS). The evaluation relied on a randomised controlled trial of these training programs, assigning treatment and control groups and collecting baseline and endline data between 2016 and 2019. My involvement in this was as principal investigator. I drafted the proposals to obtain funds, designed and followed-up the design of the evaluation and its implementation, and led the design and implementation of data collection of two rounds (baseline, 2015; and endline 2019). I led the baseline study and published it in the World Bank's policy paper series, with 4 blind peer-reviewers that provided comments on the technical and sectoral aspects of the baseline study. The study concluded that the randomisation was conducted successfully by presenting how the CAPS and household characteristics between treatment and control groups did not present statistical differences. Specifically, for the impact evaluation study and the baseline, in particular, I contributed as lead researcher in the analysis of data, review of literature, drafting, graphs and estimates, and editorial inputs for addressing peer-review comments.

Confirmation of co-author of the published paper:

March 25, 2020

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Re: Confirmation of co-authorship

To Whom It May Concern:

I am writing to confirm Christian Borja-Vega's involvement and co-authorship in the publication (*Borja-Vega, Christian; Gruber, Joshua Sean; Spevack, Alexander Matthew. 2017. Increasing the sustainability of rural water service: findings from the impact evaluation baseline survey in Nicaragua (English). Policy Research working paper; no. WPS 8283; Impact Evaluation series. Washington, D.C.: World Bank Group*.). As Co-author of the publication I confirm the contribution of the PhD candidate as stated in the thesis and his publication lists consisted of a) initial review; b) outline; c) production of tables; as well final writing inputs throughout the paper, and c) conclusions and overall edits to the document. Christian Borja-Vega contributed to the edit of this compilation, considered, hence, a co-editor.

Sincerely,

Joshua Gruber, PhD MPH
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I would like to express my deep gratitude to my family, supervisors and professional colleagues who supported me throughout this journey called PhD. To my wife (Meg) and my son (Claudio) and my parents (Mario y Maria Guadalupe), and my brother (Mario).

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Abstract

One of the perplexing conundrums in the provision of rural water and sanitation in developing countries is understanding why these systems fail or thrive. With the various institutional, technical, socioeconomic, and environmental risks intertwining with the success or failure of water and sanitation systems, the identification of the explanatory factors and complexities that explain such outcomes becomes crucial for both policy and academic reasons. In the presence of important knowledge gaps in the understanding of those factors and complexities, this thesis presents a body of work that contributes to understanding specifically the institutional and management issues that produce the desire changes in promote systems functioning and performing well over time.

Specifically, this study presents an overview and meta-analysis of the existing literature on the impacts of water supply, sanitation and hygiene interventions. In particular, the core part of this study utilized a meta-analysis technique to quantitatively explore the main research areas that analyse the effectiveness of Water Supply, Sanitation and Hygiene interventions. Also, a this study contains both correlational and causal evidence on the main drivers of rural water and sanitation systems' sustainability over time. The correlational analysis identified the institutional, governance and operational management factors that explain water and sanitation systems sustainability over time. In subsequent sections of this thesis the causal evidence is presented based on a Randomised Control Trial (RCT) to explore the main factors that explain rural water systems' sustainability through a large-scale training program to community water boards in a developing country (Nicaragua).

The RCT showed a causal attribution between the training program and the way in which rural water system performed in multiple dimensions On average, in line with the project indicators, Community Water Boards (CAPS) in treatment communities experienced a statistically significant increase in their institutional management, financial solidity, in their attention to operation and maintenance of the water basin, and in their attention to the water source. In particular, CAPS management of service providers increased by 0.41 standard deviations in the treatment group compared to the control, CAPS financial solidity increased by 0.39 standard deviations in the treatment group compared to the control, CAPS attention to operation and maintenance of the water basin increased by 0.33 standard deviations compared to

the control, and CAPS adequate protection of the water source increased by 0.24 standard deviations in comparison to the control group. There were measurable decreases in diarrhoea, but these were only mildly statistically significant.

The largest household-level effect is for sanitation indicators, where treatment households experienced increases in access to improved sanitation, increases in access to improved, unshared sanitation, and decreases in levels of open-defecation. The results are not negligible and are pointing in the right direction with respect to the overall objective of the program evaluated (The Rural Water Supply Sustainability Program—PROSASR). However, further research would be needed to assess whether these effects are long-lasting and assess the relationship between sustainability of rural water systems and these types of CAPS training programs. In striving towards attaining universal access to safely managed services by 2030, significant research is needed to understand the effectiveness of capacity building of service providers to ensure rural water supply and sanitation sustainability. Thus, it is necessary to develop a comprehensive research on the supply-side WASH interventions with various techniques including panel data and systems-based analysis,

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List of Acronyms and Abbreviations

3IE....International Impact Evaluation Initiative
ARAS …. Asesores Regionales de Agua y Saneamiento
ATE …. Average Treatment Effect
AVAR …. Aprendizaje Vinculado a Resultados
CAPS ....Comites de Agua Potable y Saneamiento
CIAS….Composite Index of IAS
DALY …. Disability-Adjusted Life Years
DARE …. Database of Abstract and Review Effects
ED ....Experimental Design
FEWSNET….Famine Early Warning System Network
FISE…. Fondo de Inversión Social de Emergencia
GDP ….Gross Domestic Product
GNI …. Gross National Income
GWSP …. Global Water Security Partnership
IADB …. Inter-American Development Bank
IAS …. Índice de Agua y Saneamiento
IE .... Impact Evaluation
IHSN ....International Household Survey Network
IRC …. International Reference Center
JMP …. Joint Monitoring Programme
LDCM …. Landstat Data Continuity Mission
MDG….Millennium Development Goals
MHCP …. Ministerio de Hacienda y Crédito Publico (Nicaragua)
MODIS …. Moderate Resolution Imaging Spectrodensity
NGO ....Non-Governmental Organization
O&M ….Operations and Maintenance
OD ....Open Defecation
OR …. Odds Ratio
PROSASR ….Programa de Sostenibilidad de Agua y Saneamiento Rural
PUBMED ....Publications of Medical Research
QE …. Quasi Experiment
RACCS ….Región Autónoma de la Costa Caribe del Sur
RACCN …. Región Autónoma de la Costa Caribe del Norte
RCT …. Randomised Controlled Trial
RIEPS…. Register of Impact Evaluation Studies
RWS ….Rural Water Supply
SE/SD ....Standard Error/Standard Deviation
SDG ....Sustainable Development Goals
SIASAR ….Sistema de Información de Agua y Saneamiento Rural
SIEF ….Strategic Impact Evaluation Fund
TA .... Technical Assistance
TS ....Trainning Sessions
UMAS ….Unidades Municipales de Agua y Saneamiento
UNICEF …. United Nations Children's Fund
USAID …. ..United States Agency of International Development
UTASH….Unidades Tecnicas de Agua, Saneamiento e Higiene
WASH ....Water Supply, Sanitation and Hygiene
WB ....World Bank
WHO ….World Health Organisation
WSS …. Water Supply Services

Chapter 1. Introduction

1.1. Background and Context

Safe drinking water, sanitation and hygiene (WASH) are important determinants of human health poverty reduction and improving well-being. As both drinking water and sanitation interventions yield health benefits at the household-level and at the community-level (Cumming et al., 2014) it is important to understand their effectiveness. Moreover, lack or interrupted provision of water is estimated to be responsible for 20 percent of total deaths and disability-adjusted life years (DALYs) in children (Pruss-Ustun et al., 2008) Understanding the evidence showing the effectiveness of WASH interventions in reducing morbidity, premature deaths, and other diseases is the steppingstone to improve well-being. Yet to build those relationships it is relevant to understand why service provision is interrupted and the factors associated to those interruptions. Foster el al. (2018) explored how WASH risks associated with water supply failures over a 30-year period. That evidence highlights the importance of post-construction support activities for sustainability in the provision of water services in rural areas.

In a context where water systems in rural areas fail to operate in sustained and efficient ways, evidence is thus increasingly relevant. There is research showing that for sustained service to be provided there needs to be a shift in focus from rolling out or implementing infrastructure to strengthening the administrative capacity of the operators (supply) and other demand-driven dimensions of service (Sara & Katz, 1998). There is a small but growing body of literature that analyses other factors affecting sustained provision, whether financial, institutional, technical or social factors that contribute to maintaining a system's operation over time (Marks and Davis, 2012). In addition, communities often face considerable barriers in sustaining operation and maintenance (O&M) of water supply infrastructure over the useful life of the infrastructure (Davis et al., 2009 and Kleemeier, 2000).

Focusing on sustainability of rural water service provision[1] fills important knowledge gaps in the literature by exploring multidimensional factors affecting safe water

[1] For more than the past 20 years, there is still no consensus of what is considered a sustainable water service (Lockwood and Smits, 2011; Carter et al., 1999). For this research sustainability does not encompass environmental performance.

provision, because of the critical implications that intermittent water delivery has on disease incidence, well-being and economic development of the poorest. To date, most analytical work that seeks to answer such questions has not dealt with supply-side capacity building interventions but rather on demand-side interventions (Gomez et al., 2019; Calzada et al., 2017; Dondeynaz et al., 2012; Haysom, 2006), using case studies, small-sample interviews or country-specific applications without exploring causal attribution between the intervention and outcomes. With quantitative studies that have been carried out, sample sizes are often small (Hutchings et al., 2015; Godfrey et al. 2009) and not necessarily statistically representative[2].

1.2. Rationale for the Investigation and Problem Definition

Access to clean water, sanitation, and hygiene (WASH) remains a central pillar of human development. For many low-income countries, reaching the Sustainable Development Goals (SDGs) of universal access to safely managed WASH services by 2030 requires institutional and technological innovations to better supply, allocate, and manage these services.

The rationale of this investigation is to understand why in poor rural areas water and sanitation systems fail or break down. Empirically testing this hypothesis in a low-income country will fill in two important gaps. First, because this research explores supply-side factors that help understand why systems are not operationally, technically and financially sustainable over time. In other words, what attributions of providers and those entities responsible for these systems in rural areas explain the sustainability of rural water and sanitation systems. Second, because that evidence could be important to inform sectoral policies on how to design and implement effective interventions under the current organisational and governance structures, and, ultimately, improve the impacts of investments, donor support and post-construction support for rural water and sanitation services.

[2] Addressing poverty and inequality through WASH is critical given the Sustainable Development Goals. The SDGs are relevant to both least developed and middle-income countries, and embrace the human rights principles of universality, non-discrimination, participation and accountability to address the structural causes of inequalities. This means creating targets that account for poor communities as well as poor countries, and that recognize inequities and disparities within communities and countries as well as between them. In this way, sustainability of rural water service provision is thus relevant from a policy perspective to accelerate poverty reduction and mitigate inequality in the distribution of basic public services.

1.3. Aim and scope

1.3.1.Aim

This research unveils and addresses the supply-side challenges that lead to rural water and sanitation systems operate in despair and impermanently. The issue of sustainability[3] (or often referred as functionality in rural water supply) is not new. For more than 35 years the sector has been talking about ways to enhance sustainability of service. However, still too little emphasis in the literature has been given to the wider institutional setting in explaining that status of sustainability. With this research, there are novel contributions to the literature by exploring an area of supply-side training and capacity building interventions to local municipal governments and community water boards that lead to WASH systems operate sustainably over time.

1.3.2. Scope

A key step to understand those demand- and supply-driven factors that explain rural water and sanitation sustainability (RWS) is to identify the causal attribution between WASH interventions and RWS (short-run), and ultimately living-standard outcomes (long-term). The causal attribution between WASH interventions and RWS outcomes is important for two reasons. First, identifying causal attribution can bring clarity on the types of programs that work and do not work at small scale (efficacy) and large scale (effectiveness). Second, the causal attribution identification helps reduce knowledge gaps in the literature about the types of programs that can be attributed directly to changes in long-term outcomes.

To fill in the knowledge gaps a series of tools and methods in the fields of environmental engineering, WASH, statistics and economics were utilized. In sum, the scope of the research is determined by the identification of knowledge gaps, and empirical evidence to fill in those gaps. The knowledge pieces included in this Thesis were developed to address the hypothesis of the *identification of those factors that drive the success (and failure) of rural water and sanitation systems with an application in a poor country*. The scope is, hence, in line with not only contributing to the literature but also generating empirical evidence as a key element of informing sectoral policies

[3] There are broader definitions of sustainability that refer to the environmental performance and the way in which these systems preserve environmental health and use water resources sustainably. These broader definitions are out of the scope of this research.

in a country that has not produced much research in this field. The specific research questions embedded in this research work are presented in Section 1.5 of this Chapter.

1.4. Strategy Employed for Research

Five key strategic steps were necessary to produce the body of research to fulfil the aim or objective, produce evidence for addressing the hypothesis, and answer the key research questions. Under these five strategic steps I was involved deeply in the elaboration of research papers presented in this Thesis. The specifics of my contributions as author in these publications are described in pages i through vi and sections 2.2, 3.2, 4.2, 6.2 and 7.2 of this Thesis.

First, it was paramount to understand what the literature is saying about the different types of WASH interventions affecting systems' sustainability outcomes. To do so, systematic reviews and meta-analysis of the literature provide a quantitative perspective of the effects that exist between the types of WASH interventions and many different types of outcomes. An important element to consider when conducting a systematic review and meta-analysis is the selection of studies based on criteria such as methods utilized, interventions, and outcomes studied; as well as the robustness of the empirical findings in each study. For that purpose, in this research I analysed a unique database of WASH impact evaluations (IE) (based on the identification of statistically reliable counterfactuals) containing the main characteristics of published papers of WASH interventions and development outcomes. In other words, the papers included in the dataset are based randomised or quasi-experimental methods. I used the dataset to conduct a systematic review and meta-analysis to determine the causal attribution amongst various WASH interventions and different types of outcomes. In the case of WASH interventions and their effectiveness, there are no public databases of research publications that have attempted to review impact evaluation studies with WASH interventions and the effects found on WASH and socio-economic outcomes.

Second, the knowledge gaps identified in the meta-analysis contributed to the identification of the types of interventions and location that were best fitted to apply this research. Nicaragua was selected as the best location to deepen the knowledge of WASH systems sustainability due to the following reasons:

- The country has developed a WASH sector in rural areas over the last 15 years with small scale interventions implemented using its governance structure of municipal (local government) and community-based organizations;
- Nicaragua is a country with one of the lowest per capita income of the Latin America and the Caribbean region, with a very limited number of studies related to the WASH sector;
- The country showed political will to develop knowledge to improve the WASH sector and reduce the inequalities between rural and urban areas in terms of WASH service provision.

As a result, I engaged with Government of Nicaragua counterparts to propose a paper on the determinants of rural water and sanitation systems sustainability in the country. This study (Chapter 4 of this Thesis[4]) utilized the Rural Water Supply and Sanitation Monitoring data of the country (SIASAR) which was not exploited for research purposes before this investigation. SIASAR covered a large amount of communities with information on WASH systems, service providers and community characteristics (see Chapter 4 of this Thesis).

The study in Chapter 4 of this Thesis contributed to the understanding how certain supply-side institutional, governance, technical and management factors correlate with the performance of WASH systems. The study was part of the initial research proposal for the Thesis and it was finally published in an academic journal in January 2017. Before the publication of the study, the data, information and findings were shared with the Government counterparts of Nicaragua and this created more interest by the Government to further study the impacts, with a robust design, of a large-scale multi-donor funded rural water and sanitation project in Nicaragua called PROSASR (Rural Water and Sanitation Sustainability Project, acronym in Spanish). The impact evaluation design was discussed thoroughly with review protocol institutions (Ministry of Health) in Nicaragua, academics and my supervisor of the Thesis. After approval of the study, the baseline data was collected months before the project started its implementation. A peer-reviewed paper with the baseline survey findings was published, and presented the balancing of characteristics between comparison

[4] The paper is titled "Sustainability of rural water systems: quantitative analysis of Nicaragua's monitoring data"

counterfactuals (treatment and control groups) before the intervention started (see Chapter 5 of this Thesis for a detailed description of the design of the impact evaluation study and Chapter 6 of this Thesis for the baseline study findings).

Third, in parallel to the word developed for Chapters 5 and 6 of this Thesis—involving the design of the impact evaluation study, and the baseline study of the impact evaluation—, I also collaborated with several co-authors on a review of available technologies to collect and monitor WASH impact measures in the field. This research invited collaborators to write chapters and resulted in a Book titled “Innovations in WASH Impact Measures” (Chapter 3 of Thesis). Although this publication came after the publication of the impact evaluation baseline study (Chapter 5 of this Thesis), it was instrumental to identify technological options to collect information in the field more effectively. Indeed, the baseline study relied on collecting household and community-based information of rural water and sanitation through paper-based questionnaires. For the endline survey of the impact evaluation, the results of Chapter 3 of the Thesis helped identify cellular phone applications (see Section 3.2 and 3.4 of this Thesis) that made the data collection process more efficient with higher data quality.

Fourth, the development of impact evaluation study was in line with the papers developed in Chapters 2, 3 and 4 of this Thesis. The publication of the Baseline results of the impact evaluation (Chapter 6) showed a proper design and implementation of the random assignment of the intervention between treatment (receiving interventions) and control (not receiving interventions) groups. The Baseline study showed that the characteristics of these groups were balanced so it was possible to determine the causal attribution between the capacity building and training interventions of the PROSASR project and the outcomes related to the sustainability of rural water and sanitation services in Nicaragua. The endline survey was a key piece necessary to complete the impact evaluation study (Chapter 7 of this Thesis).

Fifth, the results of the impact evaluation study contributed to fill in the gaps in the literature by analysing the causal attribution of a supply-side training and capacity building intervention. These findings were produced using a large-scale intervention in Nicaragua, which is also novel because not a lot of research in the WASH sector has been produced in that country recently. Furthermore, this evaluation presented in this Thesis is also a large-scale one compared to other similar studies of the WASH sector in low-income countries. Finally, it contributed to inform the Government of Nicaragua and the institutions in charge of delivering WASH in rural areas. This represents a key strategic point, where research and evidence can serve as means to improve policies, projects and programs in a sector that is fundamental for human development and poverty alleviation in the country.

1.5. Key research questions

Based on the objective, scope and strategy of the research presented in this Thesis and the knowledge gaps identified, the following are the set of questions that would be answered through the research conducted:

- *Can improved management and enhanced technical capabilities of rural water system's administrators induce sustained provision of rural water services?*
- *What is the impact of municipal strengthening on the sustainability of water and sanitation systems' management and at the community level?*
- *What is the impact of variations in rural water service provision on community's perceptions of water management and socio-economic outcomes?*

1.6. Structure of Thesis

This Thesis contains four published papers where I participated actively as Principal or co-Principal investigator. The published materials are related in the sense that they all contribute to understanding the correlations and impacts between training, capacity building, governance and institutional aspects that explain the sustainability and functionality of rural water systems over time for developing countries. One important part of the research is specifically focused on Nicaragua, based on an impact evaluation randomised trial at the community level to explore the causal effects between a large-scale training program and the outcomes related to rural water sustainability of systems in the country.

Chapter 2 contains a published meta-analysis of impact evaluation studies (with randomised and quasi-experimental techniques) applied to the Water Supply, Sanitation and Hygiene (WASH) sector. In this meta-analysis I identified the key research areas where knowledge gaps exist. This publication serves as means to identifying and justifying potential areas of research related to rural water and sanitation.

Chapter 3 contains extracts of a book I co-edited with 3 other co-authors where we reviewed the main innovations and technologies that exist to collect and monitor effectively water and sanitation information in remote and rural areas. This research contributed to this Thesis in explaining the menu of options available for collecting information in the field. The review helped in listing the most effective remote sensing or cell phone applications that contribute to reduce costs and increase efficiency in the process of collecting information in the field.

Chapter 4 presents a published paper where I explored in Nicaragua the main determinants of rural water systems' sustainability and functionality. This paper helped in identifying which factors are to be considered when exploring the main drivers of water systems' management performance in rural areas.

Chapters 5, 6 and 7 present the results of a large-scale impact evaluation that explored the causal attribution of a training program aimed at enhancing management capacities of local governing bodies of the water sector that would result in the improvement of rural water systems' sustainability over time. The research started in 2016 and concluded in the last quarter of 2019.

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Chapter 2. A Meta-Analysis of Water Supply and Sanitation Impact Evaluation Studies

Published Paper

2.1. Publications and awards derived from this chapter

- The chapter above was published in the World Bank's Policy Paper Series. The paper obtained two rounds of peer-reviews from 2 blind-academic reviewers, 2 World Bank's senior staff in specialized areas of the study, and the reviews from Prof. Barbara Evans. The paper was presented in earlier versions in the Word Water Forum (SIWI), the Global Water Forum (2018, Brazil), and in two events in Washington D.C. prior to publication. The document received also more than 2000 downloads globally since its publication, and a policy briefing report derived from the study was also published with also thousands of downloads. I participated as main co-Principal investigator (with Dr. Luis Andres) performing all aspects of the research, including data collection from papers and coding and analysing the meta-analysis dataset. The publication was also published in the USAIDI/IRC Sanitation Updates website. The reference of this paper is: *Andres, Luis Alberto; Borja-Vega, Christian; Fenwick, Crystal; De Jesus Filho, Jaime; Gomez-Suarez, Ronald. Overview and Meta-Analysis of Global Water, Sanitation, and Hygiene (WASH) Impact Evaluations (May 15, 2018). World Bank Policy Research Working Paper No. 8444. Available at SSRN: https://ssrn.com/abstract=3179267*
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- https://hubs.worldbank.org/docs/ImageBank/Pages/DocProfile.aspx?nodeid=29966167
- https://sanitationupdates.blog/2018/05/23/overview-and-meta-analysis-of-global-water-sanitation-and-hygiene-wash-impact-evaluations-world-bank/

Paper Cover as published in the Policy Paper Series of the World Bank.

Policy Research Working Paper 8444

Overview and Meta-Analysis of Global Water, Sanitation, and Hygiene (WASH) Impact Evaluations

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Christian Borja-Vega
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WORLD BANK GROUP
Water Global Practice
May 2018

Published Policy Brief of the Global Water Practice (World Bank)

Public Disclosure Authorized

WATER GLOBAL PRACTICE • KNOWLEDGE BRIEF

A Brief Summary of Global WASH Interventions

What Works and What Doesn't

Luis Andres (Lead Economist, GWADR), Christian Borja-Vega (Economist, GWASP), Crystal Fenwick (Consultant, GWASP), Ronald Gomez-Suarez (Economist, GHNDR) and Jaime de Jesus Filho (Consultant, GWASP)

MAY 2018

Public Disclosure Authorized

WASH practitioners and decision-makers lack evidence on the wider health and social effects of WASH interventions needed to create a paradigm shift in the sector. A global overview and meta-analysis on the effects of different WASH interventions on different health and socioeconomic outcomes was undertaken. The results of this analysis show that evaluations of WASH interventions continue to focus predominantly on reducing diarrheal disease and there is a strong need for larger, more rigorously designed studies covering a broader scope of outcome effects. Similarly, there is a need for greater geographical representation and finally, well-trained implementing agencies to achieve the desired results.

Background

The effects of water supply, sanitation and hygiene (WASH) interventions on the reduction of diarrheal disease in children have been thoroughly documented, however, evidence evaluating the effects of WASH interventions on other outcomes of health and well-being, such as school attendance and growth, is sparse. WASH interventions, and consequently the studies designed to evaluate their effectiveness, have similarly

> The purpose of this study was two-fold: (1) to collate existing evidence on global WASH interventions into a single, publicly available repository and (2) to quantify the effectiveness of a broad range of WASH interventions on an array of outcomes through a quantitative meta-analysis of impact evaluation (IE) studies.

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2.2. Cover Sheet: Relevance for Thesis

This paper was published in the World Bank Paper Series, a peer reviewed international publication. This paper is used as a chapter of the Thesis as it was part of the original research plan submitted in 2016 to my supervisor. My involvement in this research was as co-lead author where I contributed to all stages of this published paper: building the impact evaluation studies dataset, analysing the information and conducting the meta-analysis, and writing the report with the help of other co-authors, and addressing comments from reviewers. The publication of this paper was essential to obtain a general context and make it relevant to the Thesis on the current state of knowledge and knowledge gaps that exist in the sector, and how the proposed impact evaluation study presented in Chapters 5, 6 and 7 is justified with the evidence presented of this study. This chapter reproduces the aforementioned published paper to present the relevance of the work to the overall objective of the Thesis.

2.3. Overview (abstract as published)

This paper presents an overview and meta-analysis of the effects of water, sanitation, and hygiene (WASH) interventions around the world. It is based on 136 impact evaluations (randomised and quasi-experimental studies) that explore the effects of WASH interventions on health and non-health outcomes, ranging from behaviour change—such as the adoption of water treatment—to school attendance rates, to a reduction in diarrhoea. The selected impact evaluations were divided into five groups, and meta-regressions with fixed effects (at the regional level) and random effects were performed, controlling for each study's characteristics (implementing organization, sample sizes, type of publication, number of publication views, etc.). All results are reported as changes in odds ratios (OR), with respect to the standard deviation of reported effects. WASH interventions were found to increase the likelihood of behaviour changes and the adoption of new hygiene practices by 17 percent. The smallest effects were observed from WASH interventions aimed at reducing the rates of child mortality and non-diarrheal disease. WASH interventions implemented in schools showed statistically significant results in reducing school absenteeism and dropouts. Similarly, the results showed a statistically significant aggregate likelihood of increased access to safe water and improved water quality, as well as increased water treatment options—a difference of one-fifth with respect to the standard

deviation of the average effect size reported. Finally, the results showed WASH interventions reduced the likelihood of incidences of diarrheal and enteric disease by 13 percent, which is consistent with findings in other meta-analyses of the same subject.

2.4. Introduction and Research Objectives

Access to safe drinking water, sanitation, and hygiene (WASH) is an important determinant of human health and socioeconomic well-being. Increased access aims to reduce rates of malnutrition, morbidity, and mortality, particularly of children. Economic benefits of WASH interventions are realized through a decreased dependency on health care services and an increased accumulation of human capital (Piper et al. 2017). Hence, improved health boosts productivity. Indeed, a lack of access to WASH services is estimated to be responsible for 20 percent of total deaths and disability-adjusted life years (DALYs) in children under 14 (Pruss-Ustun et al. 2008). Despite global efforts to ensure equitable access to these critical services, the 2017 Joint Monitoring Program for Water, Sanitation and Hygiene[5] estimates that 30 percent of all people lack access to safely managed drinking water services and 60 percent lack access to safely managed sanitation services (JMP 2015).

While the effects of WASH interventions on the reduction of diarrheal disease have been thoroughly documented (see, for example, Waddington et al. 2009), a comparable body of evidence on other outcomes of health and well-being, such as school attendance and children's growth, remains conspicuously absent. Moreover, WASH interventions, and consequently the studies designed to evaluate their effectiveness, have historically focused on water quality, while little is known about the effectiveness of other interventions. For example, despite the importance of behaviour change to sanitation and hygiene, there is little evidence supporting its effectiveness in WASH interventions. Additionally, while the link between diarrheal disease and WASH services is undisputed, in their synthetic review evaluating the effectiveness of WASH interventions in reducing diarrhoea in children, Waddington et al. (2009) identified methodological weaknesses that challenged the effectiveness of water treatment interventions. Furthermore, while most studies evaluated the effects of

[5] A collaborative effort of the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF).

WASH interventions on diarrheal morbidity and others evaluated their effects on cholera, few evaluated their effects on mortality.

More recently, an exhaustive review of existing WASH knowledge concluded that more evidence is needed to optimize resources and better understand the social impacts arising from improved health outcomes (Hutton and Chase 2017). This is especially relevant given that the benefits of WASH interventions vary according to context (Waddington et al. 2009; Cumming et al. 2014), a phenomenon that has been understudied to date. Finally, given the magnitude of people impacted globally, and time and resource constraints, policy makers often face challenging ethical decisions when tasked with allocating resources to WASH programs. Consequently, understanding the evidence supporting the effectiveness of WASH interventions on outcomes of health and well-being is imperative to optimize results and improve the performance and sustainability of WASH programs in the long run.

An impact evaluation is an assessment tool used to determine the efficacy of an intervention while also assessing its design. Properly conducted impact evaluations provide high-quality evidence that help orient investment decisions, improve design policies, adjust ongoing interventions, and increase transparency and accountability. Since Waddington et al. undertook their synthetic review in 2009; a proliferation of impact evaluations of WASH interventions has been published. However, there are no dedicated research repositories and no known research endeavours that have sought to review and collectively analyse this additional evidence. Furthermore, as noted, most impact evaluations conducted to date have focused on the effects of WASH interventions—notably, to improve water quality—on diarrheal morbidity. There is a clear need for a wider body of evidence on a broader range of WASH interventions and outcomes.

Therefore, the purpose of this study is twofold: (i) to collate new and existing evidence from impact evaluations of global WASH interventions into a single, publicly available repository; and (ii) to quantify the effects of a broad range of WASH interventions on an array of different outcomes, by performing a quantitative meta-analysis of available evidence.

Conducting a systematic review and meta-analysis of a single WASH-related outcome is a time-consuming endeavour. Expanding efforts to include the panoply of studies evaluating a diverse set of WASH outcomes around the globe is exponentially more laborious, as illustrated by the time lag between the commencement of this study and the publication of its results. Although a number of other, reputable impact evaluations and meta-analyses evaluating the effects of WASH interventions on single outcomes have been published since this study began in 2013, this study remains the first of its kind to compare and contrast the effects of WASH interventions on diverse health and nonhealth outcomes through a combined meta-analysis. As such, this study represents a critical, historical review of the effects of global WASH interventions that could be a valuable starting point for any future evaluation.

2.5. Selection of Impact Evaluation Studies

To ensure the integrity of this review, only evidence-based studies were included, that is, studies that rigorously measured impacts attributed to WASH interventions. Studies falling into this category include evaluations that identify causality between interventions and outcomes of interest by estimating the true effect (or impact) of an intervention on outcomes and applying counterfactual analyses (comparing intervention outcomes with what would have occurred in the absence of the intervention). Thus, all studies included in this review reported impact estimates along with their standard error, as is customary when conducting a meta-analysis.

In terms of research methods, randomised controlled trials (RCTs) are considered the gold standard for establishing a causal attribution between interventions and outcomes. However, the choice to conduct an RCT may be limited by ethical considerations or study design, in which case experimental or quasi-experimental methods are instead applied. This review incorporates studies where RCTs, experimental design, and quasi-experimental evaluation methods were applied.

2.5.1.Search Methods

As this review focuses exclusively on evidence-based impact evaluations, an extensive yet targeted search of published and unpublished material was conducted. The primary source of published material was the Register of Impact Evaluation Published Studies (RIEPS) database, a comprehensive digital warehouse of impact evaluations with registered protocols in PubMed managed by the International Initiative for Impact Evaluation (3ie). Additionally, given that the effectiveness of WASH interventions is often measured by the health outcomes of the target population, published material from the Cochrane Library (as well as the Database of Abstracts of Reviews of Effects [DARE], accessed via the Cochrane Library) was also included. Finally, published and unpublished materials were sourced from various research institutions including the World Bank, regional development banks (such as the Inter-American Development Bank, IDB), research centres, universities, nongovernmental organizations (NGOs), and other organizations (see Appendix B for a full list of databases searched).

The initial search gave rise to approximately 850,000 studies[6]. A keyword search was then conducted using the following terms and combinations of terms: “water and sanitation,” “water sanitation,” “water supply,” “sanitation,” “handwashing,” “water + hygiene,” and “water + sanitation + hygiene.” Study designs were restricted to RCTs, and experimental and quasi-experimental evaluation methods. This refined search resulted in 136 studies[7] used to construct the data set for this meta-analysis.

2.6. Data Collection and Coding of Papers

WASH-related impact evaluations have been published at a steadily accelerating rate over the past decade. Almost 50 percent of the evaluations included in this review were published after 2008 (**Figure 2-1**). Of those, almost half were evaluations of WASH programs that combined more than one intervention, reflecting their increased popularity in recent years.

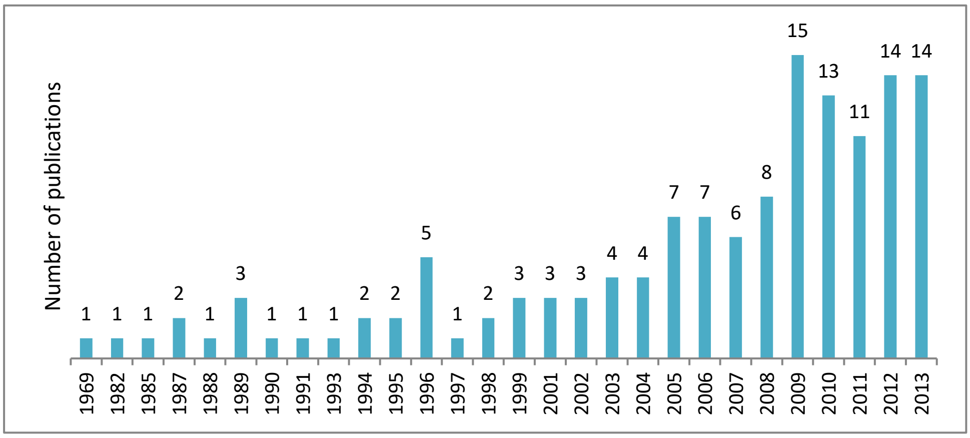


Figure 2-1 Big Uptick in WASH Impact Evaluations since 2009

Note: Number of published WASH impact evaluations 1969–2013. Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

[6] All studies and protocols in any field or scope that involve the use of experimental or quasi-experimental designs contained in all repositories.

[7] The 136 impact evaluations reviewed in this study were used to create an updated database of research papers, systematic reviews, and meta-analyses of the sector publicly available at: http://www.wsp.org/library.

2.6.1.Geography

Studies appear to be geographically biased; 80 percent are concentrated in just three regions: South Asia (34 percent), Sub-Saharan Africa (27 percent), and Latin America and the Caribbean (18 percent) (**Figure 2-2**). This finding is not particularly surprising given the significant lack of basic services in these areas. However, the scant attention paid to other regions, notably East Asia and the Pacific, the Middle East and North Africa, and Europe and Central Asia, points to a gap that future research could fill. In addition, only five publications examined multicounty or multiregional interventions. The country with the largest number of studies was India (18), followed closely by Bangladesh (16) and Kenya (12). Approximately 67 percent of all studies were conducted in rural environments, while 29 percent analysed urban and peri-urban populations, and 5 percent analysed interventions in both rural and urban settings.

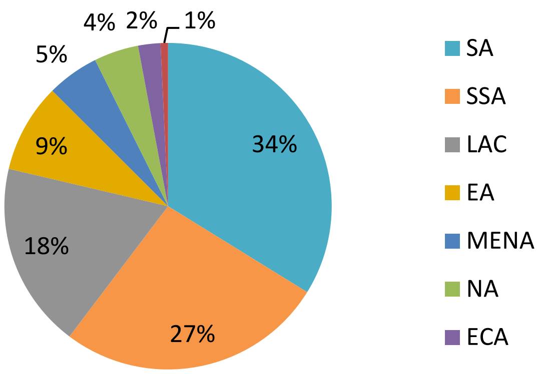


Figure 2-2 Regional Distribution of Studies
Note: SA = South Asia, SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean, EA = East Asia and Pacific, MENA = Middle East and North Africa, NA = North America, and ECA = Europe and Central Asia. The LAC, SA category (1 percent) represents studies done jointly in both regions.
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

2.6.2.Interventions

Studies were classified into one of five conventional subgroups by type of WASH intervention: hygiene, sanitation, water quality, water supply, and multiple interventions (**Table 2-1**).

Intervention	Description
Hygiene	Sought to prevent the oral transmission of pathogens through proper handwashing after defecation, before and after handling food, and cleaning infants. Often combined with handwashing infrastructure, water storage and management, training in household waste management, and strong educational components designed to drive behavioural change.

Sanitation	Aimed to prevent the transmission of disease by correctly separating faeces, especially in rural areas, by: (i) improving waste disposal facilities; (ii) building simple sanitation facilities (e.g. latrines, toilets, etc.); and (iii) building complex infrastructure (e.g., sewage systems). Although some of the interventions were innovative, such as subsidized training in the adoption of new technologies, most relied on information campaigns to reduce open defecation, promote utilization of facilities, and adopt healthy behaviours.
Water quality	Interventions that tested affordable point-of-use treatments, such as flocculation, chlorination, solar treatment, and ceramic filters, to remove pathogens or prevent them from entering water collected for drinking or food preparation. Most places are remote and vulnerable environments.
Water supply	Designed to ensure access to sufficient water for basic hygiene through: (i) new sources (wells, springs, etc.); (ii) reconstructing and maintaining current infrastructure (network rehabilitation, piped water, etc.); and (iii) introducing management and financial support innovations to spur access (such as credit, private-public partnerships, and community participation).
Multiple	Efforts that included two or more interventions in combination.

Table 2-1 Description of WASH Intervention Subgroups
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

In the case of studies evaluating multiple interventions, any specific effects reported were included in the relevant intervention subgroup and accounted for as integrated with effects. For example, a study of water supply and sanitation interventions in Pakistan (Rauniyar 2009) reported separate impacts for water supply, which was included in the water supply intervention subgroup (**Figure 2-3**).

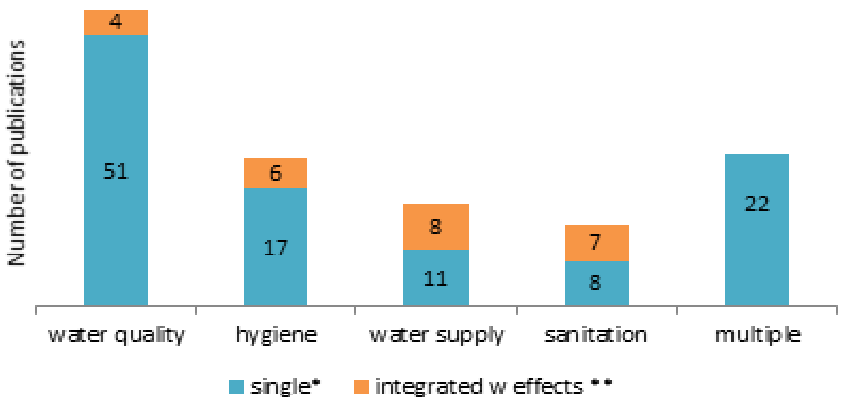


Figure 2-3 Water Quality Interventions Dominate WASH Impact Evaluations
Note: Interventions are counted in all publications. Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Studies assessing the effectiveness of interventions aimed at improving water quality are the most common, accounting for 39 percent of the 136 studies (**Figure 2-4**), followed by interventions related to hygiene (17 percent), water supply (8 percent), and, finally, sanitation (7 percent). Multiple or combined WASH interventions were reported in 29 percent of all studies evaluated.

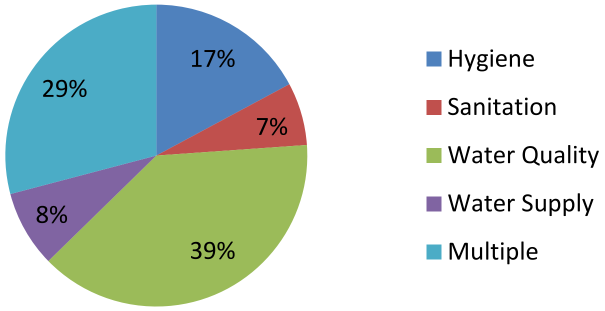


Figure 2-4 Distribution of Interventions by Subtheme
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

The prevalence of WASH interventions evaluated varies greatly by region (**Figure 2-5**). Hygiene interventions were most common in East Asia and the Pacific and the Middle East and North Africa. Water quality interventions dominated in Latin America and the Caribbean and Sub-Saharan Africa, accounting for 80 percent and 60 percent of all studies, respectively. In Eastern Europe and Central Asia, studies were split evenly between water quality, water supply, and hygiene interventions. In South Asia, the region with the most studies targeting combined interventions (41 percent), the focus was split relatively evenly between hygiene, water quality, and sanitation. Overall, sanitation interventions were the focus of studies in only three regions: North America, South Asia, and Sub-Saharan Africa. Finally, at the country level the most common intervention in India was sanitation, whereas in Bangladesh, handwashing evaluations prevailed, along with trials of point-of-use devices for water treatment.

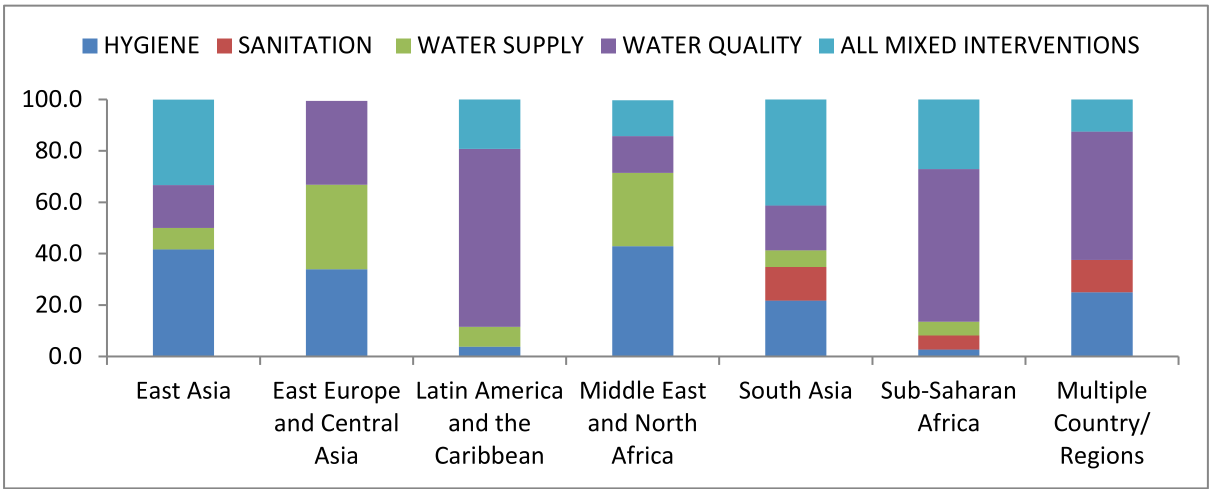


Figure 2-5 Different Regions Focus on Different Types of Interventions
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

2.6.3.Research Methods

Most studies included in this review (71 percent) were experimental, mainly RCTs (**Figure 2-6**). In such a design, the intervention is offered randomly to a subset of the eligible population (the treatment group), while assigning the rest of that population to the control group.

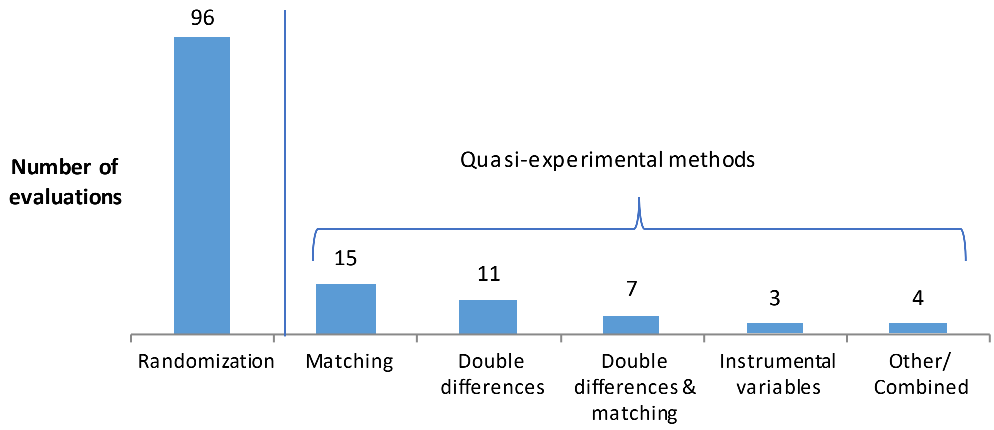


Figure 2-6 Randomisation Far Exceeds Quasi-Experimental Approaches
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Where RCTs could not be used, quasi-experimental research methods were applied, in this case, typically for studies involving multiple interventions and sanitation programs. Of these, 45 percent used matching methods to build a counterfactual and nine studies used matching to pair subsamples. Likewise, matching and double-differences methods were applied for large-scale programs pertaining to infrastructure construction or rehabilitation, and water access uptake. Instrumental variables were applied in only three studies in Asia, while regression discontinuity studies were thoroughly absent. **Figure 2-7** presents the distribution of study research methods by intervention.

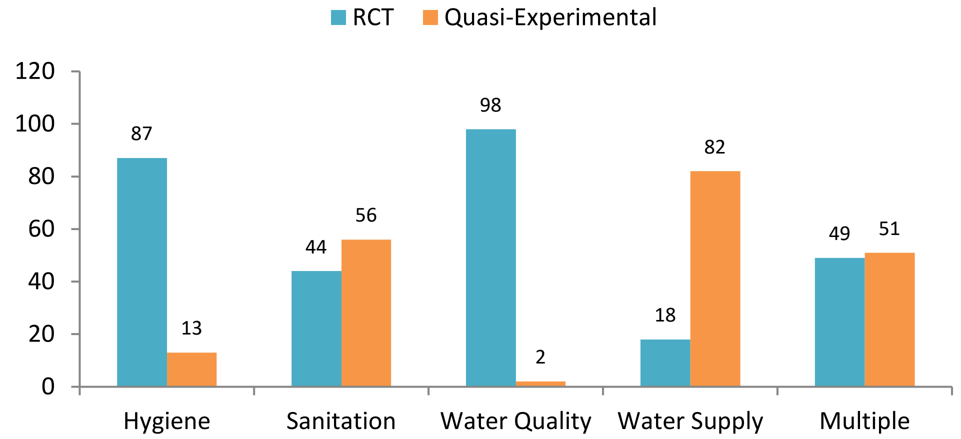


Figure 2-7 Distribution of Research Methods by Intervention Subgroup (%)
Note: The total number of papers listed here is greater than 136, given that some papers included more than one intervention. Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

2.6.4.Outcome Indicators

Twenty-one unique outcomes were identified (**Figure 2-8**)[8]. When an evaluation presented more than one outcome for each intervention, the outcome with the most significant effect was used in the meta-analysis. The prevalent unit of analysis (and unit of sampling) was children or households with children. Not surprisingly, the most frequently measured outcome was diarrhoea (prevalence or incidence). This was used in more than half of all evaluations, either as a single outcome or in combination with another indicator. The second-most frequently measured outcome was water quality (accounting for 13 percent of the total), which was classified as a direct output of water purification (or disinfection) interventions. Most of these studies used chemical tests at the household level as a proxy for water quality, for example, particle suspension.

[8] Studies evaluating the effects on enteric disease reduction (5) were classified separately from studies evaluating the effects on diarrhoea reduction (72), giving rise to 22 unique outcomes. However, for the purposes of the meta-analysis, both outcomes were combined into a single group.

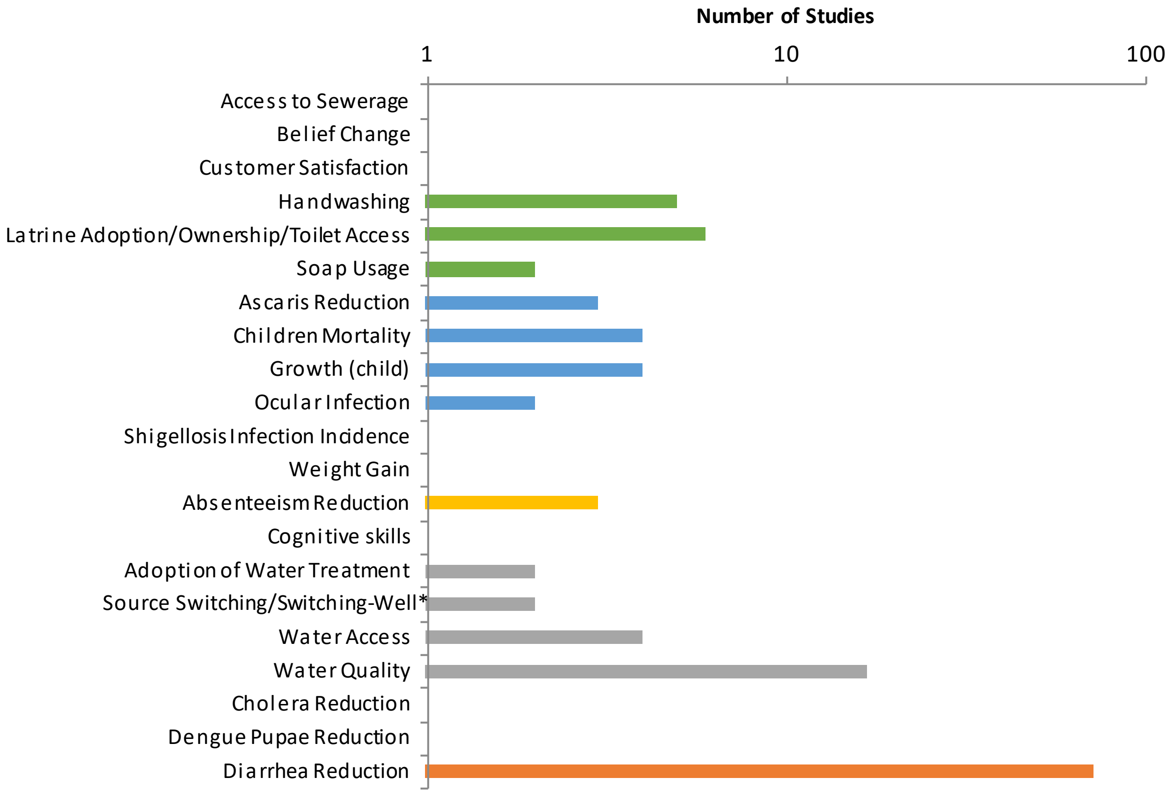


Figure 2-8 Distribution of Outcomes
Note: In this figure, diarrhoea reduction includes five studies on enteric disease reduction. * Source Switching/Switching-Well refers to any WASH intervention that, directly or indirectly, induced a change in water source from basic or unimproved to improved. Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

2.6.5. Effect Sizes

A number of systematic reviews have been conducted to assess the impacts of WASH interventions on the prevalence and incidence of diarrhoea (Esrey, Feachem, and Hughes 1985; Esrey et al. 1991; Fewtrell et al. 2005; Clasen et al. 2006, 2010; Arnold and Colford 2007; Ejemot et al. 2008; Waddington et al. 2009; Norman, Pedley, and Takkouche 2010). However, these reviews were not limited to studies that identified a causal attribution between interventions and outcomes[9]. Other, more recent, meta-analyses of WASH interventions frequently focused on only one outcome of interest.

A recent trend in WASH meta-analyses includes limiting the number of studies to those with experimental designs that identify the causal attribution between the intervention

[9] In an experimental evaluation (RCT), the treatment and comparison groups are selected from the target population by a random process. Therefore, comparison between control and treatment groups to explore causal attribution between the intervention and outcomes of interest is statistically valid. Quasi-experimental designs estimate the counterfactual by conducting measurements of a nonrandomly selected comparison group. In many cases, intervention participants are selected based on certain characteristics, whether it is the level of need, location, social or political factors, or other factors. In such conditions, quasi-experimental designs estimate a valid counterfactual through statistical and econometric methods.

and a given outcome of interest. For instance, Freeman et al. (2017) conducted a meta-analysis to estimate pooled measures of the effects of different levels of sanitation services on infectious diseases and nutritional outcomes, primarily using studies with an experimental design. Stocks et al. (2014) suggested sanitation services protect against diarrhoea, active trachoma, some soil-transmitted helminth (STH) infections, schistosomiasis, and height-for-age reductions, and have no protective effect against other anthropometric outcomes. However, their meta-analysis also highlighted the poor quality of the estimation methods used in the papers selected for study.

Garn et al. (2017) conducted a meta-analysis of 24 studies to examine the association between structural design characteristics of sanitation facilities and facility use and found that most sanitation interventions had only a modest impact on increasing latrine coverage and use[10]. The authors combined the effects of sanitation interventions into a single outcome: latrine adoption and usage.

Studies that assessed health outcomes using RCTs[11] generally showed significant effects on the prevalence of diarrhoea and waterborne diseases such as cholera (Taylor et al. 2015). In contrast, differences in the incidence of diarrhoea across groups were not significant in four quasi-experimental studies. Evidence on other health-related variables (e.g. child mortality, stunting, height, and weight) was scarce and limited to single studies, except for small-scale studies evaluating combined interventions, which reported significant effects on mortality and stunting.

The evidence related to water quality was relatively solid, given that 75 percent of the trials that tested reductions in bacterial contamination reported strong effects. These studies were typically RCTs, implemented in rural zones, with in-situ collection of water samples. Many of these were not explicitly labelled as water quality interventions yet included a purification/filtration component as a complementary add-on (frequently flocculants, chlorination, and ceramic filters) to strengthen the expected effect. In these

[10] A recent meta-analysis of hygiene interventions found an average risk ratio for diarrhoea of 0.60 for the promotion of handwashing with soap (95 percent CI: 0.53–0.68) and an average risk ratio of 0.76 for general hygiene education alone (95 percent CI: 0.67–0.86) (Hutton and Chase 2016; Freeman *et al*. 2014). Other systematic reviews found a relative risk for respiratory infection of 0.84 (0.79–0.89) compared with no handwashing (Rabi and Curtis, 2006).

[11] Including other research design methods such as quasi-RCTs, non-randomised controlled trials, controlled before-and-after studies, and cross-sectional and uncontrolled before-and-after studies.

combined interventions, the positive relationship was less evident and in 57 percent of the studies the effects were mixed.

Access to WASH was generally considered an intermediate outcome, since access is a direct result of water supply and sanitation interventions, especially those focused on improving infrastructure. Increases in access were well documented for water supply interventions and in seven out of eight studies effects were statistically verified. For on-site water access, rigorous RCTs showed that outcome effects were half those of studies that relied on other methods to identify effects, which is consistent with what is reported by Ercumen, Gruber, and Colford (2014). In combined interventions the results were not strong, especially for outcomes difficult to measure (such as collecting time and distance).

WASH interventions are increasingly adding multiple components to achieve greater impacts on access, health, behaviour change, and other socioeconomic indicators. Historically, WASH interventions have been skewed toward targeting particular health outcomes (such as reducing the incidence of diarrhoea), negating other important outcomes. However, recent trends in WASH impact evaluations suggest more complex interventions can deliver results in multiple areas of development and well-being.

A large set of studies strongly supported the effectiveness of water treatment (i) on-site[12], (ii) across the supply, and (iii) at the source in reducing children's exposure to diarrhoea. Other studies indicated the effectiveness of combining water quality and hygiene interventions (including the provision of soap for handwashing and hygiene information campaigns) in reducing several diarrhoea-related indicators (e.g. rates of incidence, episodes per person, and prevalence).

In general, impact evaluations that included many studies as well as those that applied more rigorous research methods had less ambiguous results. Specifically, individual RCTs reported significant reductions in dysentery, influenza, shigellosis, conjunctivitis, respiratory diseases, parasite infections, and impetigo. Water supply interventions also produced strong reductions in enteric and other health-related diseases. Conversely, impact evaluations that included only a small number of studies and

[12] Neither chlorine treatment nor solar disinfection had significant impacts on diarrhoea after a meta-analysis adjusted for the nonblinding of the intervention, although an earlier systematic review and meta-analysis of water quality interventions found household-level treatment was more effective than source treatment (Hunter *et al*. 2009).

studies that focused on respiratory illnesses, child growth, ocular infection, and mortality had mixed results.

Effects on widespread waterborne diseases (such as gastroenteritis, cholera, hepatitis, amoebiasis, and adenovirus) were scarcely analysed in the studies included in this overview. Yet diarrhoea, ultimately a symptom, reported in most cases as a dependent variable, may be related to the diagnosis of those diseases whose incidence is not typically measured as an outcome. Other outcomes, such as the adoption of healthy practices, take-up rates, and behaviour changes, did not show a definitive causal relationship to WASH interventions and require further empirical exploration.

Evaluations of combined interventions tended to consider behavioural outcomes. Such evaluations are important to understand if a combination of behaviours and the provision of physical infrastructure are driving impact results. However, at this point, 70 percent of behaviour outcomes come from single-intervention evaluations of either hygiene or water quality trials (**see Figures A1 and A2 in Annex)**.

2.7. Meta-analysis

Different WASH interventions produce different results for the same outcome. For instance, water quality studies using a relatively common measurement of water treatment and health outcomes (e.g. incidence of diarrhoea) varied widely in their estimates of the magnitude of outcome effects, depending on the approach or technology used. Thus, meta-analysis is required to aggregate the point estimates and generalize the results. Ideally, all study designs are expected to have an adequate sample size; however, historically most WASH impact evaluations have been underpowered and have included small-scale interventions. To counteract this problem, meta-analysis is a powerful statistical tool that estimates the overall effects of different programs by pooling data that on their own would be too small to draw confident conclusions. The conclusions of a meta-analysis are nonetheless based on the quality of the studies identified to estimate the pooled effect[13].

[13] The quality of randomised impact evaluations was evaluated and included regarding the randomization, adequate assignment, and explanation of dropouts and withdrawals; this addresses the issues of both internal validity (minimization of bias) and external validity (ability to generalize results).

2.7.1.Heterogeneity

To assess heterogeneity, papers were categorized by geographical region and intervention subtheme and plotted against the standard error and precision of estimates. Figure A3 (see Appendix A) illustrates high variation (or heterogeneity) in standard errors for the entire sample of impact evaluations. This is not surprising given that 90 percent of the impact evaluations were RCTs. To the contrary, the variation in correlations of outcome effects (*pcorr*) is generally low (or homogenous) across subgroups and especially so for sanitation and water supply.

Smaller sample sizes may overestimate effects while larger sample sizes increase sensitivity; thus, meta-analysis generally improves statistical power by increasing sample size. There is no correlation between sample size and outcome effects in the publications included in this review (Figure A4 in Appendix A), suggesting that studies with smaller sample sizes are not exerting undue influence on overall effects, and that the minimum requirements for internal and external validity have been met.

2.7.2.Bias

Evidence of potential regional bias was detected in two areas, North America and South Asia (**Table 2.2**). South Asia represented the largest subset of studies; however, the estimate was imprecise and the standard error relatively high and therefore unlikely to have exerted significant bias on the pooled outcomes. On the contrary, the subset of studies from North America was limited to six well-designed evaluations that estimated the effects of WASH interventions on diarrhoea, and these may have disproportionately influenced the pooled outcomes (**Table 2-2**).

Finally, **Figure A5 (in Appendix A)** illustrates evidence of comparability between publications given the number of views per publication and limited outliers. The size of the circles indicates the number of views and the closer and more overlapped the circles, the higher their comparability.

	East Asia and Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	North America	South Asia	Sub-Saharan Africa
Slope (Precision)	2.986***	0.660	2.904***	1.796**	1.487***	0.975	3.053***
	(0.966)	(0.472)	(0.935)	(0.882)	(0.312)	(2.068)	(0.992)
Bias	-0.245	-0.149	-0.0111	-0.171	-0.256***	1.222**	0.134

	(0.190)	(0.0899)	(0.222)	(0.159)	(0.0598)	(0.536)	(0.265)

Table 2-2 Heterogeneity Estimates by Region
Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

2.7.3.Effects trends

At least two different studies per outcome are needed to perform a meta-analysis. Thus, only the results for 13 of the 21 outcome indicators were included in the meta-analysis. **Table 2-3** lists the estimated effects and types of interventions for the remaining eight outcomes. In terms of risk differences, studies assessing access to sewerage and incidence of shigellosis infection showed the highest effects, +0.20 and -0.22, respectively. Among risk ratios, behaviour change, and child weight gain were the only statistically significant outcome effects with a reported mean higher than 1. One study measuring cholera reduction showed the third-highest risk ratio coefficient of 0.48, which was statistically significant.

Outcome	Intervention	Effect Measure	Effect	Significance
Access to sewerage	Multiple	Risk difference	0.20	*
Behaviour change	Hygiene	Risk ratio	1.11	*
Cholera reduction	Water quality	Risk ratio	0.48	**
Cognitive skills	Sanitation	% variation	0.30	**
Satisfaction	Water supply	Risk difference	0.13	*
Dengue pupae reduction	Multiple	Risk ratio	0.34	**
Shigellosis infection incidence	Hygiene	Risk difference	-0.22	**
Child weight gain	Water quality	Risk ratio	1.27	*

Table 2-3 Table Effects of Outcomes with Single-Impact Evaluations
Note: * p-value<0%, ** p-value<5%.
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Table 2-4 summarizes the results of the meta-analysis for the remaining outcomes. Overall, there are three outcomes (adoption of water treatment, incidence of ocular infection, and source switching) for which the heterogeneity of effects, combined with the heterogeneity effects of small sample sizes, led to statistically insignificant aggregate results. The pooled effects of WASH interventions on the remaining 10 outcomes were statistically significant. In particular, the odds of missing school were reduced by a factor of 0.69 for students who had benefited from a WASH intervention.

Similarly, children who received a WASH intervention were 1.44 times as likely to use soap, 0.5 times as likely to develop Ascaris infections, 0.65 times as likely to develop diarrhoea (however, this particular result may be inflated due to the potential bias of the six studies from North America), and 0.91 times as likely to die than children not receiving one. Finally, child growth, handwashing, and latrine adoption increased by 26, 8, and 22 percent, respectively, and water quality improved by 20 percent.

Outcome	Effect Measure	Effect	Significance
Adoption of water treatment	Risk ratio	1.35	-
Ocular infection	Odds ratio	0.91	-
Soap usage	Risk ratio	1.44	**
Source switching	Risk difference	0.04	-
School absenteeism	Odds ratio	0.69	**
Ascaris reduction	Risk ratio	0.47	**
Child mortality	Risk ratio	0.91	**
Child growth	Risk difference	0.26	**
Water access	Risk difference	0.09	**
Handwashing	Risk difference	0.08	**
Latrine adoption/ Toilet access	Risk difference	0.22	**
Water quality	Risk difference	0.21	**
Diarrhoea reduction	Risk ratio	0.65	**

Table 2-4 Pooled Effects of Outcomes with Multiple Impact Evaluations
Note: * p-value<10%, ** p-value<5%.
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

2.7.4. Meta-regression

Table 2-5 presents the results of the meta-regressions of the correlation of study outcomes against study characteristics hypothesized to be associated with the studies' effects (variables) for the entire meta-analysis data set. Overall, three study characteristics appeared to be significantly correlated with outcomes, namely, the type of WASH intervention, which showed a slight positive correlation, and reporting metric (risk difference) and implementing entity (government), which showed slight negative correlations.

The number of publication views is also slightly, but significantly, correlated to outcomes, which is intuitive and may be indicative of studies seeking to build upon the evidence of their predecessors. Moreover, the direction of the relationship is negative, which could suggest well-known studies are eventually refuted over time, indicative of good practice and conducive to the well-being of the sector as a whole. Overall, very few variables were significantly correlated, and standard errors were robust. Thus, the regression model was correctly specified, and 57 to 65 percent of the variation in correlations can be explained by the selected study characteristics.

Variables	Model (1) Study Correlation (pooled effects)	Model (2) Study Correlation (group dummies)	Model (3) Study Correlation (group dummies)
Region fixed effects	No	No	Yes
Number of views	-0.0113***	-0.0113***	-0.0110**
	(0.00413)	(0.00360)	(0.00444)
Journal, dummy	-0.00501	-0.00501	-0.00823
	(0.00908)	(0.00792)	(0.0109)
Report/chapter, dummy	-0.0213	-0.0213*	-0.0194
	(0.0133)	(0.0116)	(0.0178)
Single intervention, dummy	-0.00726	-0.00726	-0.00589
	(0.0116)	(0.0101)	(0.0118)
Randomised assignment, dummy	-0.00142	-0.00142	0.00184
	(0.00804)	(0.00701)	(0.00994)
Child health, growth outcomes group	-0.00409	-0.00409	-0.00317
	(0.0117)	(0.0102)	(0.0146)
Risk difference (RD) effect, dummy	-0.0389***	-0.0389***	-0.0433***
	(0.0140)	(0.0122)	(0.0109)
Subtheme groups, categorical	0.0319***	0.0319***	0.0337***
	(0.00715)	(0.00623)	(0.00548)
Years of implementation, cont.	-1.153	-1.153	-0.220
	(1.494)	(1.301)	(1.630)
Government implemented, dummy	-0.0219**	-0.0219***	-0.0259**
	(0.00870)	(0.00758)	(0.0120)
Sample size, continuous	-0.00227	-0.00227	-0.00167
	(0.00389)	(0.00339)	(0.00370)
Urban interventions, categorical	-0.0141	-0.0141*	-0.0175
	(0.00925)	(0.00806)	(0.0110)
Constant	8.906	8.906	9.821
	(11.36)	(9.895)	(12.39)
Observations	136	135	104
R-squared	0.621	0.573	0.650

Table 2-5 Correlation of Outcomes against Study Characteristics for the Entire Meta-Analysis
Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

2.8. Meta-analysis of subgroups

To facilitate the meta-analysis[14], and analyse the association between outcome effects and study characteristics in detail, outcomes were classified into five thematic subgroups based on expert review and according to conventional WASH themes. When the regression model for the entire meta-analysis data set was controlled for these outcome subgroups there was no statistical difference (**Table 2-5**), and the

[14] Aggregating outcomes ensured there was sufficient variation in sample sizes, effects, and standard errors to conduct the meta-analysis, while increasing the statistical power.

meta-analysis was therefore repeated at the group level without compromising the integrity of the results.

2.8.1.Heterogeneity of subgroups

Forest plots show differences in the results, methodology, or study populations used in the studies included in a meta-analysis. The pooled results of a forest plot show the overall result derived from combining (pooling) the individual studies. A forest plot was constructed to illustrate these elements for each of the five subgroups (**see Figure A8 in Appendix A**). The forest plots showed that the pooled effects are not within the area of "no effect" for: water quality, treatment, and access; diarrhoea reduction; and hygiene, soap usage, handwashing, and latrine adoption. The pooled effects on school absenteeism were large and significant but based on too few studies to draw statistical conclusions. The pooled effects corresponding to other health outcomes including child mortality, growth, nutrition, ocular infection, and Ascaris reduction showed ambiguous results (and for some papers were in the "no effect" area[15]).

Group 1, which primarily included outcomes related to behaviour change and sanitation, comprised 16 studies across all intervention subgroups, except water supply, and were concentrated in the South Asia region. There was limited correlation between estimated effects, and the standard error was fairly homogenous across studies with the exception of the multiple intervention's subgroup in Sub-Saharan Africa (**Figure A6 in Appendix A**).

Group 2 comprised 15 studies related to growth and mortality in children combined with infectious diseases (namely water-washed diseases), across three intervention subgroups concentrated in the Sub-Saharan Africa region. The variation in correlation between estimated effects across studies was clearly low, while the variation in standard errors was high (**Figure A6**).

Group 3 included four papers related to cognitive skills and school absenteeism, across two intervention subgroups and only three regions. The correlation between estimated effects was effectively zero yet there was some variation in standard errors (**Figure A6**).

[15] The null effect of 1 corresponds to a statistic similar to an odds ratio (OR) or a relative risk (RR). Alternatively, the statistic being used might be "absolute" such as absolute risk reduction (ARR) or standardized differences of means (SMD). Knowing the difference between relative and absolute statistics is important because it affects which number sits at the vertical line. For absolute statistics such as absolute risk or ARR or SMD, the null difference value is 0. However, this was not used in this analysis.

Group 4 included 25 studies related to water supply and water quality outcomes across all intervention subgroups except sanitation, although water quality and multiple interventions dominated. The studies were primarily concentrated in Latin America and the Caribbean, South Asia, and Sub-Saharan Africa. There was limited variation between correlations of estimated effects across studies. To the contrary, there was a high variation of standard errors across all studies owing to the high variability in water quality studies in Latin America and the Caribbean and multiple interventions in South Asia (**Figure A6**).

Finally, Group 5, which pertained to diarrhoea and enteric disease, comprised 79 studies, the highest number of all groups, distributed comparatively evenly across subgroups and regions. The variation in correlations of estimated effects was relatively low across subgroups except for water supply, especially in Sub-Saharan Africa. The variation in standard errors across all papers was high, especially for water quality in Latin America and the Caribbean (**Figure A6**).

In sum, all the groups showed low variations in correlations between outcome effects, making them highly suitable for pooling. However, slight heterogeneity was detected in Groups 4 and 5 because of the high variability in standard errors.

2.8.2.Bias of Subgroups

Funnel plots were constructed for each subgroup (**Figure A7 in Appendix A**) to assess potential bias. There is no evidence of asymmetry for Groups 1 through 4, and bias is unlikely. In the case of Group 5, while the outcome effects are relatively evenly distributed when considering all studies, the distribution of larger, more precise studies is skewed, suggesting an absence of studies. However, since most of the missing studies fall within an area of high significance, asymmetry is unlikely to have resulted from reporting bias. Group 5 includes the six highly influential studies from North America, and thus aligns with the findings from the full data set and may be the source of asymmetry.

2.8.3.Meta-Regression of Subgroups

Table A1 (see Appendix A) presents the results of a meta-regression of the correlation of study outcomes to study characteristics (variables) for each group; **Table**

A2 (see Appendix A) presents the results of a meta-regression of study characteristics on the pooled effects by group.

In the case of Group 1, studies conducted in Latin America and the Caribbean and South Asia were slightly correlated, indicating similar evidence bases in those regions. Sample size produced a slight, but significantly inverse, effect, which is somewhat counterintuitive given that larger sample sizes often lead to greater representation. Effectively, the number of studies is positively correlated with outcome effects, suggesting more studies may lead to improved results. Quasi-experimental (or nonrandomised program assignment) designs are negatively correlated with outcome effects, suggesting experimental designs (RCTs) are more likely to produce reliable results. Similarly, studies undertaken in urban areas are positively correlated with outcome effects, suggesting urban studies may produce better results than their rural counterparts. This is not surprising, given that all four evaluations conducted in urban areas used randomised methods, and studies in rural areas predominantly used quasi-experimental methods.

There was less evidence of correlation between papers in Group 2 than in all other groups except Group 3, which may indicate a lack of relationship between the different studies. Further, it may suggest that individual outcome effects are not easily explained by study characteristics. Indeed, none of the study characteristics evaluated was significantly correlated with outcomes in Group 2, which indicates a diverse set of studies that, when compared with Group 1, for example, exerts less influence on overall effects.

The ability to draw significant conclusions regarding Group 3 was limited by its small size. Nonetheless, there does not appear to be a relationship between study characteristics and outcomes here. Similarly, studies conducted in the same region were not correlated.

Studies within Group 4 were more homogenous than those of any other group, although most correlations were weak. This may be due to studies testing complementary interventions or impact evaluations being replicated in different locations. Experimental research methods (RCTs) and the implementing agency were both factors that contributed to the correlation between papers. The number of studies was significantly correlated to outcome effects and explained 78 percent of the variation, suggesting larger data sets produce more reliable results.

Finally, while certain aspects of papers within Group 5 were also significantly correlated, these papers had the widest variation in outcomes of all groups, making them especially suitable for aggregation. Two study characteristics were significantly and highly correlated with outcomes: i.e., study locale and implementing agency. Studies implemented by government agencies had a significant, negative impact on outcome effects, suggesting interventions implemented by Non-Governmental Organizations (NGOs) produce more reliable results. Studies conducted in urban areas (64 percent of all studies) had a significant, negative impact on outcome effects even though all but one of those studies were implemented by NGOs.

2.9. Discussion and Conclusions

Overall, there has been a large increase in WASH-related impact evaluations over the past decade. Studies have been concentrated in the most underserved areas, while the East Asia and Pacific, Europe and Central Asia, and Middle East and North Africa regions remain underrepresented. Despite a large increase in studies evaluating combined WASH interventions, few evaluations target multiple countries or involve multiregional interventions. Water quality interventions dominate impact evaluations, especially in Sub-Saharan Africa and Latin America and the Caribbean. This finding is not surprising, given that the more quantitative nature of water quality interventions makes them suitable for experimental methods. Although sanitation interventions were very common in India and behaviour change interventions dominated in Bangladesh, these interventions were generally underrepresented in impact evaluations, making it difficult to assess regional effectiveness.

Despite a relatively high number of unique outcomes, more than half of all evaluations focused on diarrhoea. This review corroborates the earlier findings of Hutton and Chase (2017) and Esteves Mills and Cumming (2016) that the positive effects on diarrhoea reduction are well established and thoroughly documented, particularly for handwashing with soap and water quality trials. However, while experimental designs resulted in significant effects, quasi-experimental designs did not produce the same results[16].

[16] For instance, these studies reported that a recent meta-analysis of five randomised controlled trials found a t-test differences of means of 0.08 in height-for-age z-scores of children under age five (95 percent CI: 0.00–0.16) for solar disinfection of water, provision of soap, and improvements in water quality (Dangour *et al*. 2013).

Evidence from the non-pooled studies on behaviour change and other health-related outcomes (e.g. child mortality, stunting, height, and weight) is scarce, and predominantly limited to single studies, although small-scale studies evaluating combined interventions did report weak yet significant results for child mortality and stunting. Moreover, while a range of WASH interventions was frequently employed to control cholera outbreaks, few programs have been evaluated using rigorous impact evaluation techniques, limiting researchers' ability to draw evidence-based conclusions. Further, there is a clear distinction between program effects from stand-alone WASH interventions versus programs that are designed to target multiple WASH themes. For example, the evidence for water quality in single interventions using experimental designs is solid, but less so in combined interventions.

Finally, impact evaluations specifically focused on child health outcomes were heterogeneous. Several studies included multiple sources of potential bias and all the studies failed to mask the WASH intervention of participants. Child health as a primary outcome (Fink, Gunther and Hill, 2011)—measured, for example, by weight-for-age, linear growth, weight-for-height, and height-for-age ratios—was reported in only 5 of the 136 studies, a fact that may have influenced this review. Notwithstanding, the combined data set showed little variation in estimated effects and high variation in standard errors, suggesting the studies were suitable for pooling. Further, there was no correlation between sample size and effects, that is, small samples did not exert a disproportionate influence on the pooled results.

The relationship between WASH interventions and outcomes is complex. Some interventions were combined without information reported on individual effects from interventions, which may have impacted the meta-analysis and the ability to draw concrete conclusions. Although there was evidence of regional bias stemming from the subset of studies conducted in North America, the inclusion of these studies was deemed reasonable given that the interventions included in them were large-scale with strong methodological designs for causal attribution between the intervention and outcomes.

The pooled effects of WASH interventions on school absenteeism were significant: the odds of missing school were reduced by a factor of 0.69 among students who had received a WASH intervention. Similarly, children receiving a WASH intervention were 1.44 times as likely to use soap, only 0.5 times as likely to develop Ascaris infections, 0.65 times as likely to develop diarrhoea, and 0.91 times as likely to die as children not receiving a WASH intervention—and all results were significant. Finally, child growth, handwashing, and latrine adoption increased by 26, 8, and 22 percent, respectively, and water quality improved by 20 percent. These findings illustrate the importance of increased statistical power facilitated by meta-analysis to improve evidence.

Applying meta-analysis at the subgroup level enabled a more detailed evaluation of results. There was no evidence of bias in Groups 1 through 4. Group 5, which focused on diarrhoea and enteric-disease-related outcomes, presented evidence of bias in larger, more precise studies; however, reporting bias was ruled out as the likely cause. Group 5 included the subset of studies from North America, which had similarly presented evidence of bias on the full data set of evaluations.

In certain circumstances, research methods can significantly influence outcome effects. RCTs tend to estimate larger and more precise effects. In some cases, study locale (e.g. urban versus rural) was found to affect the reliability of results; however, this varied by outcome and could not always be explained by other study characteristics. For example, though WASH interventions targeting behaviour change and sanitation produced more robust effects in urban areas, this was also a function of study design, given that the studies conducted in urban areas applied experimental methods, which have been shown to improve results. On the contrary, WASH interventions targeting the reduced incidence of diarrhoea and enteric-related diseases and conducted in rural areas produced more precise results than interventions in urban areas. This is even though most interventions in urban areas had been implemented by NGOs, which are shown to improve the accuracy of results when compared to government agencies. This could be explained by reinfection rates, which are typically higher and/or impact more people in densely populated, urban areas. However, given the potential bias in this group, results should be interpreted with caution. In general, evaluations that encompass large numbers of studies with rigorous research methods produce more precise results. This was the case for studies evaluating WASH interventions' effects on behaviour and sanitation outcomes. Improving study design specifically in rural areas for these outcomes might be one area for future research. Indeed, there is a wide range of qualitative approaches that can be employed in combination with quantitative methods to strengthen effects.

However, there is a trade-off between the internal and external validity of WASH impact evaluations that should be considered when designing studies.

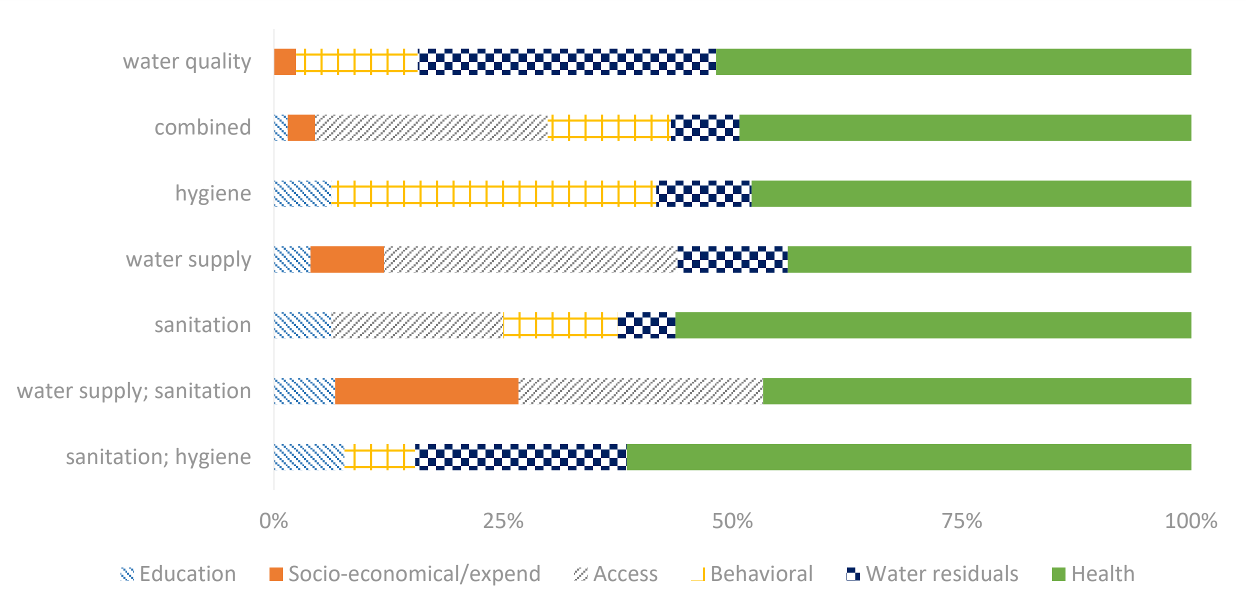
Similarly, although the effects of WASH interventions on some health-related outcomes were unambiguous—for example, water quality on the incidence of diarrhoea—other health-related outcomes such as child mortality, stunting, weight, and height showed mixed results. This would also appear to be a result of study size, and ambiguities in these other health-related outcomes would likely decrease if more studies were undertaken in those areas. Likewise, more research needs to be undertaken on hygiene and sanitation interventions overall, and greater geographical representation is needed. Finally, additional research is needed to better understand the impacts of study locale on the results of WASH interventions targeting reduced diarrhoea and enteric diseases.

The effects of multiple interventions, especially in combination with initiatives to promote behaviour change, would also benefit from additional research. Specifically, there is a need to ensure a consistent approach to undertaking impact evaluations. For example, outcome effects—and not just the combined effect—should be reported for each intervention. There are grounds to suggest capacity-building efforts in government implementing agencies would lead to more reliable results, which also supports the argument for a better, more cohesive approach to conducting impact evaluations. Clearly, more evidence is needed to support the emerging understanding of the wider health and social effects of WASH interventions. In summary, all findings seem to point to the need for larger studies, with broader geographical representation and rigorous research methods, in addition to well-trained implementing agencies.

2.10. Annexes

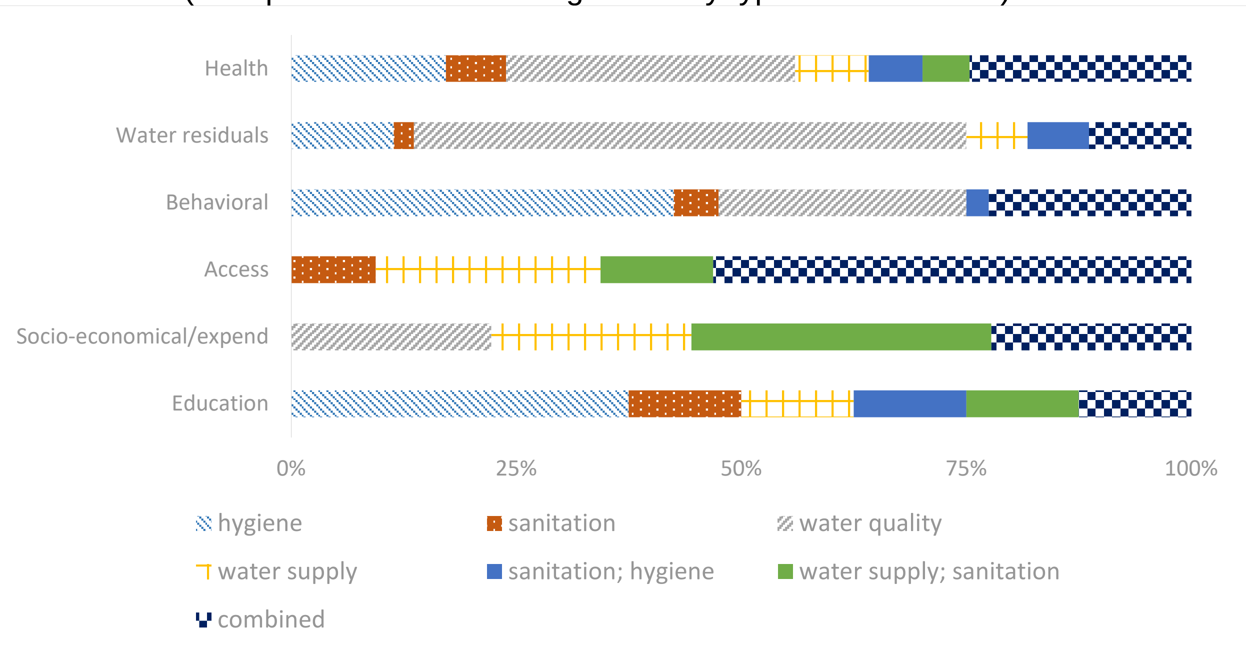
2.10.1.Distribution of Main Outcome Groups

Figure A1. Most Interventions Focus on Health and Water Residuals
(Classification of interventions and outcomes analysed)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

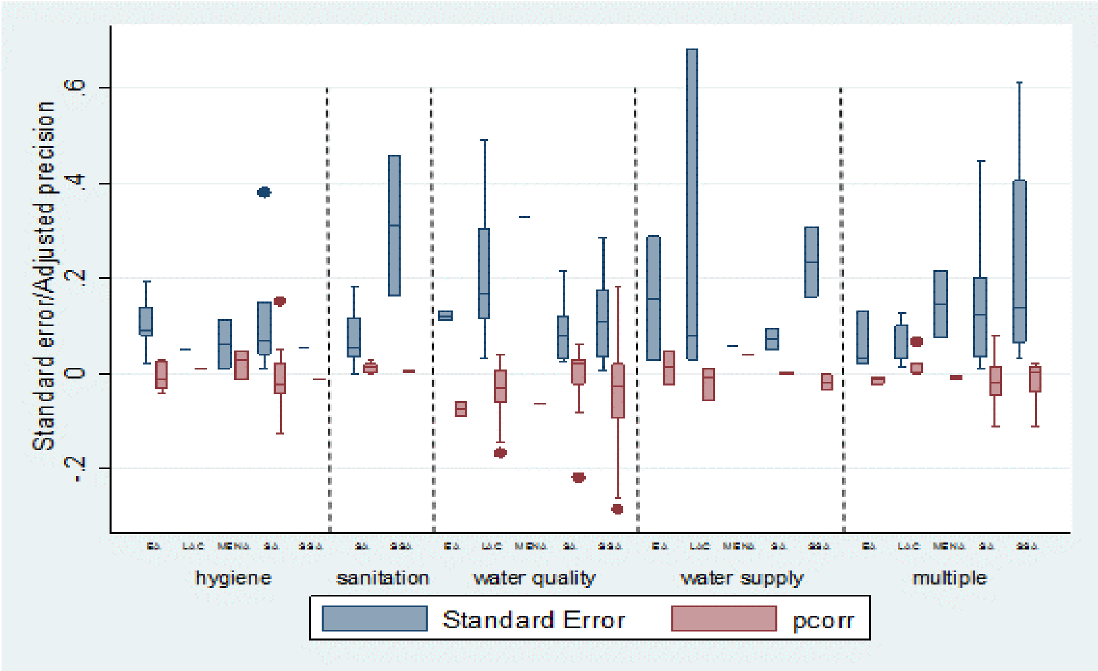
Figure A2. Water Quality Interventions Dominate
(Groups of outcomes distinguished by type of intervention)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

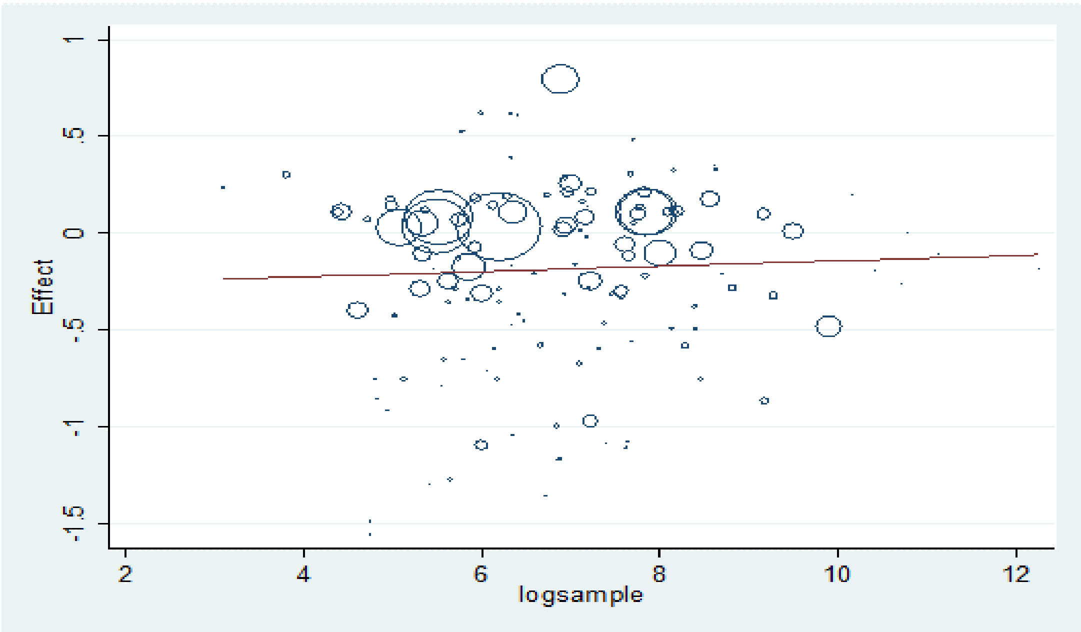
Meta-Analysis Graphical Representation of Publications

Figure A3. Variability in Standard Errors and Correlations of Outcome Effects (between publications) by Region and Intervention Type (entire dataset)



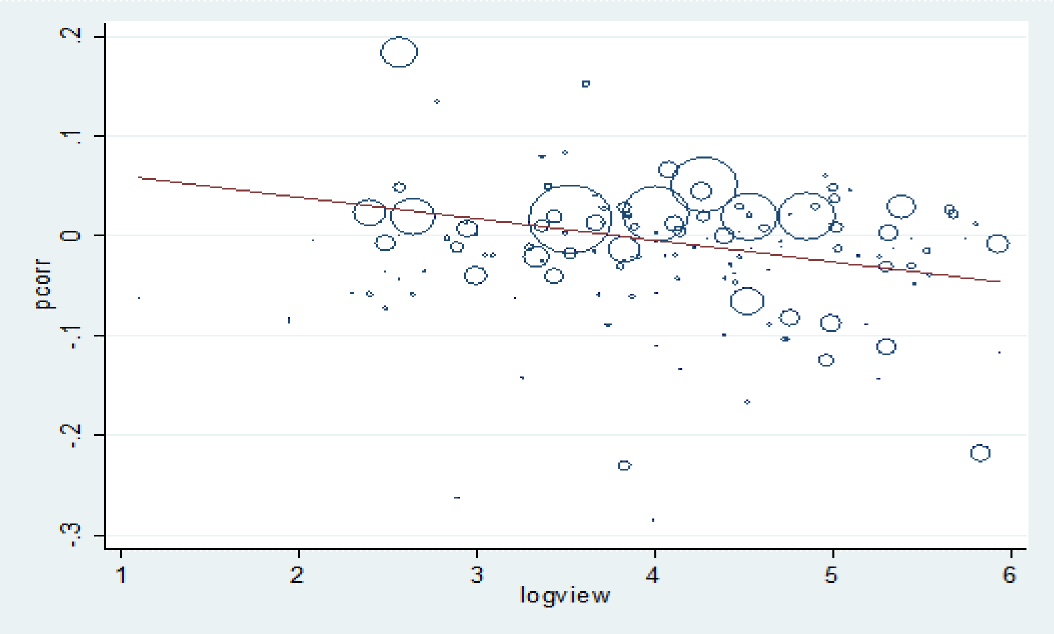
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: EA = East Asia and Pacific, LAC = Latin America and the Caribbean, MENA = Middle East and North Africa, NA = North America, SA = South Asia, SSA = Sub-Saharan Africa.

Figure A4. Relationship between Publication's Sample Size and Estimated Effects (entire sample)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

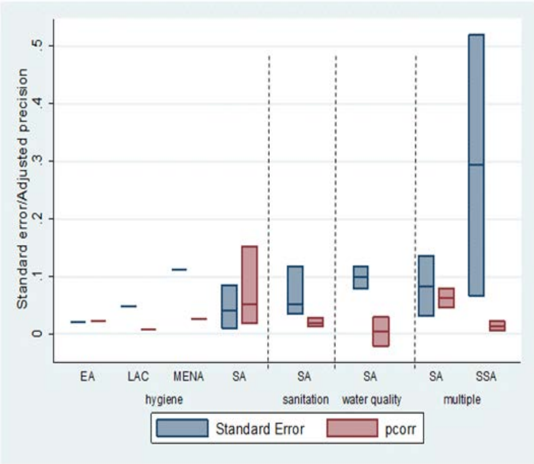
Figure A5. Paper Views and Publication Correlation



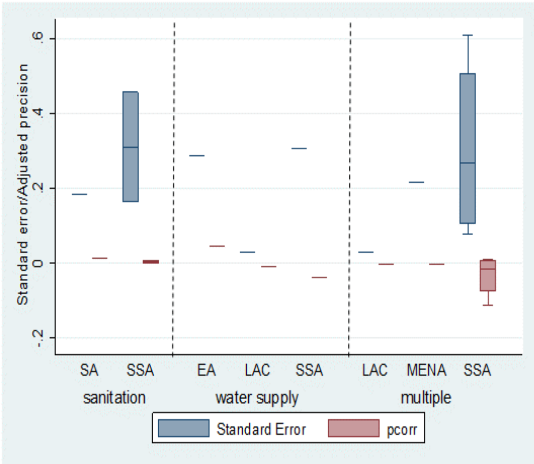
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Figure A6. Box Plots per Outcome Subgroup

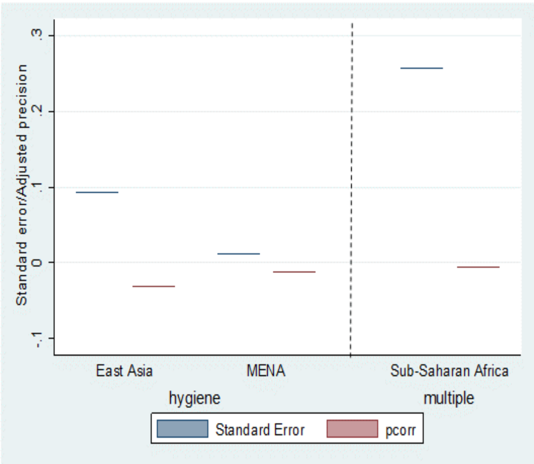
Group 1: Behaviours, Hygiene, Sanitation



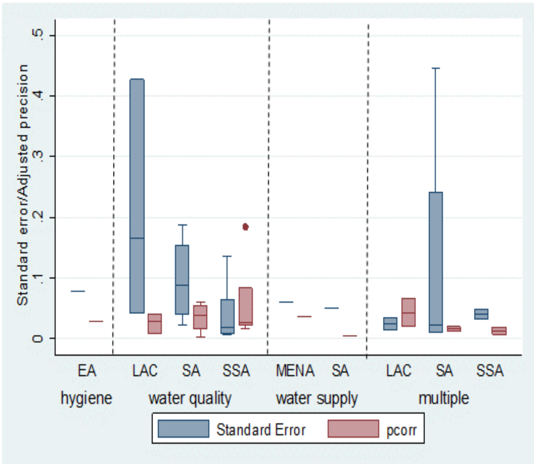
Group 2: Child Mortality, Growth, Health



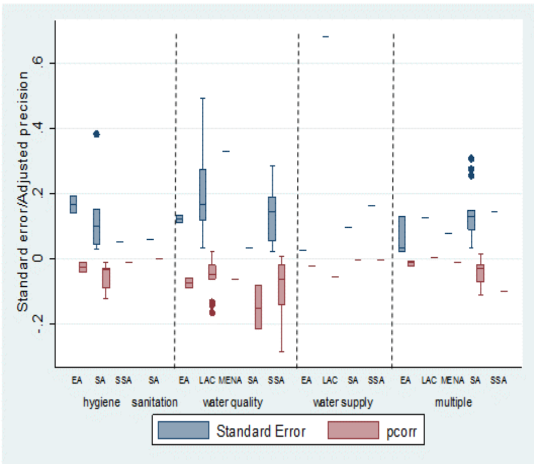
Group 3: Education/Absenteeism Outcomes



Group 4: Water Quality, Treatment, and Access



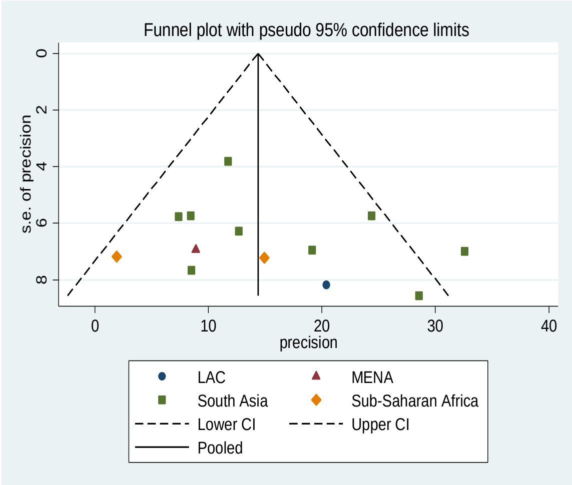
Group 5: Diarrhoea and Enteric Disease Reduction



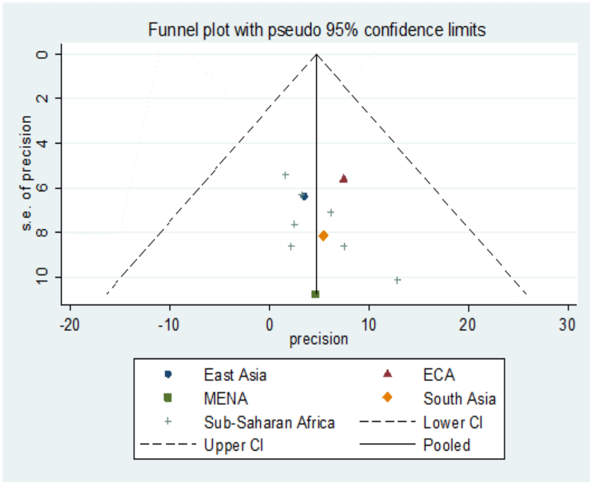
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: EA = East Asia and Pacific, LAC = Latin America and the Caribbean, MENA = Middle East and North Africa, SA = South Asia, SSA = Sub-Saharan Africa.

Figure A7. Funnel Plots (precision) per Outcome Subgroup

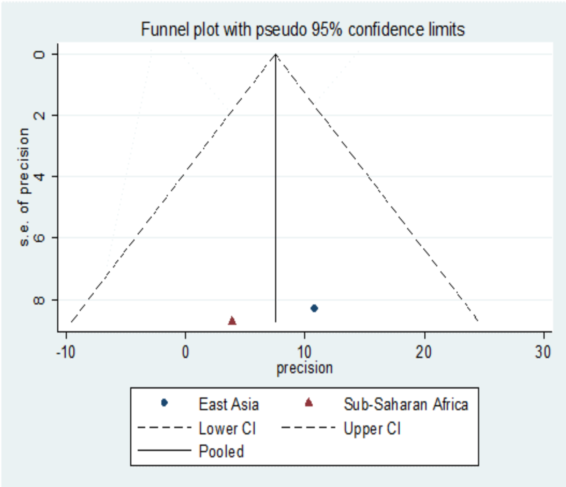
Group 1: Behaviours, Hygiene, Sanitation



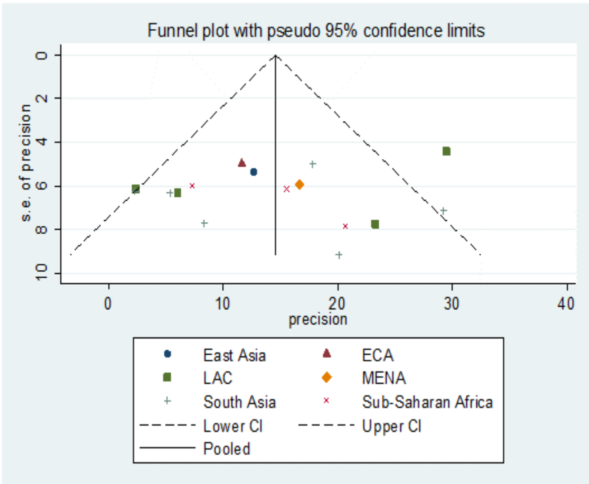
Group 2: Child Mortality, Growth, Other Health Outcomes



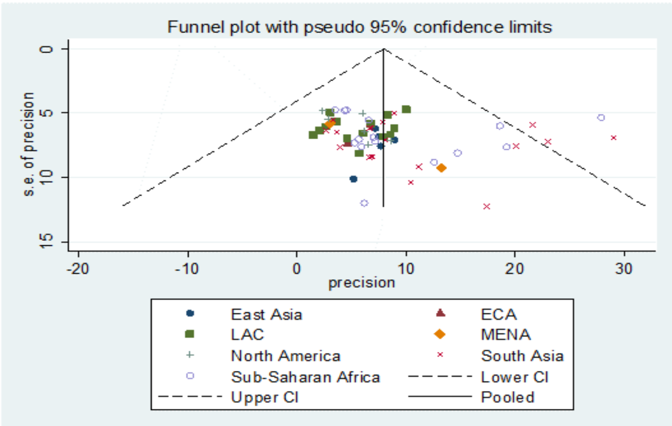
Group 3: Education/Absenteeism Outcomes



Group 4: Water Quality, Treatment, and Access



Group 5: Diarrhoea and Enteric Disease Reduction



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: CI = confidence interval; ECA = Europe and Central Asia, LAC = Latin America and the Caribbean, MENA = Middle East and North Africa.

Group Regressions

Table A1. Meta Regressions by Outcome Group (between publication corr.)

Independent Variables	Group 1 Paper Corr	Group 2 Paper Corr	Group 3 Paper Corr	Group 4 Paper Corr	Group 5 Paper Corr
Effect size (ES)	0.166**	0.0599***	0.0970**	0.198***	0.130***
	(0.0674)	(0.0132)	(0.0433)	(0.0133)	(0.0118)
Standard error of study	0.0305	-0.0235	-0.0428	-0.423***	0.193***
	(0.0848)	(0.0547)	(0.125)	(0.0633)	(0.0410)
Journal=1, 0=Otherwise	0.0231	0.0182**	0.00797	0.000547	0.0107
	(0.0193)	(0.00751)	(0.0159)	(0.00470)	(0.00753)
Number of studies	0.0352	-0.0285**	0.0339	-0.0536***	-0.00566*
	(0.0267)	(0.0124)	(0.0426)	(0.0106)	(0.00326)
Sample size	-0.0514***	-0.00338	-0.0180**	-0.00697**	0.0155***
	(0.0177)	(0.00385)	(0.00755)	(0.00295)	(0.00295)
Urban dummy	0.00187	0.00173	0.0248	-0.00241	0.000599
	(0.0313)	(0.00998)	(0.0279)	(0.00770)	(0.00776)
Government implementation dummy	0.0414	0.0159	0.0641	0.0664***	-0.0183
	(0.0318)	(0.0211)	(0.0503)	(0.0170)	(0.0133)
Quasi-experimental dummy	-0.0457	-0.00377	0.00299	-0.149***	-0.000528
	(0.0327)	(0.0139)	(0.0548)	(0.0343)	(0.0131)
LAC region dummy	0.120*	-0.0274	-0.0576	-0.00376	-0.0197
	(0.0618)	(0.0395)	(0.0855)	(0.0121)	(0.0156)
MENA region dummy	0.129	0.0225	-0.0223	0.143***	0.000652
	(0.0850)	(0.0471)	(0.0628)	(0.0361)	(0.0232)
SA region dummy	0.116*	-0.0312	-0.0298	0.00241	-0.0287**
	(0.0643)	(0.0490)	(0.0591)	(0.0117)	(0.0142)
SSA region dummy	0.0663	0.0142	-0.0103	-0.0110	-0.0234
	(0.0454)	(0.0564)	(0.0539)	(0.0122)	(0.0145)
Constant	0.0761	0.0123	0.0202	0.166***	-0.0771**
	(0.0977)	(0.0806)	(0.0999)	(0.0384)	(0.0343)
R-squared	0.43	0.21	0.07	0.58	0.72

Source World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: Standard errors in parentheses.*** p<0.01, ** p<0.05, * p<0.1. LAC = Latin America and the Caribbean, MENA = Middle East and North Africa, SA = South Asia, SSA = Sub-Saharan Africa.

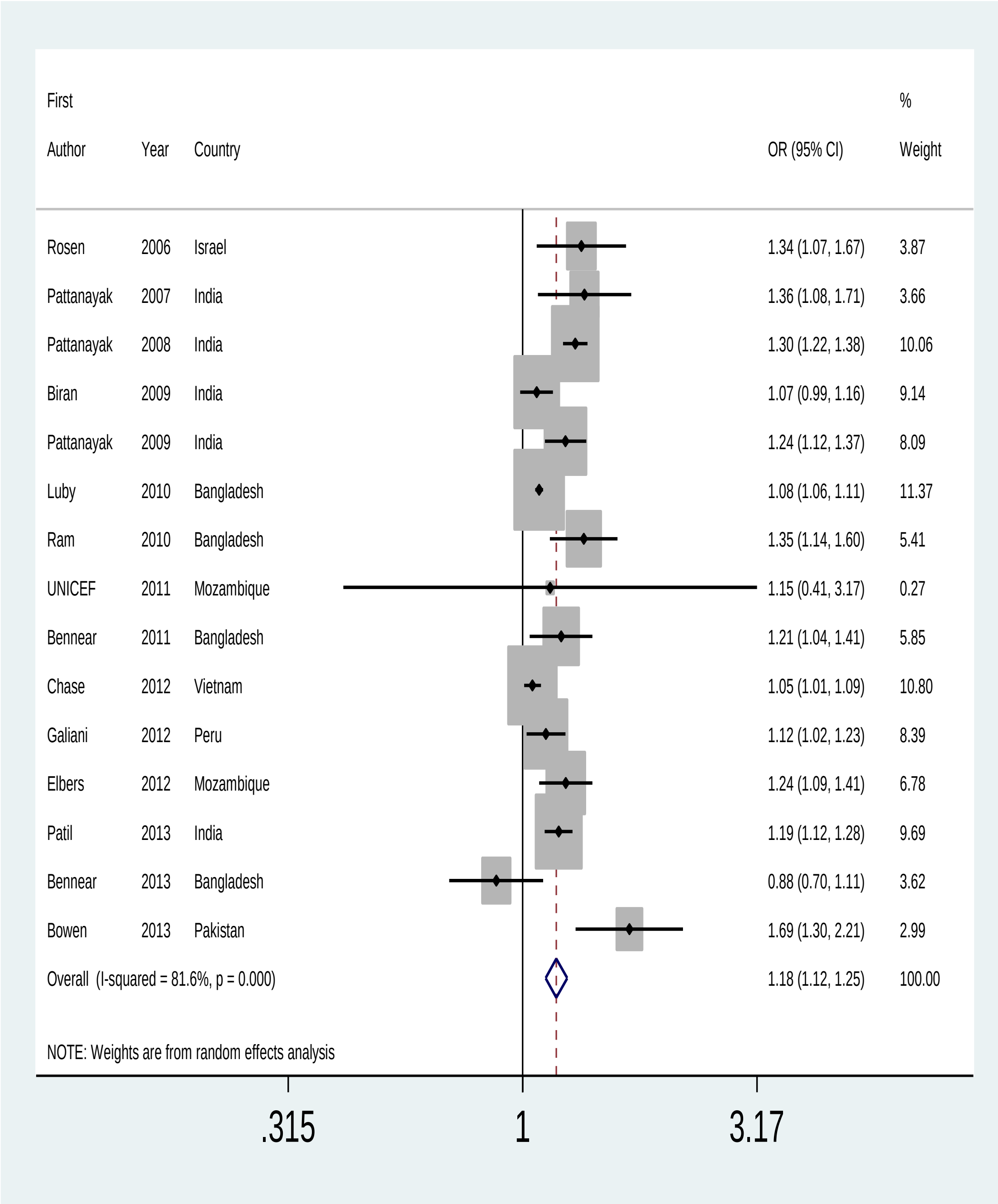
Table A2. Meta Regressions by Outcome Group (effects)

Independent Variables	Group 1 Effect	Group 2 Effect	Group 3 Effect	Group 4 Effect	Group 5 Effect
Number of studies	0.569*	0.443	0.0112	0.382**	-0.0966
	(0.288)	(0.431)	(0.683)	(0.170)	(0.0498)
Sample size	0.0840	-0.0705	0.131	-0.0262	0.0799
	(0.0797)	(0.151)	(0.159)	(0.0873)	(0.0522)
Urban dummy	0.626**	-0.378	-0.364	-0.175	-0.651**
	(0.193)	(0.566)	(0.454)	(0.266)	(0.165)
Government implementation dummy	-0.0701	0.183	0.0931	-0.0708	-1.208***
	(0.164)	(0.434)	(0.124)	(0.266)	(0.211)
Quasi-experimental dummy	-0.589*	-0.324	-0.887	-0.397	0.128
	(0.241)	(0.596)	(0.782)	(0.396)	(0.242)
Precision	-0.0206***	-0.00539**	-0.00615***	-0.0243***	-0.00567***
	(0.00455)	(0.00149)	(0.00131)	(0.00316)	(0.000394)
Mean diff. within group	0.566**	0.898**	0.890***	0.891***	1.089***
	(0.157)	(0.246)	(0.219)	(0.114)	(0.137)
Constant	-3.058***	-1.076	-1.782	-0.402	0.252
	(0.571)	(1.935)	(1.345)	(1.004)	(0.471)
R-squared	0.67	0.34	0.10	0.78	0.85

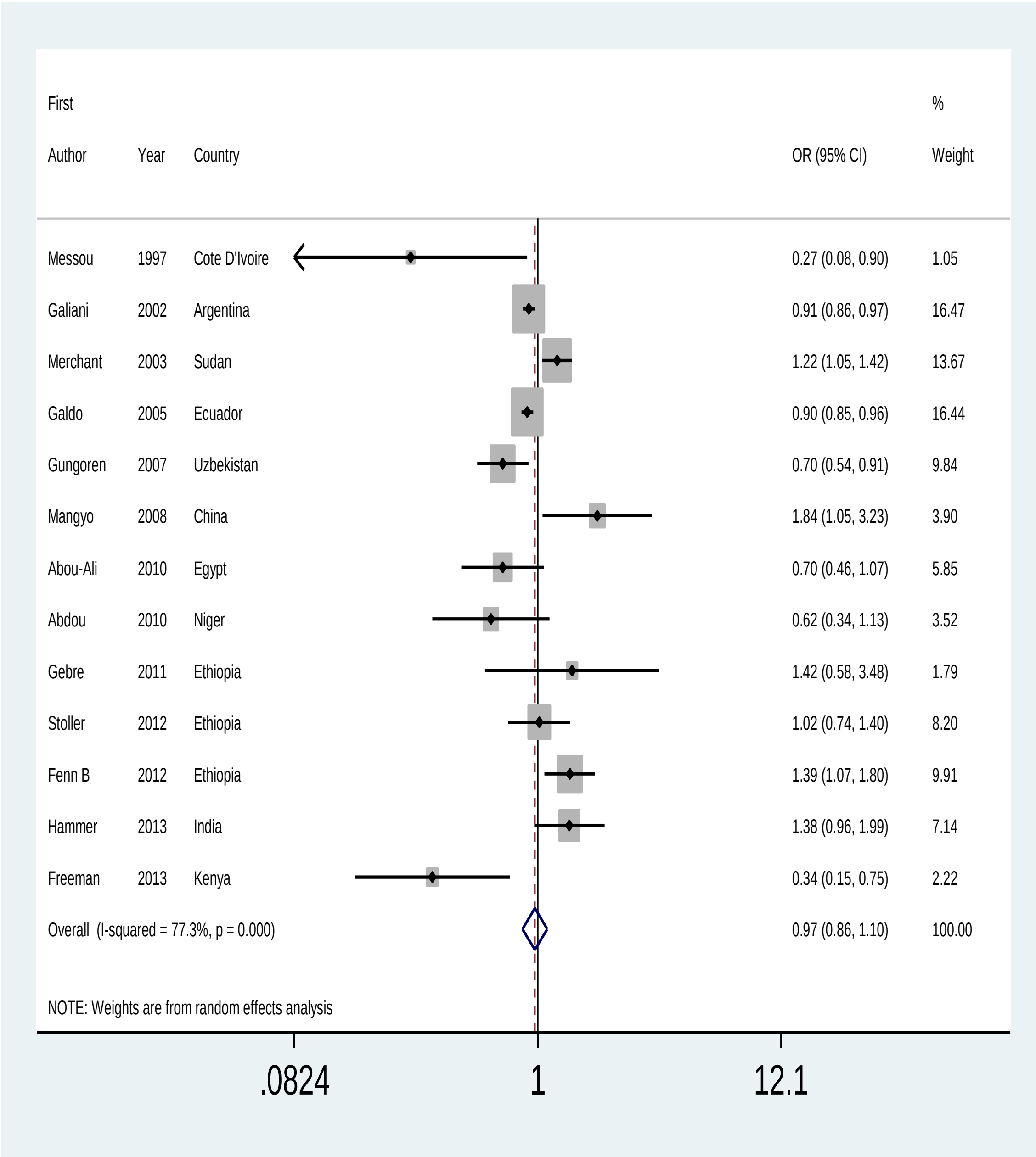
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figure A8. Forest Plots per Outcome Group

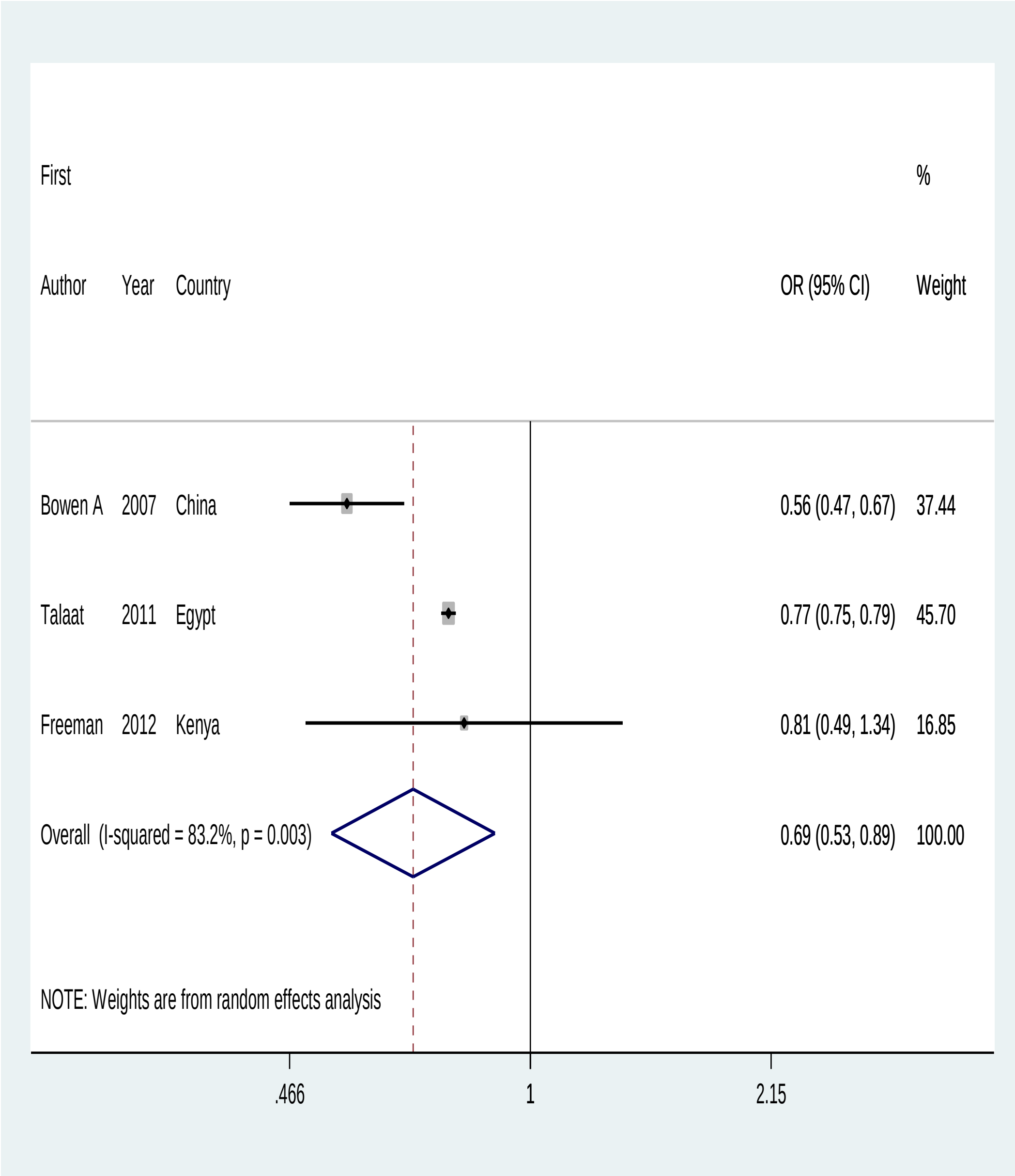
Group 1: Behaviours, Hygiene, Sanitation (outcomes)



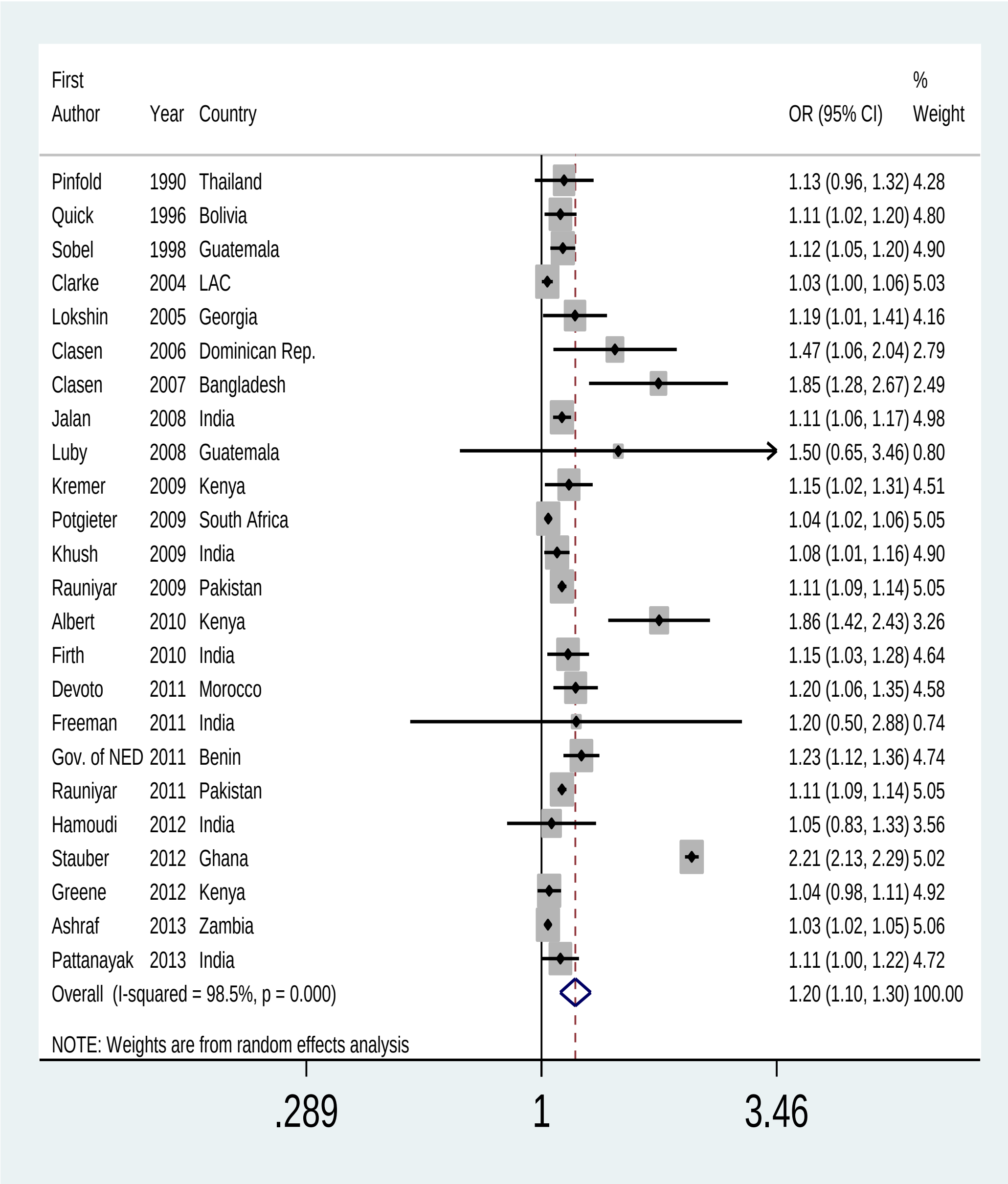
Group 2: Child Mortality, Growth, other Health Outcomes



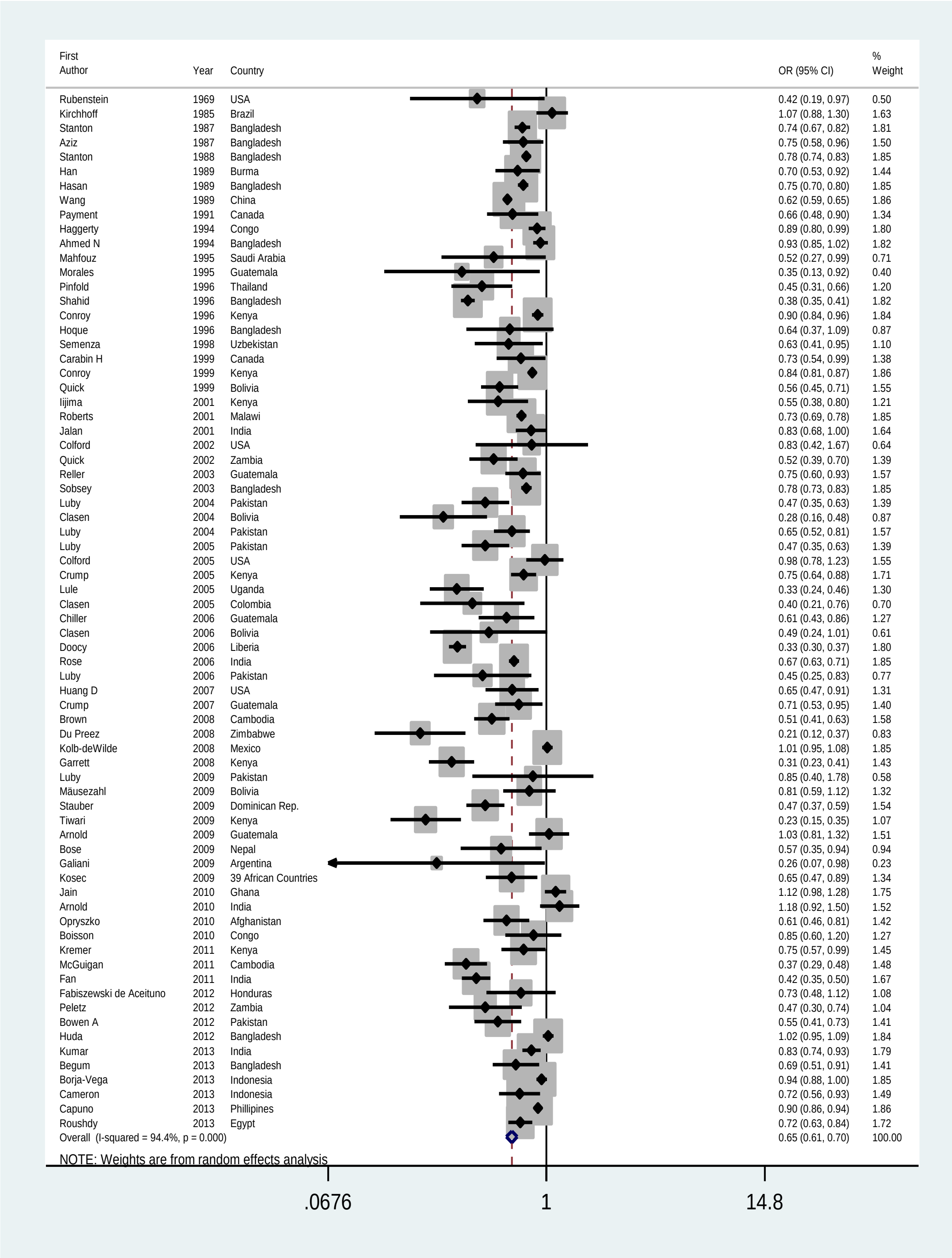
Group 3: Education/Absenteeism Outcomes



Group 4: Water Quality, Treatment, and Access



Group 5: Diarrhoea and Enteric Disease Reduction



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

2.10.2.Appendix B. List of WASH Studies Included in the Final Dataset

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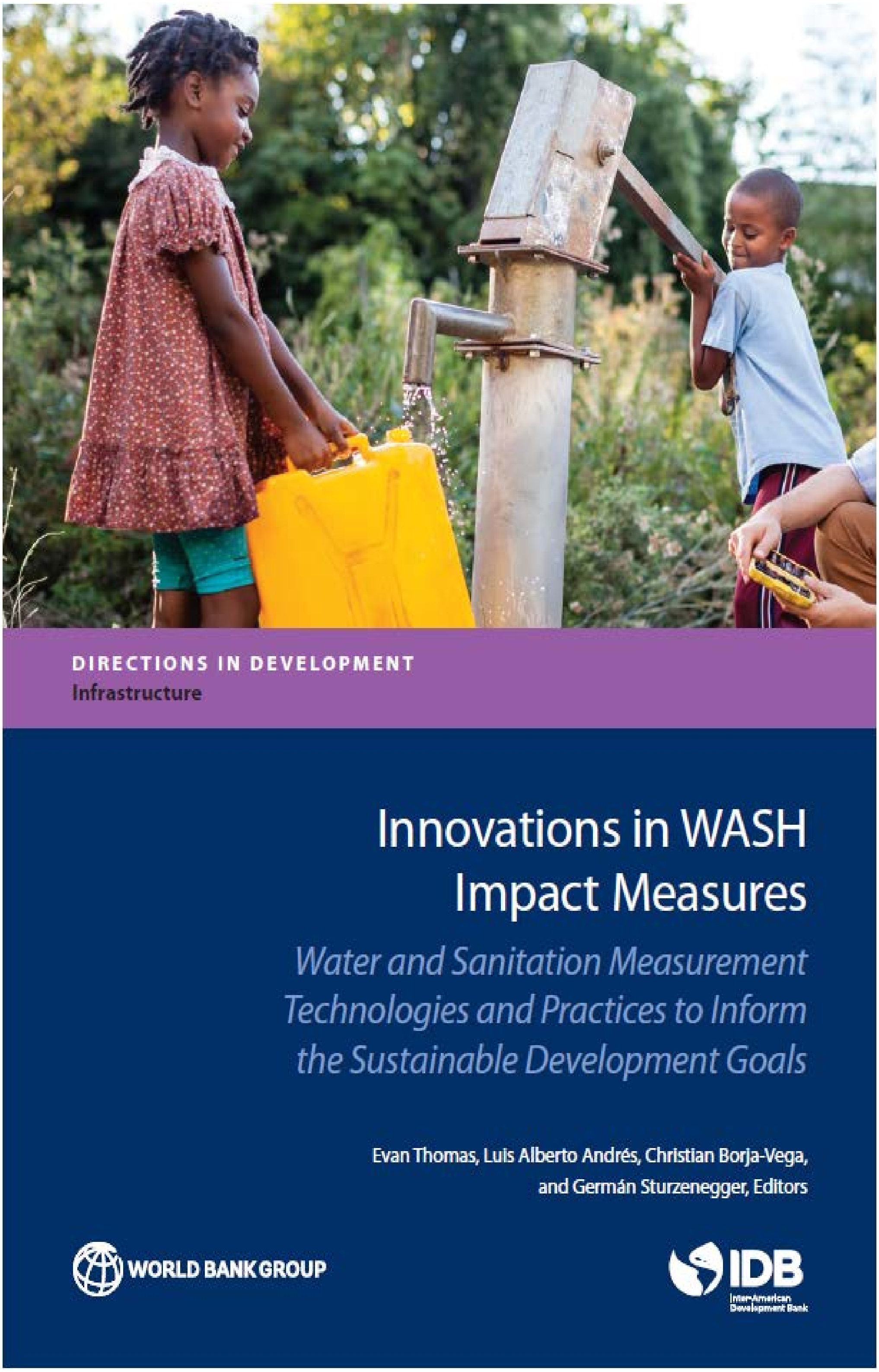
Chapter 3. Innovations in Water Supply, Sanitation and Hygiene Impact Measures

3.1. Publications and awards derived from this chapter

The references and links to the publication and publication cover are listed below:
Thomas, Evan; Andrés, Luis Alberto; Borja-Vega, Christian; Sturzenegger, Germán. 2018. Innovations in WASH Impact Measures: Water and Sanitation Measurement Technologies and Practices to Inform the Sustainable Development Goals. Book: Directions in Development—Infrastructure and Engineering. World Bank. ISBN-13: 978-1464811975 https://openknowledge.worldbank.org/handle/10986/29099
Link to download (free publication)[17]:
https://openknowledge.worldbank.org/bitstream/handle/10986/29099/9781464811975.pdf?sequence=4&isAllowed=y
This book has been downloaded almost 5,000 times from the World Bank website only. Other outlets are promoting this book, for example the following sanitary and municipal services engineering and development studies libraries:
https://www.lovereading.co.uk/book/9781464811975/isbn/Innovations-in-WASH-impact-measures-water-and-sanitation-measurement-technologies-and-practices-to-inform-the-sustainable-development-goals-by-World-Bank.html
https://www.colorado.edu/center/mortenson/innovations-in-WASH

[17] Also another paper published in the journal Water. See: https://www.mdpi.com/2073-4441/10/6/756

Cover of Publication



3.2. Cover Sheet: Relevance for Thesis

This chapter contains edited relevant highlights of work that has also been presented in (Thomas, Evan; Andrés, Luis Alberto; Borja-Vega, Christian; Sturzenegger, Germán. 2018. Innovations in WASH Impact Measures: Water and Sanitation Measurement Technologies and Practices to Inform the Sustainable Development Goals. Book: Directions in Development—Infrastructure and Engineering. World Bank. ISBN-13: 978-1464811975) which was published in the prestigious Directions for Development Series of the World Bank. This publication corresponds to a Book published in 2017 which compiles innovative methods, approaches and technologies to measure Water Supply, Sanitation and Hygiene Impact Measures.

The research on impact evaluation methods was an integral part of this PhD as a core element is the design and interpretation of results from a large-scale randomised controlled trial (RCT) in Nicaragua—that evaluates the impacts of a rural water training program. In order to prepare for the RCT I participated in a global review of WASH impact measurement. My role was to act as the primary editor of the results of this review.

Significant contributions were also made by Evan Thomas, PhD, Associate Professor and Director, Mortenson Center in Global Engineering University of Colorado Boulder (Lead Editor); Luis Alberto Andres, PhD, Lead Economist (co-Editor), and German Sturzenegger, Senior Water and Sanitation Specialist, The Inter-American Development Bank (co-editor). The book includes chapter contributions from Christina Barstow (University of Colorado at Boulder), Kwasi Boateng (Portland State University), Thomas Clasen (Emory University), Katie Fankhauser (Oregon Health and Science University), Libbet Loughnan (World Bank), Tom Slaymaker (United Nations Children's Fund/World Health Organization Joint Monitoring Programme), and Nick Turman-Bryant (Portland State University). The chapters included in this Thesis are those extracted from, the Book considered most relevant to the data collection of indicators for WASH impact's measurement, particularly given the relevance of collecting WASH indicators for the impact evaluation study. Other chapters less relevant in the Book are not included in the Thesis.

The Book contributes to a vacuum in the literature with regards to reviewing globally innovative options for measuring WASH impacts, from design, to implementation and completion of impact evaluation studies. This Book contains Chapters covering the following themes: Chapter 1 (Introduction of WASH monitoring indicators), Chapter 2 (Water Quality), Chapter 5 (Sensing WASH, in-situ and Remote Sensing)[18], Chapter 6 (Mobile, Cloud, Big Data for Measuring Progress in WASH). My contribution to this research publication consisted on a) initial review; b) outline; c) production of tables; as well final writing inputs throughout the paper, and c) conclusions and overall edits to the document. Christian Borja-Vega contributed to the edit of this compilation, considered, hence, a co-editor.

Only the Introduction, Chapter 1 and 5 of the Book are included as Chapters of this Thesis. The attribution of authorship of all chapters in the Book are the following:

- Introduction: The introduction was drafted by the co-editors of the Book (including the author of the Thesis) and highlighted the three core areas on the need to innovate on how WASH measures and impacts are measured, collected and efficiently reported. The core areas included identifying the challenges, the opportunities and the road ahead for these innovations for WASH impact measures.
- Chapter 1. Tom Slaymaker contributed to the section "Proposed WASH indicators for SDGs". This chapter outlined the guiding principles of most important and available indicators to monitor SDGs related to water and sanitation. If further developed a set of criteria and data sources to obtain a short list of measurements and indicators to build a monitoring framework for SDG monitoring. The introductory section of the chapter "A review of WASH monitoring indicators" (section 3.4. of this Thesis) was authored by all editors of the Book (including the author of this Thesis)1. The rest of the sub-sections (3.4.1.1; 3.4.1.2; and 3.4.1.3) were authored by Tom Slaymaker and are included in the Thesis due to the relevance for identifying the methodologies for household's indicators for WASH impact measurements. Section 3.4.2 was elaborated by Thomas Clasen and is included in the Thesis due to its relevance of identifying means of comprehensively assessing progress of sanitation indicators given the health impacts they produce.

[18] In fact, Chapter 5 was then published in the Water Journal. I was one of the co-authors of the study. The study is referenced as: *Andres, L., Kwasi, B., Borja-Vega, C. and Thomas, E. (2018) A Review of In-Situ and Remote Sensing Technologies to Monitor Water and Sanitation Interventions. Water. 10(6) 756.*

- Chapter 2 in the Book was titled “Water Quality Monitoring” authored by Christina Barstow. This chapter was not included in the Thesis.
- Chapter 3 in the Book was titled “Sanitation and Hygiene Monitoring” authored by Nick Turman-Bryant. This chapter was not included in the Thesis.
- Chapter 4 in the Book was titled “Behavioural Monitoring” authored by Katie Fankhauser. This chapter was not included in the Thesis.
- Section 3.5 of this Thesis (Chapter 5 in the Book) is based on the original work that the co-editors and me wrote jointly, which then was recrafted for publication in the Water Journal. The reference of the paper is as follows: *Andres, L.; Boateng, K.; Borja-Vega, C.; Thomas, E. A Review of In-Situ and Remote Sensing Technologies to Monitor Water and Sanitation Interventions. Water 2018, 10, 756*.
- Chapter 6 in the Book was titled “Mobile, Cloud, and Big Data for Measuring Progress in WASH” authored by Kwasi Boateng and Christian Barstow. This chapter was not included in the Thesis.

The material included in the Book was vast and contributed to improve the data collection process of the endline survey of the impact evaluation (Chapter 7). The Book highlighted throughout its chapters, some technological options that to be utilized for collecting and monitoring WASH information, in efficient and cost-effective manners. The use of technology reduces the costs of capturing, coding and processing, which allowed collecting data in the field in Nicaragua under a tight budget. At baseline, a paper-based surveys were collected in around 45 to 55 minutes which increased costs of quality assurance and proper coding. For the endline survey the average time of collecting the same baseline modules was 18 minutes. The Book served as a guidance to inform about the available options to ensure that enumerators use cellular applications to upload in real time the information captured from survey respondents. In particular, the Book provided useful information and guidance on the adequately reporting using cell phone surveys, which further helped in the design on a series of training workshops to enumerators based on: i) strengthen interviewing capacities; ii) the use of new technologies for capturing and uploading different modules, including water quality; and, iii) identify the best solutions to issues of data capturing.

In spite of i) the involvement of the author of the Thesis in developing and editing the Book, ii) the chapters of the Book that contributed to the impact evaluation presented in this Thesis, and iii) the value added that certain chapters of the Book brought to data collection and water quality tests, the following sections present extracts from the Book.

3.3. Introduction: The challenge

The United Nations Sustainable Development Goals (SDGs) were announced with fanfare in September 2015. Updating the Millennium Development Goals (MDGs), the 17 SDGs promise to deliver an ambitious range of global impacts, including "End poverty in all its forms everywhere"; "Ensure access to affordable, reliable, sustainable and modern energy for all"; and "Revitalize the global partnership for sustainable development."[19]

The new 2030 Agenda includes water, sanitation, and hygiene (WASH) at its core, with SDG 6 dedicating a commitment to "Ensure availability and sustainable management of water and sanitation for all." Monitoring progress toward this goal will be challenging because direct measures of water and sanitation service quality and use are either expensive or elusive. However, a continued reliance on household surveys poses limitations that likely overstated water access during the MDG period.

3.3.1.The opportunity

Emergent technologies, methods, and data-sharing platforms are increasingly aligned with impact monitoring. Improved monitoring of water and sanitation interventions may allow more cost-effective and measurable results. In many cases, technologies and methods allow more complete and impartial data in time to allow program improvements. In this chapter (book), we review the landscape of technologies, methods, and approaches that can support and improve on the water and sanitation indicators proposed for SDG targets 6.1, "by 2030, achieve universal and equitable access to safe and affordable drinking water for all," and 6.2, "by 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations." In some cases, technologies and methods are validated and readily

[19] For the complete list of Sustainable Development Goals, see the United Nations SDG website, http://www.un.org/sustainabledevelopment/sustainable-development -goals/.

available. In other cases, emergent technologies and approaches hold promise but require further field evaluation and cost reductions.

The World Health Organization and United Nations Children's Fund Joint Monitoring Programme (JMP) for Water and Sanitation has developed proposed indicators for measuring progress toward SDG targets 6.1 and 6.2. In chapter 1, authors with the JMP review the rationale for a continued primary reliance on household surveys and censuses because these data sources are readily available from national statistical offices. However, the JMP has also proposed progressively integrating other data sources, when available, including water quality testing, in situ instrumentation, and Earth observations. Notably, the JMP has proposed a "service ladder" monitoring approach, acknowledging the progressive and nonbinary nature of increased access to safe water and sanitation. The highest rung on the ladder for SDG target 6.1, "universal and equitable access to safe and affordable drinking water for all," focuses on "safely managed drinking water" as measured, when feasible, through direct water quality testing, while lower rungs measure access to "improved" drinking water sources, similar to the approach used in the MDG period. Similarly, hygiene monitoring qualifies "handwashing at home" as the highest service ladder rung, and lower levels examine extra-household services, such as handwashing in schools and health care facilities.

The data and insights gained from these improved monitoring approaches are effective only when leveraged toward improved service delivery in the broader

context of maximizing public health. The integration of service ladders and consideration of direct service quality and delivery measures are important steps toward credible and actionable data collection. Building on the JMP's indicator review, in chapter 1 of the book (in this Thesis will be sequenced in the same chapter 3) epidemiologists advance the consideration of health impact as a primary driver for water and sanitation monitoring. Reviewing the monitoring approaches used in the MDG period, this chapter highlights the significant gap between "improved" water and sanitation and impacts on health. Constructively, additional measures are proposed including measures of quantity, quality, and sustained access to safe drinking water, including direct and repeated water quality testing, and direct measures of sanitation system integrity and individual use.

Fully reconciling the benefits of measurement quality and integrity provided by direct and repeated or continuous measures of water quality, use, and service delivery with the scalability and cost-effectiveness of household surveys is beyond the scope of this report. However, we advance this discussion through the curation of available and emerging technologies, methods, and systems that may enable cost-effective and reliable water and sanitation monitoring. In chapter 2, we review water quality monitoring standards applicable to SDG 6 and the JMP's proposed water quality approach, and present methods and technologies for monitoring household and community-level microbial and physiochemical contamination. Typically, the most important water quality measures are in most cases microbial contamination, whereas other contamination may be relevant on a regional or local basis. Moving beyond the simple classification of a source as improved or unimproved, testing of actual water quality parameters will provide a better measurement of the exposure of users to harmful waterborne constituents. However, testing water at the source provides only a snapshot of water quality at the point of collection and is not representative of the actual water consumed, which may have been contaminated between the source and the point of consumption or at storage. As such, chapter 2 of the book (in this Thesis will be sequenced as a subsection of chapter 3) recommends measuring samples that come from a container from which household members drink. An array of methods exists for both laboratory and field-based measurement, all of which have their advantages and limitations. However, with any method, proper quality control and quality assurance guidelines should be adhered to when at all possible. When larger or more systematic testing is being undertaken, working with local authorities such as the ministry of health or local environmental protection agency may be appropriate.

Sanitation and hygiene quality measures are, presently, more challenging to measure than water quality. In chapter 3 (in this Thesis will be sequenced as a subsection of chapter 3), we review the myriad forms of sanitation and hygiene interventions, and the most relevant measurement characteristics including access, safety, and proper use. An inherent challenge in monitoring sanitation programs is the diversity of behaviours and facilities. Sanitation behaviours encompass defecation, urination, anal cleansing, deposition of children's faeces, deposition of cleansing products, separation of solid and liquid waste, faecal sludge management, handwashing, adherence to sanitation facility use, and menstrual hygiene. Different sanitation facilities separate excreta from human contact with varying degrees of efficacy (for example, open defecation versus a flush toilet connected to a sewer system). Finally, there are additional factors that can influence the level of contamination in a sanitation facility, including latrine cleanliness, whether the latrine is shared or private, and the degree to which all members of a household can access the latrine. These layers of behaviour, facility type, and facility characteristics interact dynamically and change in time, making it difficult to determine which sanitation features are most important for reducing human exposure to pathogens. Given this complexity, it is important to identify the sanitation outcomes that minimize exposure to pathogens before exploring the best practices and technologies for monitoring those outcomes. Chapter 3 identifies outcomes that are explicitly or implicitly identified in the SDG target on sanitation and hygiene and the extent to which those outcomes are represented in the proposed service ladders. A variety of innovative practices and technologies are described with specific attention given to their abilities to accurately measure and monitor progress on each outcome.

In chapter 4 of the book (in this Thesis will be sequenced as a subsection of chapter 3), we describe some limitations of, and alternatives to, traditional measurement methods for measuring water and sanitation use and behaviour. Measurement of adoption and compliance with water and sanitation interventions, such as latrines, water pumps, and water filters, has often relied on surveys and observations. However, surveys and other common methods for assessing behavioural practices are known to have certain methodological shortcomings, including poor correlation between observations and self-reported recall. Survey results can also be affected by errors of interpretation on the part of the informant. or the enumerator. Data missing because of participant absences or failure to follow up is another source of systematic bias. Additionally, it is known that the act of surveying or observation can itself impact later behaviour, a phenomenon known as reactivity or the Hawthorne effect. Structured observation, an alternative to relying on reported behaviour in response to surveys, has also been shown to cause reactivity in the target population. Finally, the subjectivity of the outcome studied can strongly influence reporting bias. In chapter 4 of the book, we highlight these challenges while proposing direct and indirect measures of behaviour and use that can better estimate progress toward SDG 6. Emergent technologies, including water meters, water pump sensors, and latrine motion detectors can improve the objectivity and continuity of data collection. Satellite-based remote sensing and sensors linked to the Internet of Things can be aligned with smartphone-based surveys and online “big data” tools. These technologies and services are reviewed in chapters 5 and 6, and may offer improvements in the collection of, and action on, data from water and sanitation programs. The term “remote sensing” usually describes the collection of data by satellites. In most cases, “remote” refers to spectral imagery collected by cameras and other spectral instruments across a broad range of wavelengths. In the case of Earth observation, satellites take spectral data reflected from the atmosphere and the Earth’s surface. Interpretation of these data (often represented as imagery) requires an understanding of spectral data and physical properties of the Earth and its atmosphere. Interpretation often also requires calibration against data collected on the Earth’s surface or in the atmosphere directly—data from sensors that are in situ rather than remote.

In situ instrumentation technologies vary from flow meters and water quality sensors to motion detectors installed in latrines. These sensor technologies can be used either operationally or within a statistical sampling frame. Data can be logged locally for manual retrieval or transmitted over short range to nearby enumerators, or to remote operators and researchers over Wi-Fi, cellular, and satellite networks. Some instrumentation is in common use, while other technologies are emerging. However, given the remote and power-constrained environments and the high degree of variability between fixed infrastructure—including age, materials, quality, servicing, and functionality—any electronic sensor–based solution often either is custom engineered or compensates for these complexities through analytics. For example, a conventional flow meter designed for a rural borehole water distribution scheme would have to address pipe diameter, material, pressure, depth, thread type, and other characteristics that require custom engineering and plumbing, whereas a nonintrusive ultrasonic flow meter may be more easily adapted for a variety of water schemes.

Cellular phone–based data collection with online analytics and dissemination is a rapidly growing field for water and sanitation programs. The field of mobile surveys provides a user-friendly platform to easily collect data using a mobile platform rather than a paper-based survey. The mobile platform additionally allows for Global Positioning System (GPS) coordinates, barcode scanning, and photos to be easily associated with a particular sample. The ability to look at photos and confirm GPS coordinates creates both ease of data analysis and surveyor accountability. In chapter 6, a number of electronic data collection and dissemination tools used in WASH programs are reviewed.

3.3.2.Looking forward

Each of these myriad monitoring and evaluation methods has its own advantages and limitations. It is often beneficial to leverage more than one method to get a fuller picture of water and sanitation service delivery and adoption behaviour. Combined methodologies reinforce the advantages, while also addressing the limitations, of the individual monitoring techniques that compose them. Surveys, ethnographies, and direct observation give context to electronic sensor readings that may be more continuous and objective. Overall, combined methodologies can provide a more comprehensive and instructive depiction of WASH usage.

Some of the technologies and methods presented in this chapter are well established, whereas others hold promise but require extensive field-testing and validation commercialization, and scaling. Because applications vary widely, we have not attempted to directly compare costs between methods and technologies.

Likewise, it is beyond the scope of our report to compare the relative value or reliability of different methods. Instead, we present a menu of options for policy makers, program implementers, and auditors to consider when designing impact measurement efforts.

3.4. A review of WASH monitoring indicators

During the Millennium Development Goal (MDG) period, international monitoring of water, sanitation, and hygiene (WASH) services in developing countries relied predominantly on household surveys identifying access to “improved” and “unimproved” services. However, these indicators fell short of the key health-based conditions that the MDG water and sanitation targets sought to encourage. Overly simplistic metrics used to monitor progress on important health and development goals can be misleading—monitoring that relies on poor indicators can exaggerate progress. Additionally, inadequate assessments of environmental health interventions can undermine the proper allocation of scarce resources for advancing intended goals. The beginning of the Sustainable Development Goal (SDG) period offers an opportunity to learn from these limitations to better align indicators and measures with intended outcomes. In this chapter, the current indicators proposed by the World Health Organization/United Nations Children's Fund (WHO/UNICEF) Joint Monitoring Programme (JMP) for Water and Sanitation are reviewed, followed by a summary of limitations during the MDG period, which can inform improved SDG monitoring. These new indicators address in part the MDG limitations while balancing the likely availability of robust data sources. In subsequent chapters, technologies and methods are reviewed that meet and may exceed these indicator data requirements.

3.4.1.Detailed Methodology: Safely Managed Drinking Water Services

The proposed indicator of "safely managed drinking water services" comprises four elements:

1. Improved drinking water source that is
2. Located on premises,
3. Available when needed, and
4. Compliant with faecal (and priority chemical) standards

The first three of these can be measured through integrated household surveys, and data collection will be similar to that for the "improved drinking water" indicator used for MDG monitoring. Data for these elements are immediately available for over 100 countries, although questions on availability are not usually explicitly asked in household surveys but implied when households identify their main source of drinking water. Household surveys can also provide information on water quality testing as direct measurement of water quality is increasingly adopted as a module in surveys. Regulatory authorities also collect information on the proportion of populations accessing different types of regulated water services, and the extent to which such services provide water that is available when needed, is located on premises, and meets quality standards.

3.4.2.Proposed Indicators and Monitoring Framework for Sanitation and Hygiene

The JMP defines "safely managed sanitation services" as population using an improved sanitation facility that is not shared with other households and where excreta are safely disposed of in situ or treated off-site (for MDG monitoring purposes, "improved" sanitation facility means flush or pour flush toilets to sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, pit latrines with a slab, and composting toilets—the same categories as improved sources of drinking water). Household surveys and censuses provide data on use of types of improved sanitation facilities listed above. The percentage of the population using safely managed sanitation services can be calculated by combining data on the proportion of the population using different types of improved sanitation facilities with estimates of the proportion of faecal waste that is safely disposed of in situ or transported to a designated place for safe disposal or treatment. Similar "safety factors" representing the proportion of waste that is safely disposed of in situ or transported to a designated place are required to estimate the proportion of wastewater that is safely treated under target 6.3. One of the main critiques of the water and sanitation targets in the MDGs is that hygiene was not considered despite its clear links with health and with other economic and social benefits. Hygiene behaviours are very distinct from sanitation and management of faecal wastes and require separate indicators. Accordingly, the JMP proposes handwashing at home with soap as a core indicator for tracking target 6.2. The JMP also proposes two supporting indicators: (i) handwashing in schools and health facilities, and (ii) menstrual hygiene management in schools and health facilities. Data on hygiene in schools and health care facilities will be collected through a combination of institutional surveys and sector management information systems. JMP recognizes also that food hygiene is important and will engage with evolving methods to measure food hygiene in the household.

3.4.3. Household Surveys within SDG Monitoring Indicators

The WASH MDG framework relied primarily on measurements collected through household surveys. As such, the institutional knowledge, efforts, and successes built and achieved under the MDG time frame remain relevant and contribute building blocks of SDG monitoring. Appendix A of this report discusses how the MDG framework will be built into the SDG monitoring. In appendix A, we first review the long-collected measurements used in MDG monitoring. Their continued collection remains fundamental for future monitoring under the SDGs. Second, we specify how other measurements collected during the MDG time frame, but not critical to MDG monitoring, now make their way formally into SDG monitoring. These first two groups of measurements can be understood to meet all eight criteria for indicator selection and data sources listed in this chapter.

Third, we outline the category of household survey–based measurements that are critical to SDG monitoring but that are only recently being rolled out for widespread collection. All these elements of SDG monitoring that come from household surveys are noted in **Table 3-1** as "can be reported immediately" or "can be reported in the short term" because the technology is fully ready and either widespread historically or being rolled out. Last, appendix A closes with a review of some main challenges and opportunities in the full rollout of these household survey components of SDG measurements.

SDG target	*Indicator*	*Definition*	*Data sources and measurability*	*Disaggregation*	*Timeline*
6.1. Safely managed water	Percentage of population using safely managed drinking water services	Population using an improved drinking water source that is located on premises, available when needed, and free of fecal (and priority chemical) contamination. Improved water sources: piped water into dwelling, yard, or plot; public taps or standpipes; boreholes or tubewells; protected dug wells, protected springs, and rainwater.	Household surveys can provide data on improved water on premises as well as availability when needed and free from contamination via direct water quality testing. Administrative sources including drinking water regulators can provide data on compliance with standards for water quality and availability.	Urban/rural Wealth Affordability Others	Elements from household surveys can be reported immediately. Safety/regulation will initially be estimated globally and regionally, and progressively at country level.
6.2. Safely managed sanitation	Percentage of population using safely managed sanitation services	Population using an improved sanitation facility that is not shared with other households and where excreta are safely disposed in situ or treated off-site. This is a dual-purpose indicator covering the domestic part of wastewater treatment of 6.3.	Household surveys can provide info on types of sanitation facilities and disposal in situ. Administrative, population, and environmental data can be used to estimate safe disposal/treatment of excreta.	Urban/rural Wealth Affordability Others	Elements from household surveys can be reported in the short term. Excreta management will initially be estimated globally and regionally, and progressively at country level.
6.2. Hand washing at home	Percentage of population with handwashing facilities with soap and water at home	Population with a handwashing facility with soap and water in the household.	Household surveys	Urban/rural Wealth Affordability Others	Immediate

Table 3-1 Target 6.1 Definition, Data Sources, and Disaggregation

Source: WHO/UNICEF 2017. (as it is published by the author of this chapter). Note: Top row is proposed Sustainable Development Goal indicator; following rows are part of global reporting "ladder" used by the Joint Monitoring Programme

3.4.4. Improving Safe Water and Sanitation Monitoring for Health Gains (by Thomas Clasen)

In early 2012, WHO and UNICEF made an important announcement: “The world has met the Millennium Development Goal (MDG) target of halving the proportion of people without sustainable access to safe drinking water, well in advance of the MDG 2015 deadline” (WHO and UNICEF 2012). Major news organizations heralded the accomplishment. The editors of The Lancet (2012) used the occasion to draw attention to underachievement of other MDG targets but still acknowledged the water announcement as “some good news to celebrate.” There was little celebrating, however, among many who work at the intersection of water and health. This is because the way progress was measured on the MDG water target—by counting those who have access to “improved water supplies”—did not fully address water quality, quantity, and sustainable access—key components of the target that are fundamental to human health. Similarly, even the stated shortfall in the sanitation goal—2.1 billion people gained access to improved sanitation since 1990, while another 2.5 billion still lack access to improved sanitation—exaggerates actual progress. This is due to a misalignment between the MDG sanitation goal and the manner in which progress toward that goal was measured under international monitoring. As monitoring programs are being developed for the new water and sanitation targets under the SDG, it is important that they actually address the key aspects of WASH interventions that optimize the potential contribution to human health, in particular reduced waterborne disease.

3.4.4.1. SDG Water Monitoring Review

Over the years, considerable efforts have been undertaken to expand the scope of international water quality monitoring in order to address the key components of quality, quantity, and sustainable access that are vital to improve health. The third edition of WHO’s Guidelines for Drinking Water Quality recommends a more comprehensive approach that addresses quality, coverage, quantity, continuity, and cost (WHO 1997). A health-based approach using water service levels was proposed in 2003, and a human-rights–based approach was adopted in 2008 (Kayser et al. 2013). There is increasing recognition of the need for a more comprehensive “service quality” or “service ladder” approach, as proposed by the JMP, that accounts for the different levels of service provided by various drinking water and sanitation facilities, and their associated benefits (Bartram et al. 2014). Bartram and colleagues argue that, at a minimum, this system should distinguish piped, household connections from other types of improved water supplies. They also recommend that water source functionality and reliability should be part of the analysis. Finally, for households without access to reliable household-level piped supplies, they recommend some measure of the safety of household drinking water storage methods, but it is not clear if this would constitute some type of water safety plan compliance or actual testing of water quality. Also unclear is whether this ladder would somehow incorporate measures of water quantity or actual use. Perhaps more important to comprehensive water quality monitoring, however, are the indicators for the SDG 6 targets. A recent review has described the use of a large variety of indicators to assess water source/technology type (including whether categorized as “improved,” “unimproved,” community source, or on-plot water); accessibility; water safety (quality and sanitary risk); water quantity, reliability, or continuity; affordability; and equity (Kayser et al. 2013). Although the review explored the potential for combining these indicators into a comprehensive framework, it concluded that the scientific basis for doing so was still lacking and that further research was necessary.

3.4.4.2.SDG Sanitation Monitoring Review

WHO and UNICEF have published indicators for the SDG sanitation target that address many limitations of the MDG targets. A significant improvement over the MDGs is the inclusion of the complete sanitation system chain. The new targets include the three main aspects of the MDGs—system integrity, coverage, and use—and also incorporate all services and infrastructures from the point of excretion to end treatment/disposal under the monitoring agenda, which will be a major challenge in determining indicators for assessment. By including “for all,” the target mandates that, for sanitation systems and services to be included under the definition of “improved” sanitation, they must be available at all times to all people, no matter age, gender, disability status, or income level. Incorporation of child faeces disposal into the definition of open defecation requires that all faeces, from both child and adult no matter the age, be disposed of in a safe and hygienic manner, whether in an improved sanitation facility or in a treatment system. Last, the addition of special attention to women, girls, and those in “vulnerable populations” requires that additional measures be met to provide for the sanitation needs of women and girls with regard to water collection and special sanitation requirements, as well as to ensure that all people in "refugee camps, detention centres, mass gatherings, and pilgrimages" have adequate sanitation.

Although the SDG sanitation target and its expanded interpretation address the major factors that are necessary to advance health, the SDG indicators fall short in creating a means of directly and comprehensively assessing progress toward the target (WHO/UNICEF 2015b). Under the current proposal, "basic sanitation" will be measured using a binary definition of improved/unimproved sanitation facility (WHO/UNICEF 2015b). WHO and UNICEF define open defecation as the "percentage of population that practices open defecation." In relation to "sustainable," the indicator is proposed as the "percentage of population using a safely-managed sanitation facility that reliably provides expected levels of service and is subject to robust regulation and a verified risk management plan." Inequality will also be assessed by disaggregating the data on the basis of various factors, including urban/rural location, wealth quintiles, subnational regions, informal settlements, sex, age, or disability status (WHO/UNICEF 2015b). Last, the JMP will partner with Global Expanded Monitoring Initiative, a global monitoring program, to measure indicators for target 6.2. "Safely managed" sanitation will be measured as the "percentage of population using a basic sanitation facility where excreta are safely disposed *in situ* or safely transported and treated off-site" (WHO/UNICEF 2015b).

Sanitation coverage and use will be measured only at the household level, providing no conclusion on community, neighbourhood, or city-level access and use. The negative impacts of incomplete sanitation coverage at the community level have been seen in field studies and systematic reviews (Moraes, Cancio, and Cairncross 2004; Barreto et al. 2007; Geruso and Spears 2015). A study of citywide sanitation improvements in Salvador, Brazil, saw overall reductions in the prevalence of diarrhoea by 21 percent; in high-risk areas with high baseline. prevalence, the reduction was 43 percent (Barreto et al. 2007). Use will once again be assessed in response to household surveys that ask respondents which type of facility, they "usually use," presenting the same problems discussed above with respect to the MDGs. One clear advance of the proposed indicators is the focus on faecal sludge management. The indicator defines "safely managed sanitation" as systems whose faecal waste is transported through a sewer to a designated location, is collected from systems by a process that limits human contact and is transported to a designated location, or undergoes at minimum secondary treatment or “primary treatment with long ocean outfall for sewerage” or is treated at a “managed disposal site” or wastewater treatment plant or “stored on site until…safe to handle and re-use” (WHO/UNICEF 2015b). This indicator is designed to encompass essential services and operational requirements for public health benefits (Feachem et al. 1983; Shuval 2003; Escamilla et al. 2013). At the same time, the indicator does not evaluate the integrity of the system or services, nor is there consideration of sustainability.

3.4.5. References

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3.5. Sensing WASH—In Situ and Remote Sensing Technologies[20]

3.5.1.Introduction

The resilience of water and sanitation services is dependent upon credible and continuous indicators of reliability, leveraged by funding agencies to incentivize performance among service providers. In many countries, these service providers are utilities providing access to clean water and safe sanitation. However, in emerging economies, there often remains a significant gap between the intent of service providers and the impacts delivered over time.

Remote monitoring, via satellite assets and in situ sensors, may offer some contribution to addressing some of the challenges of information asymmetry and data gaps in developing communities including unreliable survey data and relying on spot

[20] This chapter then resulted in a publication in the Journal Water, where I coauthored the study. The link for this study is available at: https://doi.org/10.3390/w10060756

checks to assess performance. Data can be used to understand programmatic, social, economic, and seasonal changes that may influence the quality of a program. Additionally, behavioural patterns of the user can be studied to better understand how and when the water and sanitation technologies are being used. In this chapter we review the use of remote sensing and local sensors for water, sanitation, and hygiene (WASH) monitoring.

The term remote sensing usually describes the collection of data by satellites. In most cases, the “remote” refers to spectral imagery collected by cameras and other spectral instruments across a broad range of wavelengths. In the case of Earth observation, satellites take spectral data reflecting from the atmosphere and the Earth’s surface. Interpretation of this data (often represented as imagery) requires an understanding of spectral data and physical properties of the Earth and atmosphere. It also often requires calibration against data collected on the Earth’s surface or in the atmosphere directly—data from sensors that are in situ, rather than remote.

In situ instrumentation technologies vary from flow meters and water quality sensors to motion detectors installed in latrines. These sensor technologies can be used operationally or within a statistical sampling frame. Data can be logged locally for manual retrieval or transmitted over short range to nearby enumerators, or to remote operators and researchers over Wi-Fi, cellular, satellite, and other wireless networks. Some instrumentation is in common use, whereas other technologies are emerging. However, given the remote and power constrained environments and the high degree of variability between fixed infrastructure including age, materials, quality, servicing, and functionality, any electronic sensor–based solution often either is custom engineering or compensates for these complexities through analytics. For example, a conventional flow meter designed for a rural borehole water distribution scheme would have to address pipe diameter, material, pressure, depth, thread type, and other characteristics that require custom engineering and plumbing. Instead, a nonintrusive ultrasonic flow meter may be more easily adapted for a variety of water schemes.

3.5.2.Satellite remote sensing

Remote sensing capabilities and techniques are well suited for monitoring regional-scale precipitation, water budgets, soil moisture, and some measures of water quality.

A recent World Bank report summarized the water resource management applications of remote sensing:

> *Remote sensing plays an increasingly important role in providing the information needed to confront key water challenges. In poorly gauged basins, at time intervals of several days, real-time satellite estimates of precipitation and derived streamflow forecasts can help managers to allocate water among users and to operate reservoirs more efficiently. In large rivers, data on river and lake surface elevation can be used to estimate flow in the upper parts of the basin and to predict flow downstream. Soil moisture observations may give insight into how much irrigation is needed, as well as help to forecast and monitor drought conditions. Water managers in snow-dominated areas can use estimates of snow cover and snow water equivalent to assess how much water is in storage and determine what watersheds it is stored in. Remote sensing also enables the monitoring of many parameters of surface water quality to assess the repercussions of river basin management policies, land use practices, and nonpoint source pollution as well as the likelihood of algal blooms and other threats to the quality of water supply systems. (Garcia et al. 2016)*

A variety of satellite data products have been leveraged to aid water and sanitation programs. Key examples include the following:

- The Landsat program of the National Aeronautics and Space Administration (NASA) and the U.S. Geological Survey was launched in 1972 and was the first Earth observation satellite designed for public use. Landsat 8, launched in 2013, has two primary instruments, the Operational Land Imager (visible, near infrared [IR] and shortwave IR) and the Thermal Infrared Sensor (TIRS). Landsat 8 covers every point on Earth every 16 days and has a resolution of 15–100 meters. TIRS was added to the Landsat 8 mission "when it became clear that state water resource managers rely on the highly accurate measurements of Earth's thermal energy obtained by LDCM's [Landsat Data Continuity Mission] predecessors, Landsat 5 and Landsat 7, to track how land and water are being used."[21]

[21] Taken from the NASA website. For more information, visit https://landsat.gsfc.nasa.gov/thermal-infrared-sensor-tirs/

- In particular, Landsat 8 data allows the calculation of the Normalized Differential Vegetation Index (NDVI). Landsat 8 NDVI allows an estimation of land surface emissivity (Sobrino, Jiménez-Muñoz, and Paolini 2004) and land cover classification (Weng, Lu, and Schubring 2004) as well as surface temperature. Remote sensing experts can use these measures for planning-level estimation of watershed health across a broad region. Additionally, land use classification can identify rural versus urban built environment and population density.
- SERVIR, a cooperative initiative of NASA and the U.S. Agency for International Development (USAID), "works in partnership with leading regional organizations world-wide to help developing countries use information provided by Earth observing satellites and geospatial technologies for managing climate risks and land use."[22] With three regional offices, SERVIR has been able to partner with remote sensing experts and national decision-making bodies. Among other activities, SERVIR focuses on monitoring bodies of water to observe effects from "human activities, climate change, and other environmental phenomena." SERVIR takes advantage of Landsat, ASTER, MODIS (Moderate Resolution Imaging Spectroradiometer), and other satellite assets to monitor water quality and changes. Specifically, SERVIR is developing rainfall and runoff models to study the availably and quality of surface water over the next several decades.
- Using Tropic Rainfall Measuring Mission data, the Nile Basin Initiative in partnership with NASA provides flood forecasts and water balance estimates for the Eastern Nile basin. Similarly, the Land Surface Hydrology Group at Princeton University developed the Africa Drought Monitor and provides maps of rainfall, temperature, and other hydrologic variables (Garcia et al. 2016).
- The USAID Famine Early Warning System Network (FEWS NET) monitors rainfall and crop production with satellite assets and combines these data with socioeconomic insights to identify population groups that may be vulnerable to food insecurity[23].

[22] Taken from the SERVIR Global website. For more information, visit https://www.servirglobal.net

[23] 3. More information is available from the FEWS NET website, http://www.fews.net/content/using-crowdsourcing-map-displacement-south-sudan

- NASA's Terra satellite includes two instruments that have been leveraged for watershed monitoring. MODIS and the Multiangle Imaging Spectroradiometer satellite assets can be used to determine aerosol optical depth, land surface temperature, enhanced vegetation index, and middle IR reflectance. Some of these data can be used to assess water quality parameters including chlorophyll, cyanobacterial pigments, coloured dissolved organic matter, and suspended matter on a large water body scale (Garcia et al. 2016).
- In Nigeria, the World Bank recently used geographic information system mapping techniques to compare household survey data against MODIS land use estimates to generate spatial distribution estimates of water and sanitation indicators, including water and sanitation service access (World Bank 2017).
- The Inter-American Development Bank (IDB) developed the Hydro-BID platform to assist countries in Latin America and the Caribbean with water management through the mapping and tracking of over 230,000 water catchment areas. The Hydro-BID platform is leveraged by government agencies and water utilities for regional water management and infrastructure planning[24].

3.5.3 Handwashing Monitoring

Sensors can also provide an objective and nonobtrusive characterization of handwashing behaviour:

- SmartSoap, developed by Unilever, is an ordinary looking bar of soap with an embedded accelerometer that measures motion on three axes, allowing the detection of use. On its own, SmartSoap can provide an accurate count of the number of times the soap bar is used each day. By combining SmartSoap data with data from a motion sensor placed on the vessel holding water for anal cleansing, researchers were able to detect handwashing events after defecation. Although overall soap use increased, they found that there was no increase in the number of soap use following defecation (Ram 2010).
- Similarly, Mercy Corps used motion detector–based latrine sensors combined with water flow sensors to monitor the prevalence of handwashing after latrine use. They found that water use after latrine use was very low (less than 10

[24] More information on the Hydro-BID simulation tool is available http://hydrobidlac.org.

percent) in all but one district, which registered almost 40 percent use of water after latrine use. They also found that self-reported use of the latrine and handwashing after using the latrine was much greater (up to 4 times and 25 times, respectively) than the latrine use and handwashing after latrine use detected by the sensors (Thomas and Mattson 2013).

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Chapter 4. Sustainability of rural water systems: quantitative analysis of Nicaragua's monitoring data[25]

4.1. Publications and awards derived from this chapter

The reference to this publication is as follows: *Borja-Vega, C., Pena, L., & Stip, C. (2017). Sustainability of rural water systems: quantitative analysis of Nicaragua's monitoring data. Waterlines, 36(1), 40-70. http://dx.doi.org/10.3362/1756-3488.2017.003*. This research has been referenced on more than 10 important publications, such as *R. Cronk, J. Bartram. 2018. Identifying opportunities to improve piped water continuity and water system monitoring in Honduras, Nicaragua, and Panama: Evidence from Bayesian networks and regression analysis. Journal of Cleaner Production 196, pp. 1-10. doi.org/10.1016/j.jclepro.2018.06.017*

Cover of publication: https://doi.org/10.3362/1756-3488.2017.003

[25] Note: This paper was published to complement the research agenda exposed in chapters 1, 2 and 3 of this thesis. Moreover, the determinants explored for Rural Water Sustainability in Nicaragua contributed to also understand, at baseline, what sort of impacts would be identified through the impact evaluation study presented in the chapters 5, 6 and 7 of this thesis. The sections of this paper as published are presented, except for the supplement material which is available in the publication's website: https://doi.org/10.3362/1756-3488.2017.003

Sustainability of rural water systems: quantitative analysis of Nicaragua's monitoring data

CHRISTIAN BORJA-VEGA, LILIAN PENA, and CLEMENTINE STIP

The sustainability of rural water supply services (WSS) remains one of the core challenges of the rural water sector in Nicaragua. The data available through the Central American Rural Water and Sanitation Information System in Nicaragua (SIASAR, in Spanish) is utilized to investigate the factors that drive the sustained functionality and quality of rural WSS systems over time. This report uses data from 6,863 communities, 4,792 water systems, 2,585 service providers, and 154 technical assistance (TA) providers contained in the SIASAR dataset. Statistical and econometric analysis provide evidence to support the hypothesis – widespread among rural WSS practitioners – that 'soft' measures in the provision of WSS are effective in fostering sustainability or 'functionality' of those systems. Such 'soft' measures include management capacity building of WSS community boards in charge of WSS oversight; demand-responsive approaches for developing, operating, managing, maintaining, rural water infrastructure; cost recovery mechanisms; community participation in the management of WSS systems; and the sustained provision of post-construction TA by local authorities. These measures are found as important determinants of the sustainability of WSS and its investments, and therefore are recommended to be included and institutionalized in rural WSS sector development policies.

Keywords: rural water, sustainability, functionality, monitoring, evaluation

DESPITE IMPRESSIVE GAINS IN WATER and sanitation coverage globally in the past couple of decades, this trend has been eclipsed by growing evidence pointing towards a marked decline in functionality and sustained service of water and sanitation schemes (Boulenouar et al., 2013). With average non-functionality rates between 30 and 40 per cent in developing countries, and as high as 67 per cent for hand-pumps

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The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the view of the World Bank, its Executive Directors, or the countries they represent. The findings, interpretations, and any remaining errors in this paper are entirely those of the authors. We would like to thank Julie Biau, Sophie Ayling, and Diana Hinova for initial inputs and research assistantship of this paper.

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4.2. Cover Sheet: Relevance for Thesis

This chapter was essential to identify those factor that play a role in explaining changes in rural water systems sustainability and functionality in Nicaragua. The impact evaluation study was also focused on Nicaragua, so this published material contributed in narrowing down the types of management, technical, institutional and governance factors critical for delivering these basic services in rural areas. I contributed as a lead author of this published paper, where my core research functions consisted on a) Literature review; b) outline; c) production of graphs, tables, estimates; as well final writing inputs throughout the paper, and c) conclusions and overall edits to the document. The analysis was done with the Rural Water Supply and Sanitation Monitoring data of Nicaragua (SIASAR) which is publicly available and helped in identifying trends and diagnose the sector more broadly, compared to the impact evaluation samples.

4.3. Abstract (as published)

The sustainability of rural water supply services (WSS) remains one of the core challenges of the rural water Sector in Nicaragua. The data available through the Central American’s Rural Water and Sanitation Sector Monitoring Information System in Nicaragua (SIASAR, in Spanish) is utilized to investigate the factors that drive the sustained functionality and quality of rural WSS systems over time. This report uses data from 6,863 communities, 4,792 water systems, 2,585 service providers and 154 technical assistance (TA) providers contained in the SIASAR dataset. Statistical and econometric analysis provide evidence to support the hypothesis – widespread amongst rural WSS practitioners – that ‘soft’ measures in the provision of WSS Services are effective in fostering sustainability or “functionality” of those systems. Such ‘soft’ measures include management capacity building of WSS community boards in charge of WSS services oversight, demand-responsive approaches for maintaining rural water infrastructure, operation and maintenance responsibilities, cost recovery mechanisms (affordable tariffs), community participation in the management of WSS systems, and the sustained provision of post-construction TA for local authorities. These measures are found as important determinants of the sustainability of WSS and its investments, and therefore are recommended to be included and institutionalized in rural WSS sector development policies.

4.4. Introduction

Despite impressive gains in water and sanitation coverage globally in the past couple of decades, this trend has been eclipsed by growing evidence pointing towards a marked decline in functionality and sustained service of water and sanitation schemes (Boulenouar et al. 2013). With average non- functionality rates between 30 to 40% in developing countries, and as high as 67% for hand-pumps in sub-Saharan Africa (RWSN 2009), this issue is becoming more prevalent among middle- and low-income countries. According to Starkl et al. (2013) several rural water supply systems face major obstacles in delivering sustainable WSS provision at the national, municipal and local levels. Inadequate management practices, lack of operation and maintenance, and technical issues drive water systems and facilities to dysfunction, often leading to the interruption of services. Few studies have comprehensively explored the economic, institutional and managerial factors that individually or jointly determine higher risks for system and infrastructure failures (Starkl et al. 2013). Recent research conducted in Africa indicates the relevance of operational, technical, institutional, financial, and environmental factors as predictors of the functionality of rural water systems (Foster 2013). Typically, non-functioning water systems are characterized by the absence of cost-recovery mechanisms and lack institutional support to carry out system's operation, maintenance and administration over time.

In Nicaragua, as in many other developing countries where rural WSS are managed at the community level, it is not uncommon to find water and sanitation facilities that have fallen into disrepair and no longer provide the community with an adequate level and quality of services. In some cases these systems have simply reached the end of the time period for which they were designed to function. Most systems collapse prematurely due to a combination of factors, such as inadequate maintenance, insufficient replacement materials, low tariff payment and collection, insufficient funding to cover the cost of keeping systems or facilities fully operational, or limited administrative and technical skills among service providers and users.

Demand-responsive approaches[26], capacity building of community's water boards and robust post- construction support are becoming common across rural water supply

[26] The demand-responsive approach (DRA) allows consumer demand to guide key investment decisions. In other words, a project is demand-responsive to the degree that users make choices and commit resources in support

program design, based on a widespread belief that the quality and sustainability of services improve when community-based service providers receive steady support and are empowered to own their systems. However, as Verhoeven and Smits (2011) argue, the quantitative evidence on the determinants for sustained WSS service delivery is "largely anecdotal [and] statistics to back this up are generally lacking." Furthermore, Smits, Rojas and Tamayo (2013) state that "there is widespread recognition of the importance of support to community- based water service providers for sustainability of rural water supplies. However, there is little quantitative evidence to back this claim and a very limited understanding of the characteristics most significant in support agents providing effective support."

In isolated cases[27], some quantitative analysis has been carried out, but mostly using a small sample of communities and water systems, and focusing on a particular intervention, that may not necessarily address sustainability, with limited opportunity to generalize findings. The key definition of rural water sustainability recognized in the literature relates to understanding what enables a water supply system to remain operational over a long period of time (Kwena & Moronge 2015). The present analysis addresses this definition in Nicaragua by quantitatively analyzing the multidimensional factors that determine water services sustainability, using the updated 2014-2015 data available through the Sistema de Información de Agua y Saneamiento en Áreas Rurales (SIASAR rural WSS information system, www.siasar.org) for 6,863 communities, 4,792 water and sanitation systems, 2,585 service providers and 154 technical assistance (TA) providers in the country's rural WSS sector. Based on the analysis of the SIASAR dataset, conclusions show quantitative evidence towards the importance of 'soft' measures currently being

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of these choices. Under this approach, community participation prioritizes the improvements users are actively seeking to their water services. In addition, this approach establishes clear linkages between the type and level of service people want and how much they are willing to pay for these services.

[27] Indeed, the role of community management, technical assistance, and organizational factors in the sustainable delivery of WSS has been addressed by multiple authors and organizations, but most frequently from a qualitative perspective based on case studies [see for instance Njonjo & Lane (2002) on community management and sustainability in three African countries]. The study "Predictors of sustainability for Community-managed hand pumps in sub-Saharan Africa: evidence from Liberia, Sierra Leone and Uganda," (Foster 2013) presents an exception to this statement. However, this study focuses on simple water supply systems that require relatively simpler and cheaper operation and maintenance, such as hand pumps; while the present case also analyzes more sophisticated water systems (such as piped systems equipped with electric pumping) and includes sanitation. See also for instance Katz & Sara (1997) which surveyed 1,875 households representing 125 communities served by 10 projects, or Robinson (2004), which carried out detailed analyses of eight projects in the Philippines.

promoted in the rural WSS sector in Nicaragua. Specifically, findings suggest that community participation, user tariffs, capacity building of community water boards, and post- construction TA all play a critical role in enhancing the sustainability of WSS services.

This chapter is organized as follows. The next section (4.3) describes Nicaragua's Rural Water Supply and Sanitation sector. Section 4.4 describes the primary sources of data used as well as secondary sources. Section 4.5 presents the results of descriptive statistics of both water availability and sanitation use and hygiene behaviors; water quality, service provision, and infrastructure. Section 4.6 identifies the main determinants of sustainability in WSS services, including the conceptual framework and empirical models used, in particular from the multivariate regression analysis. The results of these estimations are shown in this same section. Finally, section 4.7 summarizes key findings and provides conclusions.

4.5. Nicaragua's Rural Water Supply and Sanitation Sector

Despite improvements in both poverty levels and equality in recent years, Nicaragua remains one of the poorest countries in the Latin America region. The country has sustained an annual growth of roughly 3.2% of GDP over the past years, but its Gross National Income (GNI) per capita was only US$1,650 in 2012. Approximately 42.5% of the country's 5.9 million inhabitants still live below the poverty line and 14.6% live in extreme poverty (World Bank 2014). During 2005-09, income for the bottom 40% grew at 4.8% per year - almost five times as fast as income for the population as a whole (1.02%), surpassing regional performance for Latin America and the Caribbean and for Central America (World Bank 2014). However, challenges remain on poverty reduction and shared prosperity given that most of the poor live in rural areas (43%) and many in remote communities where access to basic services is constrained by limited infrastructure. Indigenous peoples, at 9% of the total population, (ECLAC 2014) have historically experienced economic deprivation and social exclusion (World Bank 2014).

Nicaragua has 189 urban localities with a population of 2,000 to 1 million inhabitants. Of the 189 urban localities, 105 are considered small towns, each with a population of less than 5,000 people. The rural sector is composed of approximately 7,500 rural communities. According to international figures from the WHO/UNICEF Joint

Monitoring Programme (JMP 2010), there is a large disparity between access to services in urban and rural areas in Nicaragua, both for water (98% urban coverage compared to 68% coverage in rural areas) and for sanitation (63% urban but only 37% rural). Among the country's departments, the Caribbean Coast (RACCN and RACCS regions)—which is home to most of the country's indigenous and afro-Nicaraguan population— presents some of the lowest coverage levels (**Figure 4-1**).

In Nicaragua, the Fondo de Inversión Social de Emergencia (FISE) is the institution responsible for investments and the overall management of the rural WSS sub-sector. FISE currently has a large contingent of regional and local staff, including regional water and sanitation advisors. The central FISE staff have the overall mandate for planning and coordinating investments in the sector, with guidance and financial support from the Ministry of Finance (MHCP)[28] [3] and are assisted by municipal WSS units and by liaison activities of local FISE representatives with communities. Local FISE representatives report to FISE's staff at the central level on any developments discussed or agreed with communities in terms of planning and implementation of projects or issues flagged by dwellers. The institutional management of the rural water supply sector in Nicaragua follows the Sustainability Chain displayed in **Figure 4-2** below.

[28] In general, the primary legal instruments established by the Republic of Nicaragua to regulate the water sector are: (i) Law 620, the National Water General Law; (ii) Law 722, Water and Sanitation Committees Special Law; (iii) Law 297, Drinking Water and Sewage services General Law and its bylaw; and (iv) Law 40, Municipality Law. FISE is in charge of the contracting and implementation of works, as well as capacity building at the local level (municipalities and CAPS – Comités de Agua Potable y Saneamiento, community water and sanitation boards), coordination with the Caribbean Coast, policy guidance and technical follow-up support to regional and local WSS actors. As part of this sectorial work, FISE has helped to strengthen municipal WSS units in municipalities throughout the country, whose staff provides technical assistance to the communities in their area. At the community level, WSS systems are operated by CAPS, which are staffed by elected community members. These community boards have a special status as provided by the law (Ley No.722).

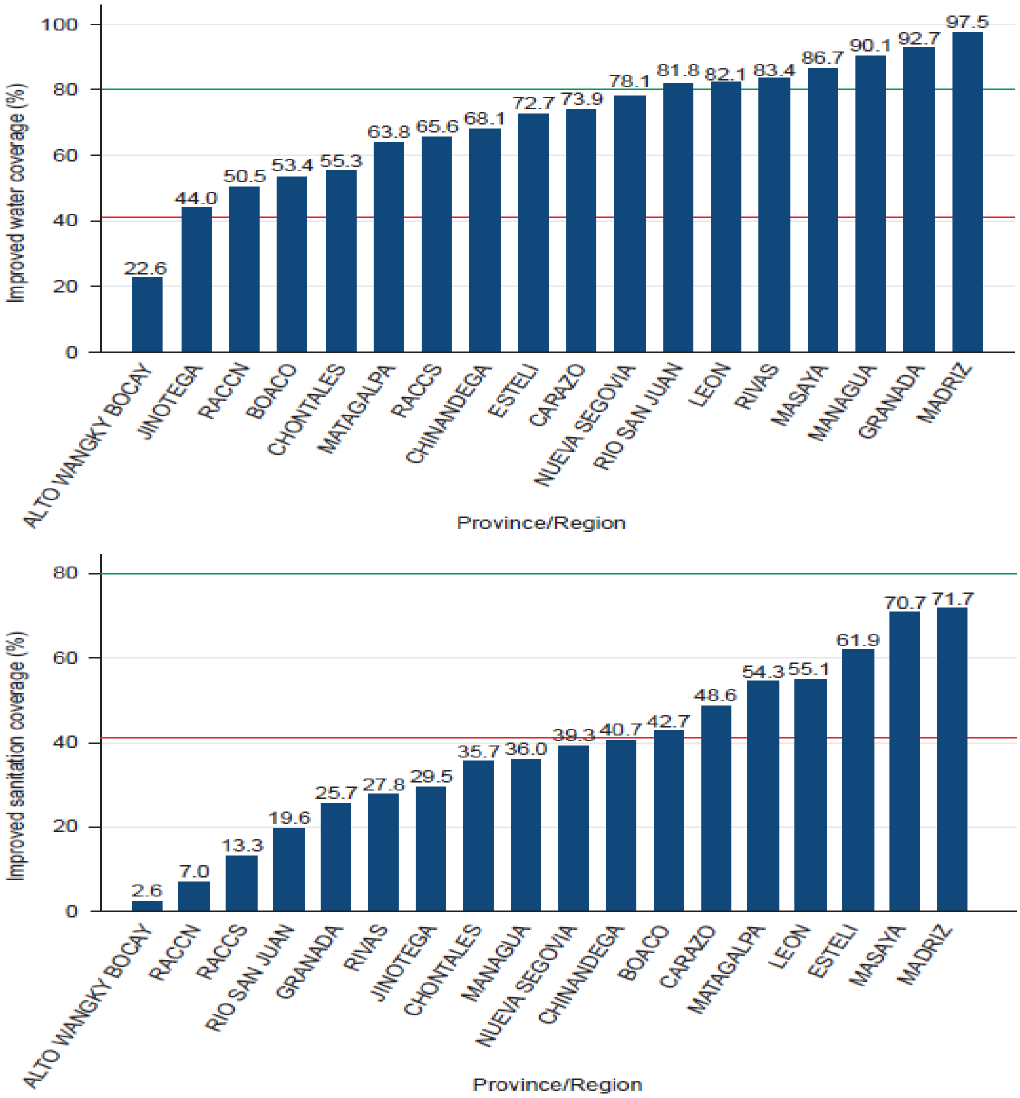

Figure 4-1 Water and sanitation coverage by department/region (horizontal axis), Nicaragua SIASAR

Source: Own estimations based on SIASAR 2015 data

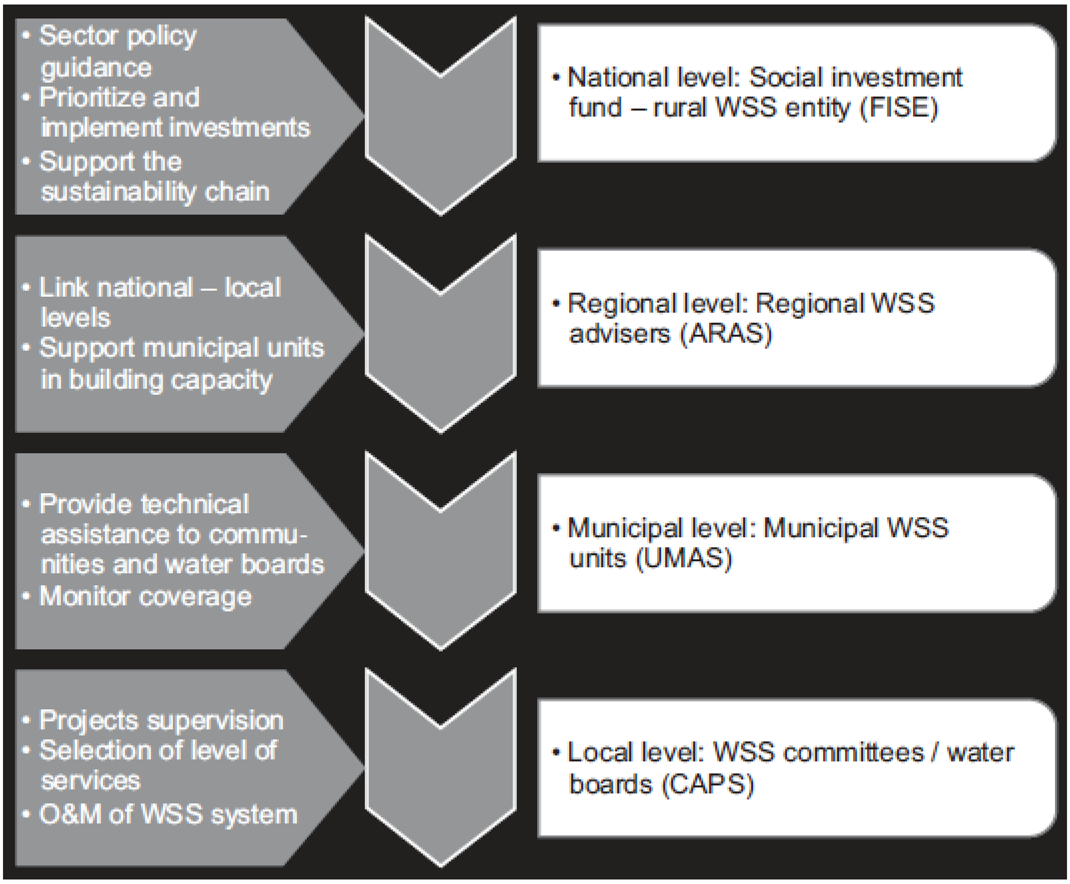

Figure 4-2 Sustainability chain (Nicaragua rural WSS sub-sector organization)

The structure in the figure links all rural WSS institutional levels, from FISE (within the central government, responsible for overall sector coordination, policymaking, financing, and planning); to regional sector advisers (decentralized FISE staff that oversee sector needs at the departmental level and advise municipalities on best-suited systems and options to implement rural water projects); to municipal/territorial WSS units (UMAS, Unidad Municipal de Agua y Saneamiento), in charge of providing TA to the community water boards for WSS (CAPS); and CAPS in each community, in charge of operating and maintaining the rural WSS systems[29]. FISE's interaction with the other levels of the sustainability chain, on top of providing financing for rural WSS systems, consists of providing training and guidance to the UMAS and, thereby, also supporting the UMAS in their role of assisting the communities continuously[30].

[29] Wherein one sub-project consists in bringing WSS services to one community through WSS solutions chosen by the community as part of a participatory planning process following the project cycle outlined in the Manual for WSS Project Implementation (MEPAS).

[30] Amongst the aspects that the Manual for WSS Project Implementation (MEPAS, the manual outlining the rules for WSS engagement under any of FISE's interventions) highlights are: (i) Social accompaniment: intensive

Post-construction support of various kinds is provided to these community boards by municipal WSS staff whose capacity has been strengthened by ongoing projects funded by international donors and other partners[31]. However, despite the general success of this participatory methodology, its relationship to the quality or sustainability of WSS systems has not been quantitatively substantiated[32]. As mentioned above, at the community level, the responsibility for the administration, operation, and maintenance (O&M) of the WSS systems relies on the CAPS, elected water boards formed by community residents. Despite promoting local participation and ownership, this arrangement is fragile, especially as the CAPS and their WSS systems have traditionally received variable and often precarious technical assistance and post-construction support in some communities[33]. After five years of implementation of this methodology developed by several stakeholders across the country, the recently harmonized and upgraded SIASAR monitoring tool (see Box 4.1) provides enough data to analyse and assess which aspects of design, implementation, and follow up are most conducive to the sustainability of WSS systems. This report aims to use the

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community work (before, during and after construction works) to accompany the physical investment, including training of the community water board (CAPS) in managerial and technical operation and maintenance issues, and training of the wider community in hygiene and correct water management; (ii) Demand-responsiveness: the MEPAS requires capital cost contribution from beneficiaries (10%), full operation and maintenance cost recovery from user fees, and purchase of meters by households; and (iii) Community ownership: once the system is built, projects are run entirely by a community water board, typically a group of elected volunteers who operate and maintain the system, charge tariffs, and oversee service delivery. FISE works towards increasing WSS coverage in the rural areas of Nicaragua by developing community-level WSS infrastructure solutions through a participatory sub-project cycle with community involvement and stern financing policies, following a demand-responsive design whose principles are defined in the MEPAS, which is ratified by all donors in the rural sub-sector. The methodology presented in the MEPAS places a strong emphasis on community participation in the identification, design, implementation and management of WSS systems. The MEPAS also relies on metering (for piped systems) and charging for water consumption to ensure that funds are secured for systems operation and maintenance, and on technical assistance provision before, during and after the implementation of WSS works in order to prepare the community-level WSS committees (CAPS) to manage their community's WSS systems. Additionally, the MEPAS contains protocols for educating communities on hygiene and sanitation practices (FISE 2013).

[31] Such as the Swiss Cooperation and, until recently, UNICEF.

[32] The overall approach for promoting social participation in WSS systems roll-out used by FISE is described in the MEPAS. Some systems functioning over 5 years may well have used a different participatory approach. There is limited data on the type of social participation approach used in each community.

[33] The MEPAS defines three modalities of implementing new and/or rehabilitation of projects: (i) community-driven development: in which the funds are transferred to the community and they are in charge of contracting the works; (ii) decentralized project: in which the municipality is responsible for contracting the works and then delivering it to the community; and (iii) centralized, where the central government (FISE) carries out all contracting and funds management (though this third option is rare in implementation). The decision of which modality to apply is based on the cost of the works and the organizational capacity of the community. In all cases, however, the community has an active role in the sub-project cycle, as they are in charge of selecting the type of WSS they want and commit to pay the respective tariff for system O&M and contribute counterpart funds (or in-kind contribution) for the works.

SIASAR monitoring data to assess the sustainability of rural WSS systems in Nicaragua, and thereby explore which technical and organizational aspects of WSS provision may be most conducive to the sustainable operation of water systems.

Box 4.1 SIASAR background

The Rural Water and Sanitation Information System (SIASAR) is an innovative platform designed to monitor the development and performance of rural water supply and sanitation services. Since 2011, in response to demands from Honduras, Nicaragua, and Panama for systematic and reliable information, a World Bank team has worked in close collaboration with the governments of these countries to develop the SIASAR and provide a variety of actors in the WSS sector, ranging from municipal staff to national decision-makers, access to regularly updated and comprehensive information on the quality, coverage, and sustainability of WSS services in their rural areas. Up to early 2015, the system is being implemented in five countries (Honduras, Nicaragua, Panama, Dominican Republic, and Peru) and in one State in Mexico (Oaxaca) with over 16,000 communities already presenting data on the interactive web platform. The next countries lined up to join the initiative are Costa Rica and Brazil (State of Ceará). Although targeted at water policymakers and practitioners in participating countries, the SIASAR can also be used by a host of regional and international institutions. Its conceptual model goes beyond water points mapping and covers a broader range of information to serve as a guide for intervention planning, in terms of both investments and local institutional strengthening measures. It not only tracks the physical condition of water systems but is itself a tool for monitoring coverage in rural communities, identifying capacity gaps of rural water service providers and measuring both the quality of the water and sanitation services and the effectiveness of available technical assistance. This initiative aims to improve resource allocation in the participating countries' rural WSS sector by allowing them to better identify needs and target future investments more effectively. The data collection system is adapted for Android cell phones and tablets, which facilitates easy data capture and storage, and takes advantage of pre-established field visit mechanisms in all participating countries. The SIASAR relies on existing in-country institutional structures to monitor the development and performance of WSS services and displays the collected data on a public, web-based platform. The monitoring tool collects and updates information periodically on the performance of WSS systems, service providers, sanitation indicators, community demand for WSS services, technical assistance and management, and the main characteristics of service providers and WSS committees. Through the data collected by SIASAR, it is possible to assess quantitatively the state of water systems, sanitation practices and facilities, coverage, and capacity gaps in rural WSS providers.

4.6. Data Sources

The main data source for this analysis was the Rural WSS Information System (SIASAR) of Nicaragua. The SIASAR displays WSS data at various levels of aggregation through an open-source web platform. This data is first collected at the different levels of local WSS components (community, system, service provider – water committees, and technical assistance provider – municipal authorities). After data is captured, pre-defined indicators are calculated and compiled into performance rankings of service sustainability through the online platform. The processed data is then displayed through geo-referenced mapping to provide a geographic picture of the national, regional or municipal service levels and local institutional performance. In Nicaragua, the SIASAR data is collected by FISE staff, the regional advisors, as part of their routine visits to the communities and municipalities to provide technical assistance on WSS systems' O&M. The quality of the data is ensured by different rounds of field work validation involving internal and external reviews of the information, as well as consistency checks. The multilateral and bilateral donors participate actively in supporting quality reviews and validation of the information. See the supplemental information for a full description of SIASAR.

4.7. Descriptive Statistics

This section provides a basic snapshot of data on a) water availability and sanitation and hygiene behaviours; and b) water quality, service provision and infrastructure. By comparing information on WSS services and community/system basic characteristics, factors that may be correlated to existing differences in coverage and service provision between different types of communities and their WSS systems can be identified. These factors can also explain which factors (such as technical, economic, or social) increase the likelihood of dysfunctional or unsustainable WSS services over time.

4.7.1.Water availability and sanitation and hygiene behaviours

Table 4-1 shows the descriptive statistics between water systems availability and sanitation/hygiene indicators. Around 55% of the 6,618 communities analysed had improved water systems. The existence of a water system in the community is positively associated with 'systematic' hand washing [see Annex for definitions], regardless of the type of water system in place (well, piped gravity-fed and piped electric pump). This finding is consistent with results reported previously in the literature (Starkl et al. 2013; Curtis et al. 2011; and Dasha & Sahoob 2010) where the functionality of systems is crucial as it is closely related to hygiene practices. 'Systematic' hand washing is also positively correlated with sanitation coverage in general, flush-toilet sanitation coverage, and open defecation free status. These relationships highlight how the lack of improved water and sanitation facilities and low practice of basic hygiene and/or proper environmental sanitation behaviours complement each other. Ultimately, enhancing the quality and continuity of service could result in better health outcomes by promoting uninterrupted basic hygiene practices or proper environmental sanitation (UNICEF 2010).

There are large differences of open defecation rates between communities with and without improved water systems (21% versus 47%, respectively) as shown in **Table 4-1** toilet use and safe water handling rates are higher in communities with water systems, yet this difference is less pronounced with respect to other measures of behavioural and environmental hygiene. The differences of means (significance test (t-test)) between hygiene indicators (such as handwashing, safe water handling and garbage disposal) are statistically significant when comparing communities with available water systems to those without water systems, which implies that the provision of both "hardware" (water infrastructure) and "software" program components are necessary to generate positive hygiene behaviours and the provision of water yields hygienic practices.

Indicator	Measurement	Water System Available	Without Water System	Differences of means t-value
Total toilets per community	Average Number	414	282	-9.11***
Communities with low-cost toilets	Average Number	39	35	0.15
Open defecation High	% of communities	21%	47%	-20.41***
Open defecation Low	% of communities	69%	15%	10.21***
Toilet use Never	% of communities	8%	18%	-6.56**
Toilet use Systematic	% of communities	49%	24%	16.14***
Hand washing Low	% of communities	3%	5%	-5.149**
Hand washing High	% of communities	30%	18%	11.69***
Safe water handling Never	% of communities	14%	30%	-12.4***
Safe water handling Systematic	% of communities	43%	28%	10.14***
Improperly disposed garbage High	% of communities	9%	15%	-2.7
Improperly disposed garbage Low	% of communities	16%	11%	5.85***

Table 4-1 Differences of means between Water Availability and Sanitation Indicators
Note: *** p<0.01, ** p<0.05, * p<0.1
Source: Own estimations based on SIASAR 2013-2015 Data

Table 4-2 compares SIASAR's water system classification (see Annex) and the coverage rates of improved sanitation. Higher quality of water systems is associated with higher latrine sanitation coverage rates, and as the water system's quality deteriorates, open defecation tends to consistently increase. As the SIASAR system classification improves, open defecation rates decrease. In summary, the relationships of **Tables 4-1 and 4-2** indicate that water availability and sanitation coverage are closely linked to improved hygiene behaviours. For example, higher quality of water systems is associated with a higher proportion of communities reporting improved hygiene practices such as handwashing or garbage disposal. Similarly, higher proportion of households with high-quality water systems classifications are also associated with a higher percent of latrine and sanitation facilities across households.

Indicator	**SIASAR System Classification**			
	Poor (D)	Fair (C)	Good (B)	Very Good (A)
Average number of households with (improved) sanitation per system	21.1	34.4	77.7	108.3
Percent Coverage of Improved Sanitation	27.2	40.2	71.0	90.4
Percent Systematic Handwashing	15.1	25.7	33.3	47.8
Percent Systematic Water Management	15.2	26.0	35.3	51.2
Percentage Proper Garbage Disposal	5.1	10.8	22.0	31.0
Average Number of Households with toilets per community	49.3	53.5	57.5	65.6
Average Number of Households per community	77.8	85.4	109.4	119.9
Percent of Open Defecation per community	49.7	31.5	31.9	25.7

Note: coverage rates corresponding to each sub-group classification. For each group percentages could not add up to 100% due to missed reporting. Source: Own estimations based on SIASAR 2013-

Table 4-2 Sanitation Indicators and Water/Sanitation Facility Quality/Functionality Classification

4.7.2.Water Quality, Service Provision and Infrastructure Status

In rural areas in Nicaragua there are three predominant types of water systems: well (pozo), gravity-fed piped systems (gravedad) and electric pump piped systems (por bombeo). Comparisons between the performance of gravity-fed and electric pump systems are important as these systems do not differ greatly in the number of communities served on average, the main source of financing, or average functionality age (11 years for electric pump and 12 for gravity-fed systems). Most of these water systems (70%) are administered by a CAPS.

Water quality. There are non-negligible differences in water quality between the three types of systems based on those receiving and not receiving TA, as judged by the proportion of systems having passed coliform and chemical analyses (**Figure 4-3**; **Table 4-3**). In addition, water quality in terms of residual chlorine is consistently higher for systems receiving TA[34] from the UMAS than for those that do not, for all types of water systems. Chlorine levels that are acceptable for human consumption are between 4.0 and 4.5 mg/l, based on the Environmental Protection Agency Standards of the United States. For those systems receiving TA, chlorine residual levels are closer to the acceptable thresholds of 4.0 mg/l, regardless of the type of system in place.

System Type	TA status CAPS*	Number	Systems (%) passed coliform density analysis	Systems passed chemical analysis (% of systems)	Chlorine Residual Level (mg/l)**
Electric pump	No TA	287	47%	43%	9.7
	With TA	**321**	**72%**	**67%**	4.8
Gravity-fed	No TA	756	49%	56%	8.8
	With TA	**381**	**68%**	**77%**	6.3
Manual pump	No TA	1,298	30%	42%	5.9
	With TA	**588**	**55%**	**50%**	4.2
Total		**3,631**	**54%**	**56%**	**6.6**

Table 4-3 Water Quality by Technical Assistance (TA) Provided and Type of System
* Note: Based on CAPS Q24 includes only those systems in which all of the associated CAPS receiving TA. ** Acceptable EPA levels of chlorine are 4.0 mg/l. The figures are consistent with Nicaragua chlorine levels and for the estimation of these figures 10 outlier observations were removed. Source: Own estimations based on SIASAR 2013-2015 Data.

[34] Reception of technical assistance is self-reported by communities. For water quality tests, FISE uses strips to test chlorine residue and takes water samples to a lab in Managua to test for the presence of E.coli. The standards used are from WHO Guidelines for Drinking-Water Quality (WHO 2008). Some instruments used to collect data infer to validated standards in order to determine water quality provided by systems. Note that these tests are not systematically carried out in all communities for which data is collected.

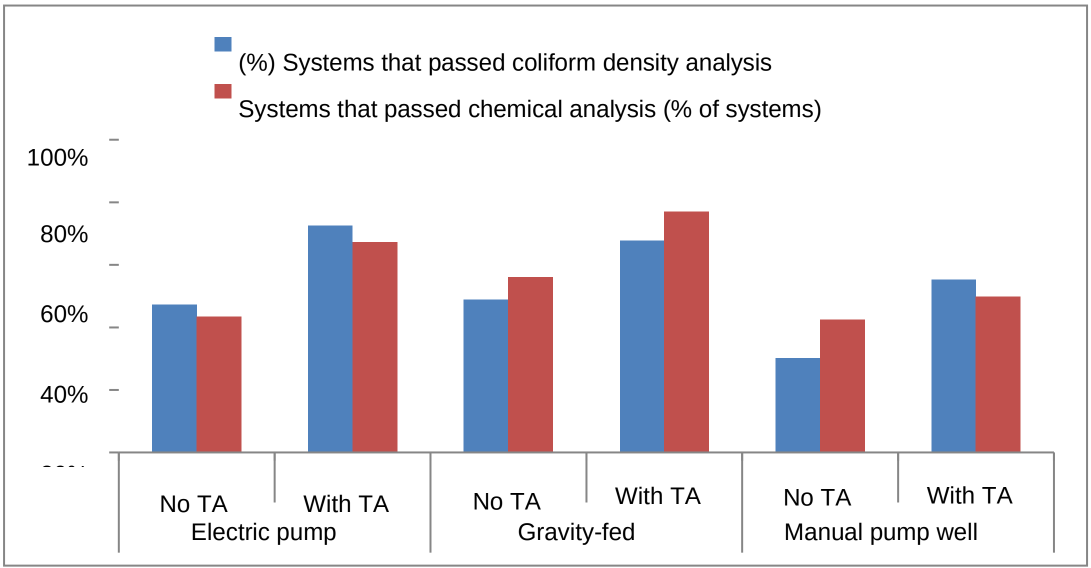

Figure 4-3 Water quality tests by type of system that received and did not receive technical assistance
Source: Own estimations based on SIASAR 2013-2015 Data.

Metering. According to the database, the percentage of water supply systems with installed water meters varies depending on the type of system in place. Water systems with metering devices installed reach 91% for electric pump systems (with a standard deviation of 26%) while only 74% of gravity-fed systems have water metering devices installed (with a standard deviation of 33.3%) (**Table 4-4**). In principle, the presence of water metering devices is related to systems with well-maintained or adequate functioning status. **Table 4-4** correlates the average number of meters installed with system performance, focusing only on water systems built after 2010. Among well-functioning systems, the percentage of meters installed and registering use or consumption is positively correlated[35] with the system's storage capacity and the water source being in good or regular condition, and negatively correlated with system age. The water source determines the minimum flow from the water source (proxy for water availability) to the system water flow (proxy for continuity of service).

Most electric pump systems with installed meters (84%) report that 95% of their meters do register consumption, while this proportion is closer to half (46%) among gravity-fed systems. In summary, having functioning water meters is more likely in electric pump than in gravity-fed systems, and appears to be linked with the overall physical

[35] Where correlations are discussed, this specifically indicates pairwise correlations at significance level 99% level of confidence, estimated with SIASAR but not reported.

condition of the system as well as factors specific to the type of system (watershed condition for gravity-fed systems and storage capacity for electric pump systems). More importantly, having a meter installed increases the likelihood of having a well-performing system.

	Meters installed	**Standard Deviation**
Electric pump	95.3%	19.0%
Gravity-fed	78.7%	27.1%
Hand-pump	2.0%	0.5%

	Systems built 2010- 2014
Status	
Not performing properly	16.5
Well maintained/Functioning	45.4

Table 4-4 Types of water systems and meters installed and Average number of water meters installed per system
Source: Own estimations based on SIASAR 2014-2015 Data.

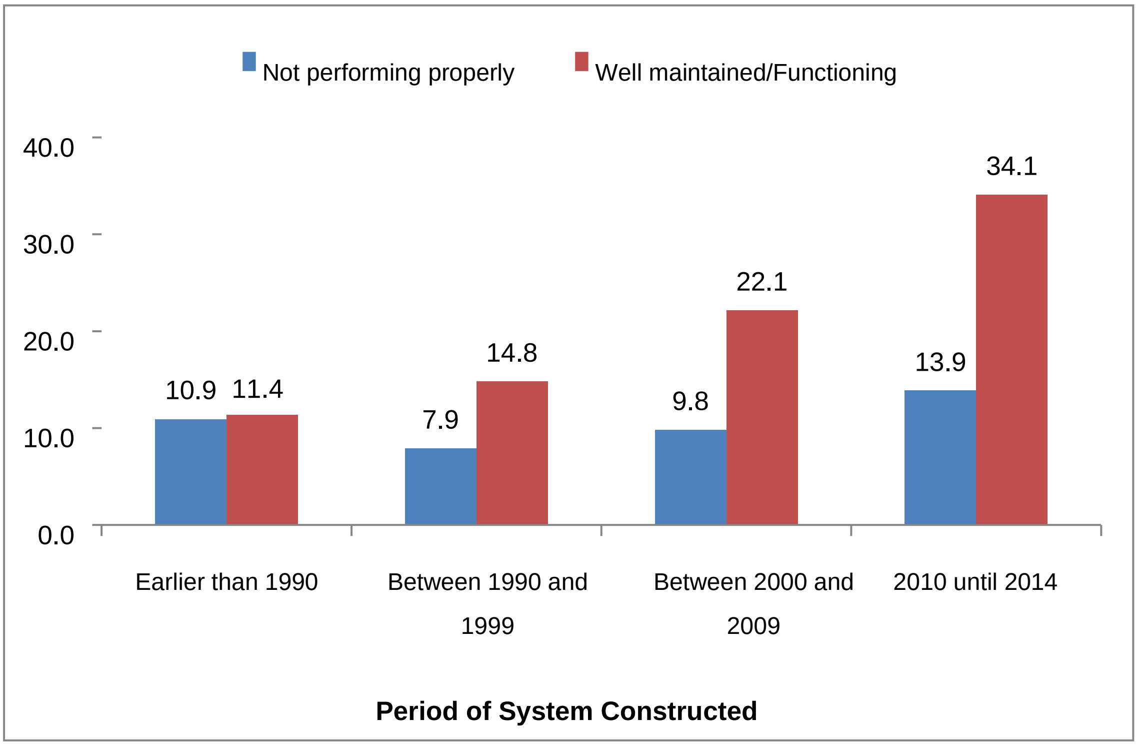

Figure 4-4 Average number of meters installed
Source: Own estimations based on SIASAR 2014-2015 data

Service continuity. Hours of service per day are correlated with the type of water system available and each technology differs in certain elements such as water sources used, storage, and distribution network capacity. Among electric pump systems, almost 63% of systems provide interrupted service for more than 6 hours per day on average (**Table 4-5**), against 71% for gravity-fed systems. Electric pump systems also have higher coverage, in terms of average number of households connected, compared to less sophisticated water systems (wells and gravity-fed). However, all systems have similar numbers of years of operation (between 11 and 14 years) and a low percentage of systems have continuous service (**Figure 4-5**)[36].

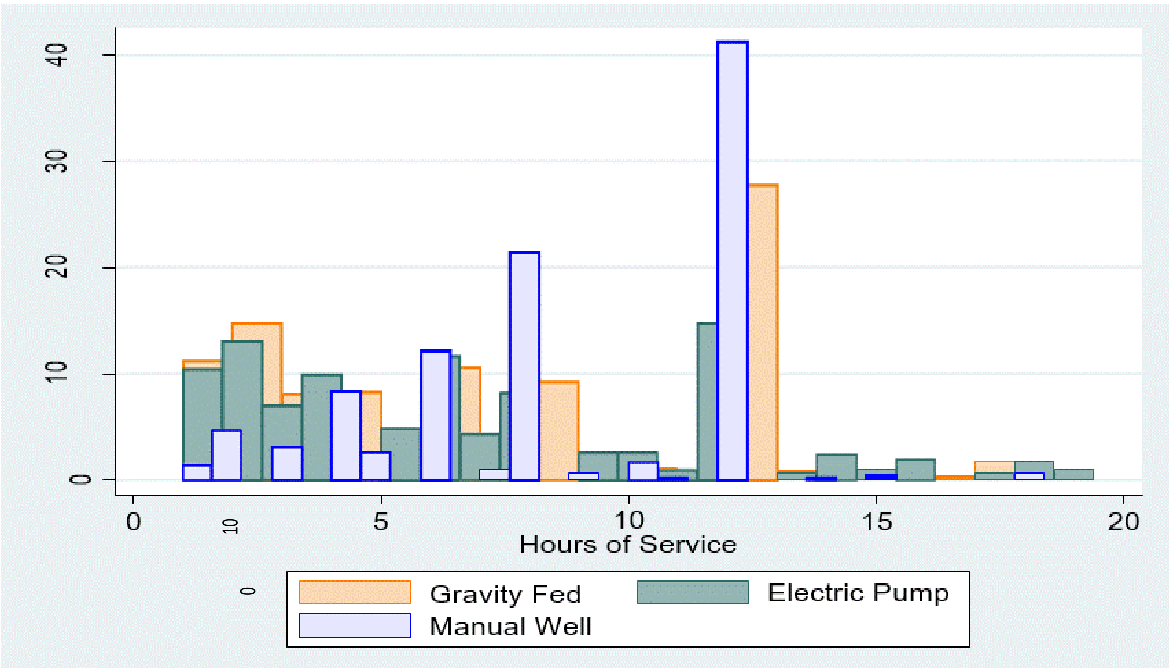

Figure 4-5 Percent distribution of hours of service per day by Type of System
Source: Own estimations based on SIASAR 2015 Data.

[36] Note that piped systems provide household connections and therefore are more convenient to users. Additionally, the definition of continuity of service may be interpreted differently by surveyor depending on type of technology, wells being referred to as available service. The distribution of hours of service for those electric pump piped systems, manual pump wells and gravity-fed piped systems working fewer than 24 hours per day. Around 40% of electric pump systems and 20% of gravity-fed systems do not provide service more than 5 hours per day. Overall, the data shows that electric pumps have higher number of households served, compared to gravity-fed or well systems. However, it is important to note that the SIASAR data on hours of water service per day considers an average of the minimum daily hours of service; looking more specifically at the performance of different types of water system in different seasons, it is noticeable that both electric pump and gravity-fed systems have similar minimum water flows and both are reported as having sufficient water in the rainy season (94% for electric systems and 96% for gravity-fed); in the dry season, however, electric pump systems tend to perform much better on average than gravity-fed systems, with 82% of the former reporting sufficient water compared to 62% of the latter. This result is related to the available quantity of water and its seasonality.

Indicator	Electric pump	Gravity-fed	Manual pump well
Total number of systems with data	1,020	1,607	1,170
System age (average years)	12.8	14.0	11.1
Percent Constructed last 5 years	28.9%	33.4%	22.8%
Household connections (average)	96.2	45.4	28.7
Providing service less than 6 hours a day	29.7%	18.9%	18.9%
Providing service more than 6 hours a day	63.3%	71.4%	79.2%
Providing continuous service (24 hours a day)	7.0%	9.7%	1.9%

Table 4-5 Types of water/sanitation facilities and service continuity

*Note: There is a distinction between the number of households served by the systems and the actual on-site connections. Piped systems (electric pump and gravity-fed) have on-site household connections as part of a service network whereas manual wells have an area of influence that "serves" households. In terms of hours of service there is an important distinction between electric pumps and gravity-fed systems, and manual wells. Piped systems (gravity-fed and electric pumps) measure hours of service delivered to connected households whereas manual wells only rely on availability of water from the source to consider them a 24-hour system. Therefore, the figures of service provision between network-based systems and manual wells may not be comparable. Source: Own estimations based on SIASAR 2014-2015 Data.

Physical condition and O&M. When comparing the physical condition of various system components between electric pump and gravity-fed systems, each quality component except storage (water collection, conveyance and distribution), appears to be in good condition, though gravity-fed systems require regular maintenance more often than electric pump systems. However, a higher percentage of electric pump systems require reconstruction in all components compared to gravity-fed systems, although these percentages are still low. These figures indicate that recently-built electric pump systems are in better physical condition in all four dimensions compared to recently built systems with other types of technology. Those recent systems were exposed to more technical assistance activities, which may in turn lead to fewer breakdowns compared to systems that were built 10 years ago or more. CAPS operate and maintain rural WSS systems in Nicaragua and are able to perform these activities based on TA and training provided by FISE and/or the municipalities (usually through their UMAS). The quality and frequency of the TA, however, varies from UMAS to UMAS, depending on the management capacity of each municipality[37].

[37] For instance, from the 153 municipalities of Nicaragua, 90 have a well-established UMAS; while 63 are still in the process of creating and consolidating a formal WSS unit. This may mean that they have an environmental or other unit seeing to the topic of WSS as well as other responsibilities. For older systems built before 1990 and in

CAPS legal status and financial solvency. CAPS undergo a legalization process that gives them access to certain benefits, such as discounted electricity prices and increased certainty on tariff collection. However, many CAPS operate without a legal status: less than half of the 2,585 CAPS[38] in the SIASAR database are legalized and 17% are in the process of legalization. Legalization rates of CAPS vary depending on the type of water system in place and whether TA is provided to communities (**Figure 4-5**). Those systems without legal status directly correlate with lack of TA, improper watershed management and low financial solvency of water systems. Those CAPS that are not legalized lack procedural rules and process, public accounts, and available funds for emergency repairs. Consequently, the legal status of CAPS can have implications on the quality and sustainability of water infrastructure. Thus the level of a CAPS' internal organization and its accountability to users is related to its legal status; in part because more organized and accountable CAPS find it easier to become legalized. Additionally, the presence of technical assistance from municipalities appears to contribute to the level of organization and financial solvency of CAPS, and to possibly encourage CAPS to seek legal status.

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the decade of the 1990s, based on the four conditions of functionality (capture, conveyance, storage, distribution), only 42% showed to be in good condition, while the rest required maintenance or minor works, or even entire reconstruction. For those systems built during the 2000s and in the subsequent decade, 64% showed to be in good condition. Regardless of when the system is built, a low percentage of systems require reconstruction (from 2 .3 to 8.7%), and what changes depending on system age is whether systems are in good condition or require maintenance. For older systems, the percentage of systems requiring maintenance even for capture, conveyance, storage or distribution purposes ranges from 51.4 to 63%, whereas for systems built in recent years this percentage is halved, ranging from 23.3 to 31.7%.

[38] The data include several structures, some of which are not CAPS, but are committees or associations intended to serve the same purposes. Only 40% of CAPS report monthly income greater than costs. This status is positively correlated with receiving technical assistance, keeping accounting records, giving public accounts, frequency of elections and the number of meetings in the last six months. It is significantly correlated with greater income, but not so with greater costs. These correlations may suggest that better accountability and management practices by the CAPS and sustained technical assistance are related to improved cost recovery. Only a minority of CAPS (25%) has no women on their management board, and more than half of all the CAPS have one or two women on the Board. The number of women on the board is positively correlated with the CAPS having all board positions filled, being legalized, having a watershed management plan, and with higher frequency of member elections. It is also weakly but positively linked with financial solvency and having sufficient repair funds. These correlations suggest that having a woman on the CAPS Board is related to better institutional management practices and to improved financial solvency. However, the causal direction is unclear (whether good management practices lead to having more women on the Board, or if the presence of women on the Board improves CAPS's management practices). Also, this indicator of gender balance may not be sufficient to draw conclusions on the impact of gender on CAPS sustainability.

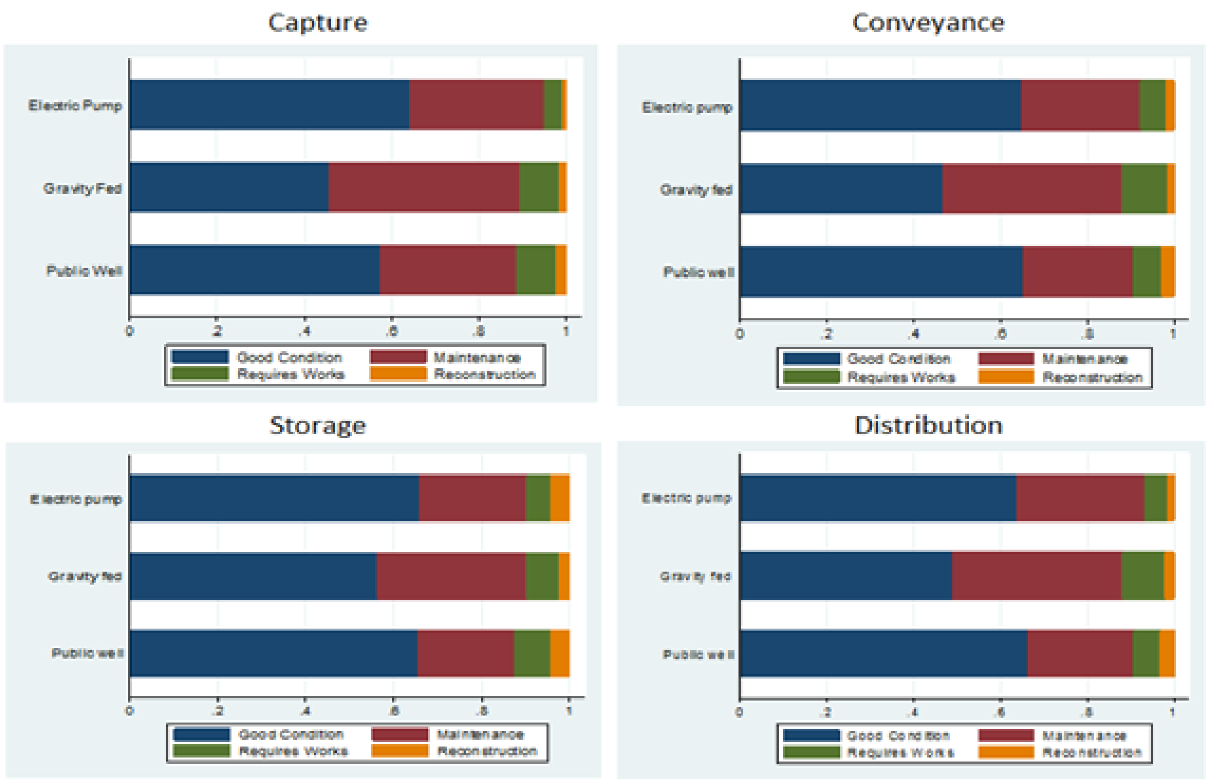

Figure 4-6 System's Physical Condition by Type of Water System and Quality Dimension
Source: Own estimations based on SIASAR 2014-2015 Data.

Technical assistance to CAPS, CAPS organization and financial solvency. Nearly 40% of CAPS report that the income generated from their water bills collection is greater than water systems operation costs. TA provided by the UMAS is moderately correlated with CAPS organization and financial sustainability, including charging consumption-based tariffs, amount of monthly income, having monthly revenues greater than operating costs, having sufficient funds for O&M, and other measures of institutionalization captured by SIASAR. For example, in the case of all CAPS not receiving TA, a third did not hold a community board meeting in the last six months before being surveyed, while among those receiving TA only 1 out of 5 did not meet in the previous six months. CAPS that do not receive TA are less likely to be legalized, charge consumption-based tariffs, conduct maintenance or be financially solvent[39] (**Table 4-6**).

[39] In addition, CAPS associated with gravity-fed or electric pump piped systems are on average more institutionalized than those operating manual pump well systems, whether receiving technical assistance or not. This may arise as the greater complexity and costs of electric pump and gravity-fed piped systems force CAPS to organize themselves in order to manage them, irrespective of the level of external support.

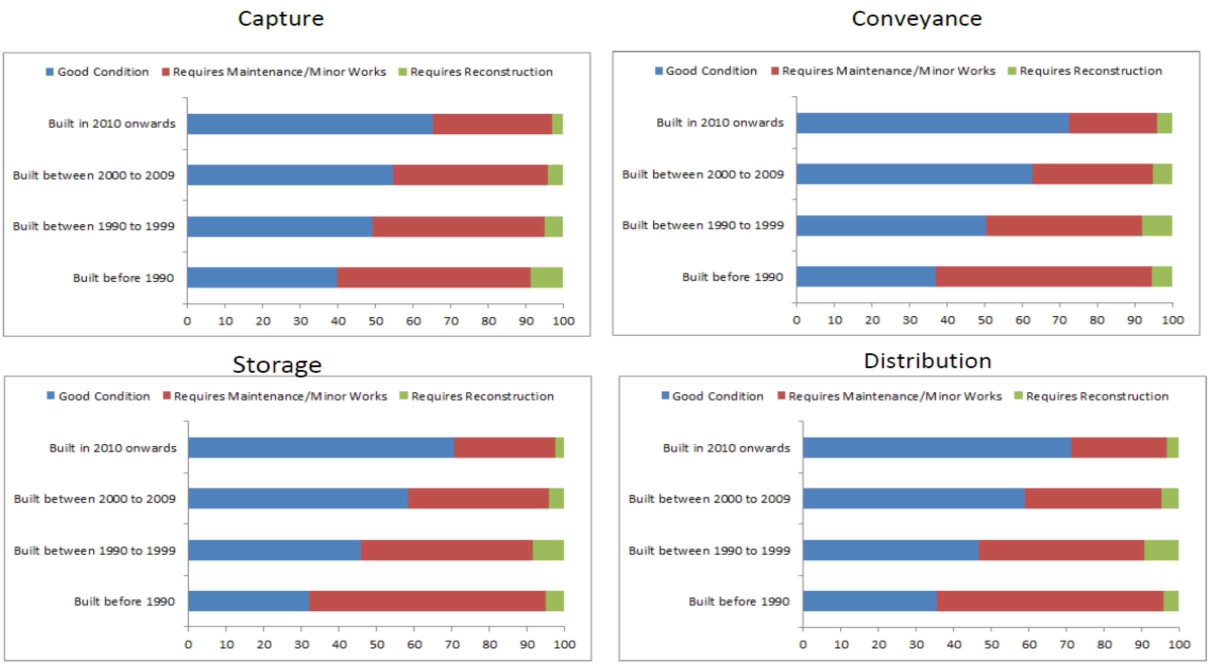

Figure 4-7 Physical Condition by Type of System and Quality Dimension, and Systems' Age
Source: Own estimations based on SIASAR 2014-2015 Data.

Indicator	Measurement	Without TA	With TA	Differences of means t- value (absolute value)
Legalized	% of CAPS	25%	40%	9.57
Women on CAPS Board	Avg. Num. per	1.8	2.1	4.25
Consumption-based tariff	% of CAPS	10%	28%	4.34
Income > costs	% of CAPS	41%	73%	20.5
Systematic safe water	% Communities	27%	36%	5.8
Handwashing Systematic	% Communities	22%	33%	1.8
Conduct maintenance	% of CAPS	35%	52%	4.13

Table 4-6 Differences of means for Water Availability and Other Indicators

Source: Own estimations based on SIASAR 2013- 2015 Data.

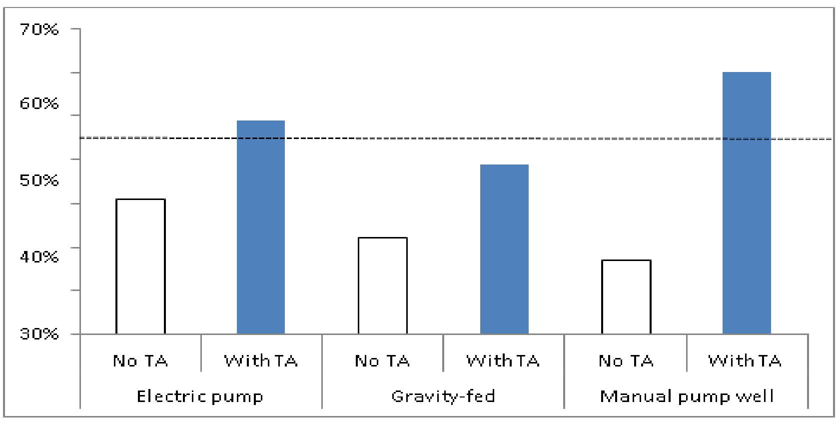

Figure 4-8 Percentage of legalized CAPS by type of system and technical assistance delivered
Source: Own estimations based on SIASAR 2014-2015 Data.

Tariff structure and financial status. In rural areas in Nicaragua the TA provided to CAPS and TA providers is intended to improve basic financial, operational and technical management of water supply systems. The information typically used to measure progress on the basic financial health of such systems is revenue-cost ratios and users' payment default rates. These systems also have different types of consumers based on the level of water consumed per day. Low-consumption users tend to be poorer or experience economic limitations[40]. **Table 4-9** shows that for CAPS receiving TA (financial, administrative, management and operational), average monthly bills are lower compared to those CAPS that did not receive any TA. Furthermore, the water bill payment default rate is higher for those CAPS that did not receive TA[41]. CAPS with a fixed tariff and no TA show the lowest amount of revenue collected from users on average and have the highest proportion of bills not paid-to-date. Finally, a larger share of CAPS is financially solvent when receiving TA in each tariff structure.

		Fixed tariff			Consumption-based tariff		
		No TA	**With TA**	Total	No TA	**With TA**	Total
CAPS	Number	1,353	**644**	1,997	281	**287**	568
Total monthly billing ($)	Average	80	**67**	73	182	**139**	160
Bill Payment Default	Percentage	38%	**12%**	25%	21%	**9%**	15%
Revenue per system ($)	Low 20th percentile	32	**54**	43	50	**62**	56
	Monthly Average	118	**163**	141	195	**201**	198
	High 80th percentile	142	**208**	175	258	**279**	268
Costs per System ($)	Monthly Average	139	**147**	160	133	**104**	119

Table 4-7 CAPS Financial Solvency Variables by level of Technical Assistance and Tariff Structure. * All $ figures in 2015 USD
Source: Own estimations based on SIASAR 2014-2015 Data.

Figure 4-9 shows the revenue-cost ratios for different consumption levels and tariff structures, differentiating CAPS that did and did not receive TA. Overall, CAPS with TA have better revenue-cost ratios compared to CAPS without TA. More broadly,

[40] The CAPS that show monthly revenues greater than operating costs reflect progress towards improving their financial performance.
[41] Both monthly revenues and costs are higher for CAPS implementing a consumption-based tariff on average, for all types of consumers.

CAPS applying consumption based tariffs also show higher revenue-cost ratios than fixed tariffs systems. The revenue-cost ratios are consistently higher for high-consumption users compared to low-consumption users, which denotes that the collection structure of revenues and costs is progressive according to water consumption levels. Higher revenue- cost ratios for high-consumption users can in principle cushion lower-consumption users that show low revenue-cost ratios.

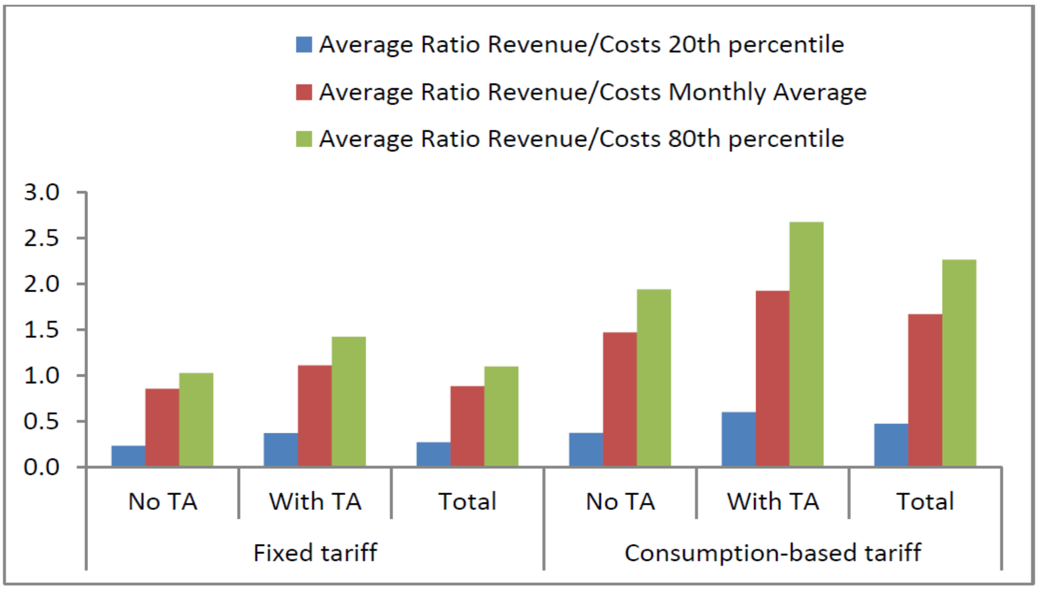

Figure 4-9 Revenue/Cost ratios (y-axis) for consumption percentiles and monthly averages, tariff structures and technical assistance provided
Source: Own estimations based on SIASAR 2014-2015 Data.

4.8. Determinants of WASH service level performance

4.8.1.Indexing performance with SIASAR data

With different dimensions of the 2015 SIASAR data (system, provider, community, and so forth), SIASAR builds a composite index that provides a quantitative indicator to approximate well-performing criteria for rural water supply services. This index (IAS) is composed from partial indices applied to specific topics contained in the SIASAR dataset. These indices assess various aspects such as water infrastructure status; water service level; community-based WSS indicators; community-based infrastructure; technical assistance providers; and service providers. However, for the purpose of this analysis, only four of these dimensions were used to define the IAS in terms of ratings of quality of water infrastructure and services: sanitation and hygiene infrastructure (CSH), service provider assessment (SEP), system infrastructure (WSI) and water service (WSL). Each of these four dimensions had equal weighting to build the composite index (heretofore "composite IAS" or "CIAS") and took into account the number of households associated with each infrastructure system. Finally, these sub-scores were weighted by the proportion of homes served in each community and multiplied by the community level score for the level of sanitation and hygiene, in order to calculate the final CIAS score. Some variables left out of the index were used as independent variables in a regression model to identify which factors play a larger role in determining water system performance (see Annex I of this chapter). The IAS (and CIAS) also includes a wider range of demand-side characteristics of water supply and considers aspects of community hygiene and sanitation. The categorical classifications are not applied until after the frequency weights and continuous variables are used (**Table 4-8**).

Province	Mean	Standard	Observatio
BOACO	0.485	0.077	98
CARAZO	0.666	0.090	106
CHINANDEGA	0.574	0.100	194
CHONTALES	0.521	0.087	62
ESTELI	0.585	0.125	201
GRANADA	0.660	0.000	1
JINOTEGA	0.602	0.122	250
LEON	0.671	0.096	181
MADRIZ	0.618	0.096	221
MANAGUA	0.593	0.113	51
MASAYA	0.700	0.050	16
MATAGALPA	0.625	0.096	281
NUEVA SEGOVIA	0.540	0.091	228
RACCN	0.656	0.130	14
RACCS	0.498	0.115	102
RIO SAN JUAN	0.526	0.110	52
RIVAS	0.661	0.063	38
Total	0.592	0.115	2096

Table 4-8 Distribution of IAS score by Province

Source: Own estimations based on SIASAR 2014-2015 Data.

4.8.2.Factors that determine system performance

The regression model aims to answer the following question: what are the main determinants of system and WSS service performance in rural areas of Nicaragua? The main regression model used the calculated CIAS as the dependent variable, while variables excluded from this index (to avoid endogeneity issues) were used as independent variables in the specification:

$$CIAS_i = \beta_0 + \beta_1 SF_i + \beta_2 SA_i + \beta_3 X_{ik} + \gamma + \varepsilon_i$$

This model incorporates the CIAS and sub-indices as the dependent (outcome) variables, and a set of independent variables. The specification follows the empirical work of Nkongo (2009) and Mehta & Movik (2014). Among the independent variables, SF corresponds to system flow capacity, SA corresponds to sanitation practices in the community (e.g. handwashing, etc.) and X corresponds to institutional variables related to community i and CAPS k. The term γ corresponds to controls of province fixed effects. It is important to add fixed effects controls in the regression so that effects of the independent variables on the outcome variable are not biased by any contextual factor of the region where the community is located. The last term εi corresponds to an error term. In addition, standard errors were estimated with Huber/White robust estimator. The regressions used the CIAS and sub-indices as dependent variables, leading to 10 different estimation results. The first estimation results used the CIAS index. Further, five infrastructure indices were used to estimate a) autonomy of system management, b) production quality of infrastructure, c) state of infrastructure to protect environmental areas, d) presence of additional water infrastructure in the community, and e) the overall state of infrastructure quality performance. In addition, there were three indices used as the outcome variables measuring: a) access to service, b) continuity of service, and c) seasonally dependent service. Finally, two sub-indices were used as outcome variables for the existence of a) operation and maintenance activities conducted by the provider, and b) active demand of service by the community. The results of 10 models described are presented in **Tables 4-8 and 4-9**. The principal model to pay attention to is the one that used the CIAS index as the main outcome variable (model 1). The rest of the models used sub-indices of different attributes of water systems (autonomy of management, secondary facilities, production capacity and demand, and so forth). These sub-indices were also included as dependent variables. The models were specified identically using many controls that were not included in either sub-index or in the CIAS. Other important controls that capture qualitative information from communities and systems are not collected as part of the SIASAR data, such as the types of maintenance performed, and education level of individuals in charge of performing water systems maintenance. Since the CIAS is indexed between 0 and 1 (1 being the highest community ranking in all dimensions), the coefficients represent the percent change contribution to the index. The results of model (1) show that those systems with legalized CAPS improve their CIAS ranking by 4%. The contribution of technical assistance is even higher: the provision of technical assistance significantly increases the CIAS coefficient by 7.4%. Proper water management in the community and reported systematic handwashing contribute to improve the CIAS by 6.2% and 6.8%, respectively. The higher the poverty rate in the community, the less likely this community is to have an improvement in the index (by 9.4%). The model fit indicators show that this model has an explanatory power of 46% and a statistically significant fit of the independent variables in explaining the outcome variable (Model test=9.5, P>F=0.000). For model (2) the main sub-index used referred to the community's autonomy in keeping and sustaining the water supply infrastructure. In this case, the most important determinants have rather small effects.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Main Factors	CIAS (index)	Sub-index Autonomy (Infrastructure)	Sub-index Water Production Facility (Infrastructure)	Sub-index Water Source in Protected Area	Sub-index water infrastructure
System's Flow	0.015	**0.018****	0.006	0.005	0.007
s.e.	(0.028)	(0.006)	(0.006)	(0.006)	(0.010)
Legal Status of CAPS (=1)	**0.039*****	0.001	0.014	**0.047*****	**0.082*****
s.e.	(0.005)	(0.01)	(0.012)	(0.011)	(0.020)
Technical Assistance (=1)	**0.074*****	**0.030****	0.009	0.013	0.030
s.e.	(0.006)	(0.013)	(0.013)	(0.012)	(0.021)
Proper Water Management	**0.062*****	**0.039****	**0.046*****	**0.141*****	**0.079*****
s.e.	(0.004)	(0.013)	(0.012)	(0.011)	(0.020)
Systematic Handwashing	**0.068*****	0.014	0.003	0.001	0.027
s.e.	(0.005)	(0.015)	(0.013)	(0.013)	(0.023)
Poverty (%)	**-0.094*****	**-0.376*****	**-0.042*****	**0.214****	**-0.2473****
s.e	(0.023)	(0.069)	(0.006)	(0.101)	(0.110)
R-squared	0.46	0.10	0.07	0.24	0.22
Model Test (Wald/F)	9.5	8.7	4.4	6.6	14.1

Table 4-9 First-tier of Models on the Determinants of Water Service Categories

.*** p<0.01, ** p<0.05, * p<0.1 Note: Fixed effect (F.E.) robust standard errors estimated. Standard errors in parentheses. Based on SIASAR 2015 data.

The rest of the models (**Table 4-10**) used the exact same specification as in the previous estimates (**Table 4-9**). The sub-indices used as dependent or outcome variables in **Table 4-10** are the following: a) water accessibility (model (6)), b) continuity of service (model (7)), c) water service available in (dry) seasons (model (8)), e) provider's O&M delivery (model (9)), and f) water demand levels (model (10)). For water accessibility, the determinants showed rather small effects. Only TA and systematic handwashing showed positive and statistically significant effects on the outcome variable, but with small coefficients of 2.5% and 1.6%, respectively. Nevertheless, the explanatory power of model (6) is the highest. The small and insignificant effects may be driven by relatively small variation between independent attributes and the outcome sub-index. For model (7) the factors associated with water service available in the community are the legal status of CAPS and presence of systematic handwashing. Poverty levels in the municipality are negatively correlated with water service availability. Model (8) shows two factors determining water provision throughout different seasons. The first relates to systems flow. Higher system flow increases water service availability by 4%. This may be related to the technology in place, since higher system flows are associated with more complex water systems that allow extracting and pumping water from remote locations. Poverty is strongly and negatively correlated with service provision throughout the year. For model (9) TA has the strongest effect on determining the provider's ability to deliver O&M to rural water systems. TA on average increases the number of providers with O&M activities by 10.3%. The legal status of CAPS is also related to increasing providers with O&M activities. Finally, model (10) shows a very strong effect of system flow and legal status of CAPS in delivering water service according to the demand.

	(6)	(7)	(8)	(9)	(10)
Main Factors	**Sub-index of Water Accessibility**	**Sub-index Community Water Service**	**Sub-index of Water Service in Yearly**	**Sub-index Provider's O&M**	**Sub-index of Water Demand**
System's Flow					
s.e.	(0.003)	(0.003)	(0.019)	(0.005)	(0.008)
Legal Status of CAPS (=1)	0.001	**0.028*** **	**0.048*** **	**0.033*** **	**0.125** **
s.e.	(0.006)	(0.007)	(0.014)	(0.008)	(0.052)
Technical Assistance (=1)	**0.025*** **	0.001	0.003	**0.103*** **	0.022
s.e.	(0.007)	(0.005)	(0.015)	(0.009)	(0.056)
Proper Water Management	**-0.012* **	-0.001	0.010	0.0134	-0.009
s.e.	(0.007)	(0.006)	(0.014)	(0.008)	(0.053)
Systematic Handwashing	**0.016** **	**0.083*** **	0.042	**0.017* **	-0.017
s.e.	(0.007)	(0.0035)	(0.016)	(0.009)	(0.058)
Poverty (%)	**-0.177*** **	**-0.029* **	**-0.131* **	**-0.024**	**-0.841*** **
s.e	(0.034)	(0.014)	(0.076)	(0.046)	(0.279)
R-squared	0.46	0.10	0.07	0.24	0.22
Model Test (Wald/F)	9.5	8.7	4.4	6.6	14.1

Table 4-10 Second tier of Models on the Determinants of Water Service Categories

*** p<0.01, ** p<0.05, * p<0.1 Note: Fixed effect (F.E.) robust standard errors estimated. Standard errors in parentheses. Based on SIASAR 2015 data. S.e.= standard error.

4.8.3. Determinants of Well-Performing Systems: Survival Functions

In order to describe which factors may determine higher shifts in the quality and sustainability of water systems, survival functions were used to estimate the probability of the services and operation of water systems failing over time. By using the system as a unit of analysis, 'survival'[42] functions of WSS systems can be calculated. Usually a set of systems can present two states in terms of sustainability: failure (shifting from a high classification to a low one) or success (moving up or maintaining a high-quality classification over time). SIASAR collects data on the dates of construction and the dates of O&M visits, so it is possible to construct survival functions to assess the probability ratio of success and failure of systems over time. Survival functions are probability models that are fed with three indicators: i) the age of the system, ii) the failure indicator (which takes value of 1 when systems change their classification status from A or B to either C or D, and iii) the identification of the unit of analysis. The CIAS was used in order to have the highest number of observations available to perform the survival function analysis.

4.8.4.Changes in Quality of Systems (Survival Functions)

Based on the conceptual framework explained in the previous section, survival functions[43] of WSS systems were estimated according to some of the main determinants found to be statistically significant. Survival functions show the probability of a system preserving its quality/functioning status (survival) across time. **Figure 4-10** shows the survival functions distinguishing those associated with legalized and not legalized CAPS[44] and the presence of accountability measures of water system management.

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[42] Survival analysis is time-to-event analysis, that is, when the outcome of interest is the time until an event occurs. It is based on estimating probabilities of failure-success over a period using a common unit of analysis.

[43] In these functions the vertical axis contains the probability or odds of having a system functioning over time (=1) or a broken system (=0). The "survival" of systems has a higher probability when CAPS are formally legalized (or in the process thereof), and conversely those systems managed by CAPS who have not filed for formal legal status tend to have higher probability (odds) of failure earlier. In the case of Nicaragua, accountability of water systems relates to management activities opened to informing the community, such as accounting systems in place, definition of roles and decision meetings involving community members.

[44] Other survival functions were estimated using the main determinants of sustainability resulting from the regression analysis. Only the Legal Status of CAPS showed contrasting differences in the probability survival functions. Nearly three-quarters of the 2,585 CAPS covered in the SIASAR system in Nicaragua are either not legalized or in the process of legalization (48%). One important issue that may arise when estimating survival functions between systems with legal vs. non-legal CAPS is endogeneity: systems survive more because of their legal status, or systems have a legal status because they survive longer. To avoid this problem, the dates of

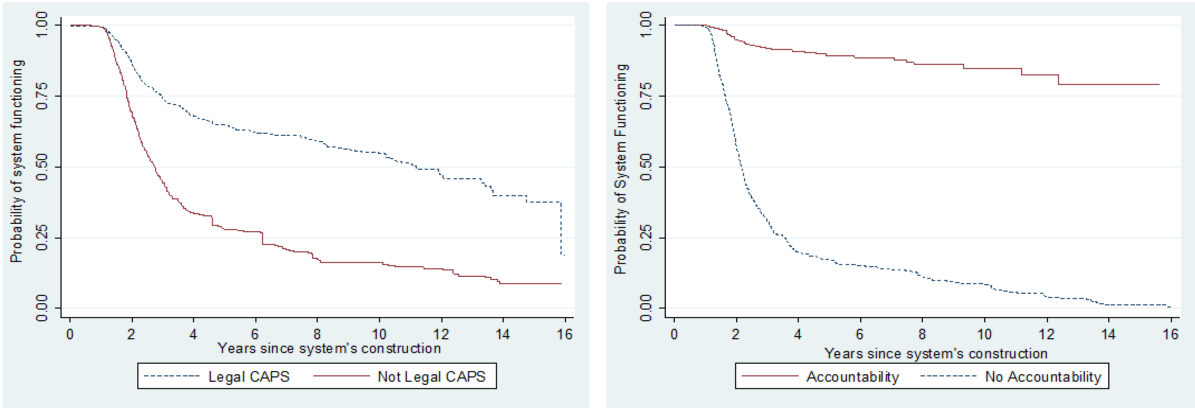

Figure 4-10 Survival Functions for Systems based CAPS Legal Status and Accountability

Source: Own estimations based on SIASAR 2014-2015 Data.

Figure 4-11 shows the survival functions between CAPS reporting to have received any sort of TA (from their UMAS) and those not benefiting from TA. For those CAPS that reported receiving TA, there is a higher probability (25 to 35%) of water systems preserving their functionality compared to systems without TA from the UMAS; the probability of system failure between TA statuses is wider between 2.5 and 10 years of operation. In addition, **Figure 4-11** also compares systems survival probability depending on the type of maintenance provided. Systems are less likely to fail or the quality of their service to decrease when preventive or even corrective maintenance is carried out compared to when they do not receive any maintenance whatsoever. This tendency is exacerbated after 2 years of system operation.

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systems operation go back to more than 5 years. This timeframe is larger than the timeframe when the option of obtaining CAPS legal status was offered. In addition, adjusting the survival functions to the number of beneficiaries may reduce biases related to the community characteristics that may drive CAPS to self-select into a process of legalization. It is important to note that the mechanism through which CAPS legalization encourages the sustainability of WSS systems may be that CAPS that work to be legalized generally present better characteristics in terms of organization, financial solvency, and technical assistance received (as explained in the previous sections, there are strong positive correlations between these variables). It is therefore likely that the CAPS with better financial turnover, good internal organization, and receiving technical assistance are more likely to both legalize and ensure the sustainability of their WSS systems. These correlations are consistent with the survival function that relates system's reliability with existing accountability measures. Water systems with only five years of operation without any accountability measures have a probability of preserving their quality or functionality of 20%, whereas the systems with at least one accountability measure in place have a probability of keeping its quality and functioning status of 82%.

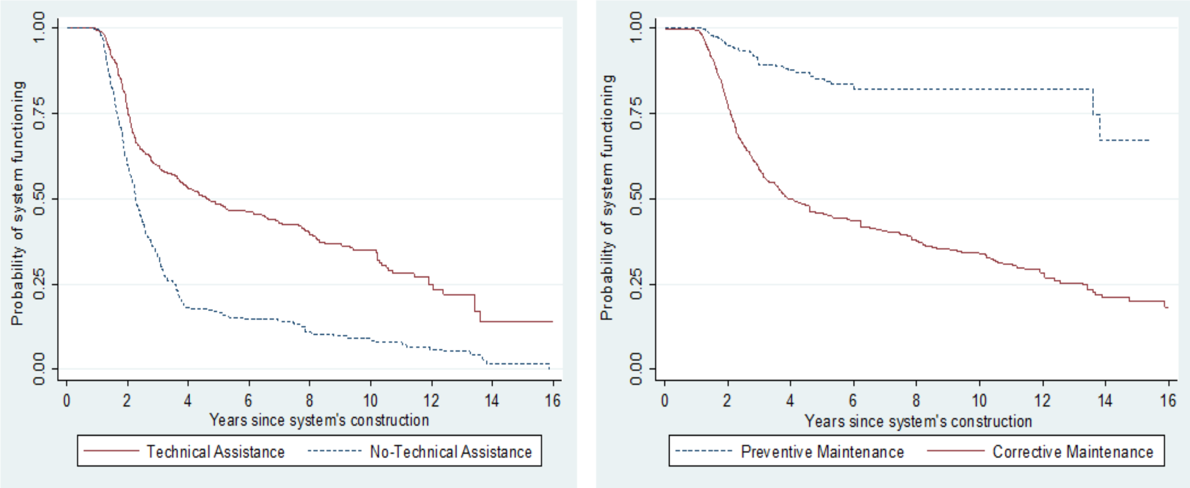

Figure 4-11 Survival Functions for Systems with technical assistance and maintenance status
Source: Own estimations based on SIASAR 2014-2015 Data.

4.9. Conclusions

This chapter (published in Waterlines Journal) used the SIASAR monitoring data for Nicaragua's rural WSS sub-sector between for 2014- 2015[45]. The available data covers 6,863 communities, 4,792 water systems, 2,585 service providers (CAPS) and 154 technical assistance providers (UMAS). This paper contributes to a small but growing body of quantitative analyses about WSS systems sustainability (World Bank 2009; Starkl et al. 2013; Foster 2013). Its findings address a large knowledge gap in the rural WSS field of study by providing strong quantitative evidence of the importance of user tariffs, capacity building of community water boards, and post-construction support (TA) in enhancing the sustainability of WSS and water systems.

Some of the most important policy implications of these results are presented below:

- Clear evidence in favour of TA, which enhances almost all dimensions of sustainable service provision for all types of water systems and tariff structures: Regardless of the type of water system and of the tariff structure (fixed or consumption-based), TA improves CAPS organizational structure (in terms of CAPS legalization, giving of public accounts, and attention to the watershed), and financial solvency. Receiving technical assistance thus appears to be systematically associated with

[45] Recent literature (Sullivan & Meigh 2007; Foster et al. 2013; Valenzuela Montes & Mataran Ruiz 2008; Ioris, Hunter and Walker 2008; Babel et al. 2011; Lachavanne & Juge 2009) has focused on sustainability issues in small samples of projects. This report covers the majority of rural communities in the country, making it a large-scale analysis.

better institutional organization and financial solvency of CAPS for all types of water system. Investing in institutional capacity for post-construction maintenance is fundamental to enable water services sustainability over time. Interestingly, the marginal impact of TA on the institutional and financial status of CAPS is largest for wells, which are the poorest performers in the absence of TA. In addition, more evidence is needed to better understand how reducing water supply interruptions and improving operations of water systems in rural areas non-only are affected by technical assistance but how these factors also play a role in shifting community-based sanitation and hygiene behaviours. Additional research is needed to explore the relationship between reliable water provision and sustained sanitation behaviour requires further in-depth analysis that does not fall within the scope of this study.

- Sustained provision of water services in rural areas is linked to the type or technology of water systems in place and its O&M arrangements: Water system technology determines the types of financial, management and technical activities needed to preserve service over time. The O&M needs differ in terms of the frequency and seriousness of systems' breakdowns, yet preventive maintenance can be crucial to avoid the high costs of fixing or replacing water systems.

- Financial solvency of service providers is fundamental to prolong systems' "lifetime," but solvency is influenced by the service provider's organization and institutional set up. This suggests that more complex technologies such as electric pump piped systems may be more sustainable in the long-run as they require better organized and financially solvent CAPS. It is however not clear whether the presence of an electric pump system forces a community to better organize itself in order to manage such a technology in a sustained manner.

- The role of metering water supply: Descriptive statistics show that functioning water meters are linked to the overall good physical condition of the system. However, the regressions analysis showed that metering does not appear to contribute to the financial solvency of CAPS or service continuity of water systems. This deserves further investigation, beyond the scope of this study.

- Cost-recovery and consumption-based tariffs: Descriptive statistics suggest that consumption- based tariffs are more conducive to the financial solvency of CAPS compared to fixed tariffs. CAPS with a fixed tariff that do not receive TA have the lowest revenues from service delivery, the highest proportion of bills not paid-to-date and are often financially insolvent. This finding points to the importance of tariffs that reflect user consumption in promoting bill paying.

• A leading role for service provider organizational variables and legal status in determining system sustainability: The analysis suggests that CAPS legalization is a good proxy for better organizational or financial performance of CAPS. Furthermore, CAPS legalization has a strong positive effect on the sustainability outcomes analysed, such as the physical condition and quality of service of a water system. Likewise, exploratory work with survival functions suggests that rural water systems have a longer survival rate when their CAPS are legalized (and hence well-organized more generally) than when they are not.

4.10. Limitations

A potential weakness of the approach adopted in this analysis is that the indices used follow a methodology composed of a broad range of factors and variables collected at different levels of analysis, and these do not include changes in sustainability due to household or individual factors. Additionally, information was collected only at a single point in time for systems with a design life of ten years or more. It should therefore be possible to refine the findings once SIASAR data is updated (so that historical data is available) and data collected at the household level to inform community indices. The SIASAR dataset is also currently in its early stages, and the quality and reliability of data collection should improve considerably in the near future, at which point follow-up analysis should be carried out.

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4.12. Annex I SIASAR's definitions of sustainable water and sanitation systems

The index is built upon 4 broad categories of indicators contained in the SIASAR dataset. The IAS index has the following thresholds:

	D	C	B	A
Intervals	0 - 0.399	0.40 - 0.699	0.70 - 0.899	0.90 - 1
Qualitative threshold	Worst performing/not functional	Underperforming	Acceptable/Above Average	Exceptional/Optimal

Table 4-11 SIASAR's IAS categories of performance

The following are subcategories of the broad index:

a. Service provider survey (SEP) – This is directed at establishing the size, level of organization, financial and operational soundness of the existing system in place. It asks questions around tariff setting, whether they have the tools, resources and systems set up to conduct operations and monitoring. Finally, it asks whether the service provider considers any environmental protection activities such as protection of the topsoil or prevention of pesticide use round the river basin.

b. In the service provider survey, it is also asked whether they receive technical or financial support from the government or other entities such as an NGO or private service provider. There is currently no Technical Assistance Provider (TAP) survey available for data download as there is not enough data, but for a future version of the IAS it will be considered.

c. Infrastructure survey (SIS) – This is directed at establishing the status of the water infrastructure being operated. For example, whether it is a well or a gravity pump, the water source, treatment and storage infrastructure in place and involves an analysis of the water´s chemical composition for chlorine and coliforms to establish effectiveness of the treatment. It also looks at surrounding conditions such as contamination at the source.

d. Community survey (COM) – This is a survey conducted at the household level and establishes a few socio-economic characteristics such as size of household and native language, followed by an assessment of their WASH infrastructure, such as whether they have their own septic tank or piped water to their homes. There are also questions here about health center services, sanitation and hygiene such as hand-washing. The IAS is made up of 6 partial indices, which act as overarching categories for refined indicators, applied to specific variables and questions. Each of these indices draws from one or more of the surveys described above.

Partial indices	Components	Indicators	Source surveys
WSL. Water Service Level	Accessibility	• Improved water coverage • Time to gain access to water	Community
	Continuity	Hours of service per day	System
	Seasonality	Minimum water supply (cubic liters)	System/Community
	Quality	Water quality tests (bacteria)	System (PAHO standard)
CSH. Community Sanitation and Hygiene	CSH.ACC: Sanitation	Improved sanitation coverage Hydraulic	Community
	CSH.PER: Personal hygiene	Handwashing reporting by sample of community dwellers	Community
	CSH.WAT: Household	Safe water management by sample of community dwellers	Community
	CSH.COM: Community Hygiene	Observation of garbage or inadequate environmental sanitation	Community
	SHC.SWA: Water supply in schools	Percentage of schools with improved water supply	Community

SHC. Schools and Health Centres	SHC.HWA: Water supply in health centers	Percentage of health centers with improved water supply	
	SHC.SSA: Sanitation in schools	Percentage of schools with improved sanitation	Community
	SHC.HSA: Sanitation in health centers	Percentage of health centers with improved sanitation	
WSI. Water System Infrastructure	WSI.AUT: System autonomy	Days without water production	System
	WSI.INF: Infrastructure of production	System's capture, conveyance, storage and distribution	System (4) indicators
	WSI.PRO: Water caption	Qualitative assessment of protection of water catchment area	System
	WSI.TRE: Treatment system	• Type of water system treatment • Treatment system functioning status	System
SEP. Service Provider	SEP.ORG: Organization	• Service provider legal status • Organization structure in place • Management/Transparency	Service Provider
	SEP.OPM: Operation & Maintenance	Corrective or preventive maintenance Basic chlorination frequency	Service Provider System
	SEP.ECOE economic mgmt.	• Cost recovery ratios • System's financial solvency (revenue vs costs)	Service Provider System
	SEP.ENV: Environmental management	Presence of environmental protection activities and promotion	Service Provider
TAP. Technical Assistance Provider	TAP.ICT: Information systems	Adequate information systems and access to internet for PAT	Technical Assistance Provider (6)
	TAP.INS: Institutional capacity	Water quality testing equipment (sufficient) Ratio of technicians per community Ratio of economic resources to cover training	
	TAP.COM: Community coverage	Percentage of communities covered with TA	
	TAP.INT: Intensity of assistance	• Diversity of TA provided (financial, management, operational)	Technical Assistance Provider

Table 4-12 Subindices of different SIASAR's dimensions

Chapter 5. Impact Evaluation Study in Nicaragua: A randomised-control trail to assess the effectiveness of rural water program

5.1. Introduction

To corroborate the findings and recommendations of previous chapters presented in this Thesis, an Impact Evaluation study with a randomised assignment of the intervention was designed and implemented between 2015 and 2019. Chapters 5, 6 and 7 present the overall impact evaluation design, the results of the balanced characteristics between comparison groups at baseline (published paper), and the results of the entire impact evaluation, respectively.

The objective of this impact evaluation is to assess if good quality technical assistance provided by municipalities translates into better functionality and durability of WSS systems at the community level in rural areas of Nicaragua. The impact evaluation was designed within the context of the Nicaragua Sustainable Rural Water Supply and Sanitation Sector Project (PROSASR), a multi-donor-funded investment project that has the overall objective of increasing access to sustainable WSS services in selected poor rural areas of Nicaragua through the consolidation of rural WSS sector institutions and the provision of adequate infrastructure. In Nicaragua's rural WSS sector, WSS systems are administered, operated and maintained at the community level through local water committees (Comité de Agua Potable y Saneamiento, CAPS), which are elected water boards formed by community residents. The CAPS receive technical assistance from the municipalities, their municipal WSS Units (Unidades Municipales de Agua y Saneamiento, UMAS). FISE's interaction with the other levels of the sustainability chain consists of providing training, staffing, equipment and guidance to the UMAS, and supporting them in their provision of assistance to communities. Therefore, in most cases, capacity building is shaped according to the CAPS' needs to administrate, operate and maintain the rural water systems. The program to be evaluated in Nicaragua is the Sustainable Rural Water Supply and Sanitation Sector Project (PROSASR). PROSASR's project intervention aims to strengthening the rural water supply and sanitation sector, by delivering training packages in financial and economic management through an integrated approach to address sustainability of rural water services. PROSASR focuses on strengthening the country's rural water and sanitation institutional structures (through a 'sustainability chain') by providing capacity building at each institutional level (central government, municipalities and communities), encouraging skills transfer to municipalities and communities, and helping FISE and local institutions to develop better coordination within the sector.

5.2. Theory of Change

Consistent with the PROSASR Project Development Objective, this impact evaluation will assess whether timely and well-structured technical assistance provided by the municipalities to the CAPS/communities impacts the sustainability of the rural WSS systems. All municipal strengthening activities will train and equip the municipalities to provide quality and timely technical assistance to the communities within their jurisdiction, independently of their receiving Project funds to build a WSS system. As a result, the UMAS is expected to provide better quality technical assistance to its assigned communities, which in turn will create a better response mechanism if a problem arises at the community level. In turn, a reduced response time and a higher quality solution to the problem strengthens sustainability: if a community's WSS system were to break down, or if there were to be a dispute regarding tariff-setting, the community will feel more confident and supported in appealing to the municipality or governing body and receive useful advice, thus resolving the problem and ensuring proper continuation of operation and maintenance of the system (**Figure 5-1**). In addition, the pre-existing characteristics of the CAPS in charge of a given WSS system (legal status, ability to set tariff, effective O&M cost recovery, percentage of women on the CAPS board, etc.) should also influence the sustainability of WSS services. The evolution of sustained water access over several years and the incidence/prevalence of the water-related health outcomes in rural communities could also be assessed in the long-run, as part of a continued investigation beyond the Project lifetime.

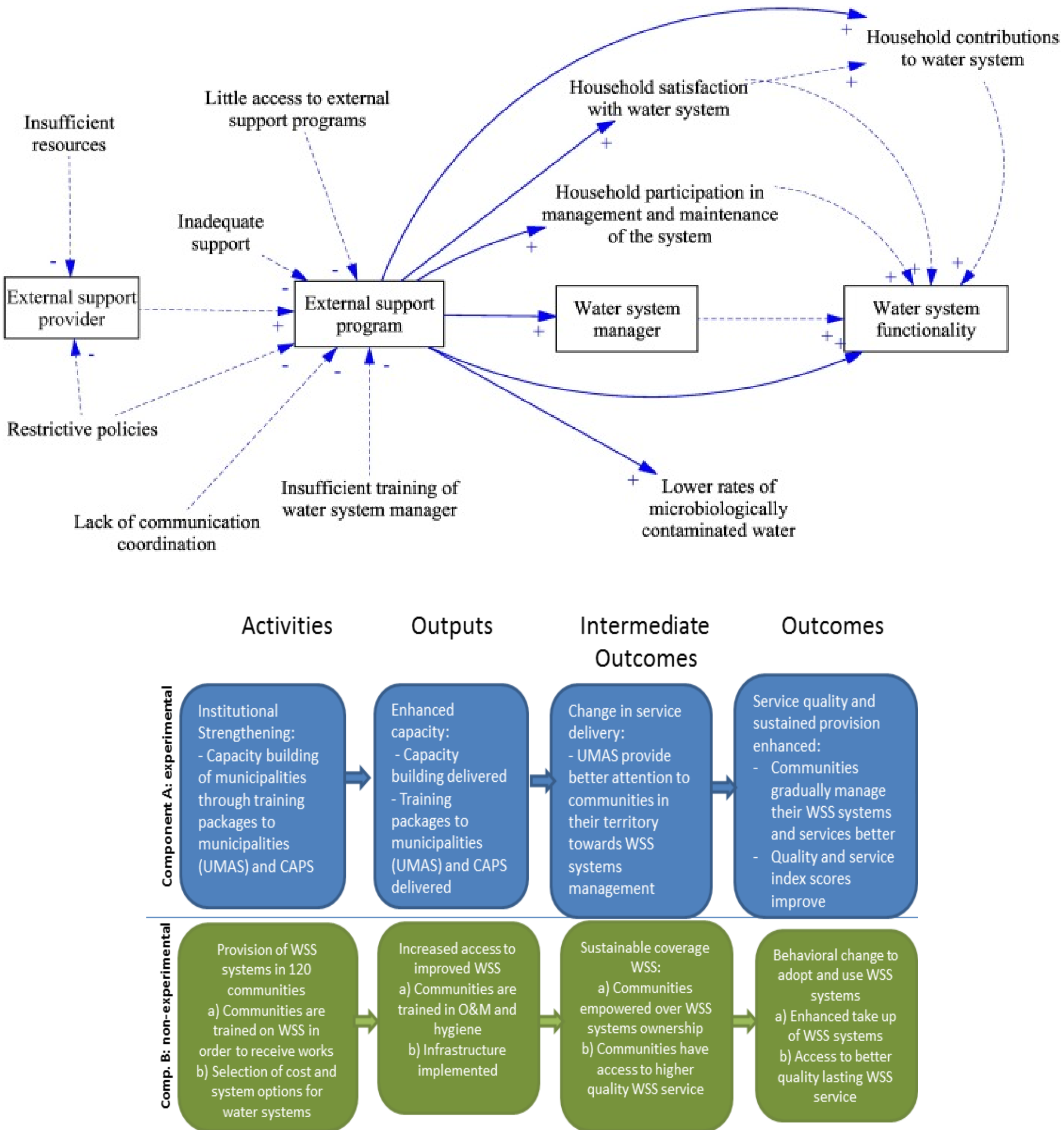

Figure 5-1 Theory of Change/Results Chain of the PROSASR program

Source: Own elaboration

5.3. Study design and sample

The PROSASR was evaluated through an impact evaluation design involving community-based random assignment of two key interventions. The first one is the *Aprendizaje Vinculado a Resultados* (AVAR). A series of water training workshops, AVAR, administered in three-different occasions, meant to strengthen the institutional and water-management capacity of the local water government sector. The AVAR includes training in water tariff calculation, operation and maintenance (O&M)

procedures, water treatment methods, accountability mechanisms, CAPS legalization procedures, and meter reading, among other topics that involve administrative and corrective maintenance of rural water supply systems. The second intervention is the technical assistance provided by the *Asesores Regionales de Agua y Saneamiento* (ARAS), and the additional support aimed at institutional strengthening guided by the metrics outlined in the Rural Water and Sanitation Information System (SIASAR). The ARAS consisted on deploying a trained technical expert who provided regular assistance to help monitor the progress of the AVAR, and offered wide-ranging support in strengthening the capacity of local water institutions. The expert also offered technical support to the UMAS and CAPS in the elaboration of operational and maintenance water system plans, and preventive and corrective plans to protect potable water systems. Both of these interventions subject to the evaluation presented in chapters 6 and 7 were carefully designed to assess how these training programs would or would not induce better and prolonged functioning and operation of rural water systems in Nicaragua.

The institutional strength of the local government water agencies was first measured with the baseline collection of SIASAR in 2015. Each UMAS/UTASH and CAPS was assigned a ranking, based on their performance along a set of indicators, gathered through the SIASAR datasets. The rankings are updated with the biennial collection of the SIASAR. Administered primarily to staff from the UMAS, a central component of the AVAR and the assistance from the ARAS is to help the UMASH/UTASH strengthen the Comités de Agua Potable y Saneamiento (CAPS). The CAPS are water-sector boards tasked with managing the water systems, and water operations, at the community-level. The CAPS are the main point of contact with the communities, and report directly to the UMAS/UTASH. Support from the AVAR/ARAS was implemented at the municipal level and was administered in 148 out of Nicaragua's 153 of municipalities that are part of the study. To comply with the experiment's research design, the UMAS/UTASH were instructed not to transmit any of the learnings from the AVAR trainings to the CAPS in the control communities, and the ARAS were also indicated to withhold assistance to the communities/water systems/CAPS in the control group.

5.3.1.Program assignment and comparison groups

The design of the impact evaluation consisted in a random-assignment through public lotteries of two groups divided into control and treatment groups, stratified by region, municipalities to account for potential differences linked to municipal resources in the treatment effects; the key feature of this design was randomisation at the municipal level and community levels, following the design of the interventions of ARAS and AVAR. Within each randomly selected municipality two communities were randomly assigned to treatment and two communities to control. Selecting treatment and control units at the community level reduced the inter-cluster correlation imposed by selecting groups of communities at the municipal level. Reducing this correlation structure reduced the sample size requirements to achieve 80 percent power, and improved overall evaluation efficiency. Selecting at the community level allowed for stratification at the municipal level, which allowed the team to control for impacts of municipal characteristics that might influence evaluation outcomes by design (e.g. implementation intensity, municipal geographic and socio-economic characteristics), consistent with the original design. Additionally, at the community level there is wider variation in characteristics and outcomes compared to municipalities so in principle statistical inference is strengthened as well. From an implementation perspective, the original design would have forced FISE to postpone the intervention from entire municipalities (control group) until the completion of evaluation activities in order to avoid contamination of the control arm; this would have required delaying implementation in hundreds of communities that were not actively enrolled in the evaluation. Hence, selecting at the community level improved the political and logistic feasibility of implementing a robust randomised design. Community eligibility criteria were introduced in order to focus the evaluation on communities that would most likely improve their indicators with the intervention, given their initial status. These criteria did not introduce any sort of bias or non-random criteria. The eligibility criteria were:

- To be eligible, a community had to have an existing WSS system with a SIASAR infrastructure rating for the system, the EIA[46] greater than or equal to 0.4. An EIA score lower than 0.4 would correspond to a system in severe disrepair, and unlikely

[46] The WSS system questionnaire generates an index, the EIA (Estado de la Infraestructura), which uses a score from 0 to 100 that indicates the state of the WSS infrastructure (in good condition, needs minor repairs, broken down, etc). This index was constructed before baseline and during the evaluation design with SIASAR 2015 data to be able to have a quantitative eligibility criterion of communities being part of the study.

to experience any impacts from the planned intervention being evaluated, which focuses on capacity building rather infrastructure enhancements. Although communities without system infrastructure were excluded for the same reason, those without a service provider were included in the sample, as the technical assistance from UMAS specifically promotes the creation of CAPS where they have not yet been constituted as part of building up and supporting community-level WSS services sustainability.

- A community could also have more than one water infrastructure system and more than one CAPS. However, communities that shared either CAPS or systems were excluded from the study. Since randomisation was at the community level, it was likely that if two or more communities shared a water system or CAPS those communities would have different treatment assignments, leading potential contamination between treatment and control communities.
- A community was also excluded if it had an overall Index of Water and Sanitation Service (IAS) score[47] of >0.75, as those with high IAS scores were already operating and providing services in a sustainable fashion and unlikely to experience detectable impacts from the intervention (see annex for IAS thresholds).
- A community was excluded if it was classified as having fewer than 20 households in the SIASAR database (for logistical purposes). Similarly, communities classified as having greater than 1,000 households were excluded as they likely did not meet the Government of Nicaragua's definition of a rural community (Population < 5000 people, assuming 5 people per household).
- A municipality was considered eligible if it had greater than 4 eligible communities, to allow for balanced stratified randomisation of communities (within each "poor" and "non-poor" municipality, respectively).

In addition to the SIASAR-based surveys, the actual Impact Evaluation design also included household-level surveys, in which a quick questionnaire (15-20 minutes) geared towards assessing where families collect their drinking water, whether they had access to and used sanitation facilities, and their needs, perceptions and costs

[47] For an explanation of these indices that are considered to assess different SIASAR's dimensions, see: http://www.siasar.org/sites/default/files/documents/170529_webinar_1_marco_conceptual_red.pdf

regarding WSS services in their community. The household surveys also included question on household assets.

5.3.2.Sample design and power estimations

Based on the power calculations and the balance established from the SIASAR data, 300 communities were needed to allow at least for 80 percent power (**Table 5-1**), with a total of 4,500 household surveys. Household surveys were to be distributed among communities according to community size (total number of households) for representativeness. The sampling was done with 4 communities per municipality (two treatment and two control) for representativeness and a balanced design. This yielded a total of 75 municipalities to be randomly selected from all eligible municipalities. Given that there is substantial geographical and economic variation between regions, care was taken in the selection of the 75 municipalities to ensure the characteristics of the chosen 75 municipalities were representative of the national distribution. Once the sample of 300 communities was selected, across 75 municipalities, within each municipality the 4 eligible communities were randomised to either treatment or control (2 allocated to treatment and 2 allocated to control). This resulted in 150 treatment communities and 150 control communities evenly distributed across the 75 municipalities (**Table 5-2**).

	Assumptions[1]			MDE[2]	
	Control Mean	SD	ICC	80% Power	90% Power
IAS	0.61	0.12	0.26	**0.04**	**0.04**
Improved Water Coverage	68%	31%	0.23	**10%**	**15%**

MDE: Minimal Detectable Effect; SD: Standard Deviation, ICC: Intra-cluster correlation
[1]Estimated from SIASAR data prior to baseline data collection, assuming 150 Treatment and Control communities, and 4500 randomly sampled households; [2]MDEs Calculated using alpha = 0.05

Table 5-1 Minimum detectable effect of main outcomes under evaluation

Size of the community (No.of HH)	No. Communities in the sample	Total HHs in communities in the sample	Sample of HHs per community	Total HH in the sample
20 - 80	155	7811	11	1505
81 - 140	77	8080	17	1209
141 - 240	46	8057	25	1050
241 - 554	22	7827	38	736
Total	300	31875	91	4,500

Table 5-2 Proposed number of households sampled per community

The **Figure 5-2** describes the full sample selection process for the evaluation. Note that some communities were excluded at the beginning due to not having a full set of eligibility criteria, including not having the elements to calculate the IAS. Some particular Indigenous areas located in special territories in which FISE did not wish to have controls in (such as Alto Wangki y Bocay) were also excluded at the beginning. A minimal number were also excluded at the end, due to crosscutting interventions being rolled out by other development initiatives. In addition, due to political, logistical and enumerator safety issues 9 communities were replaced during baseline data collection. The actual randomisation for the evaluation was carried out at FISE's office in Managua, with the participation of the research team, and validated by IRB members. A Stata software (v.9) do-file was prepared in advance of the meeting to ensure it functioned properly. During the meeting, members of the FISE management team and the Bank team each selected a single number, which were combined to create a random seed for the do-file. The do-file was run once with this random seed during the meeting and the resulting list of evaluation municipalities and communities (with random allocations) were shared with FISE (control communities only).

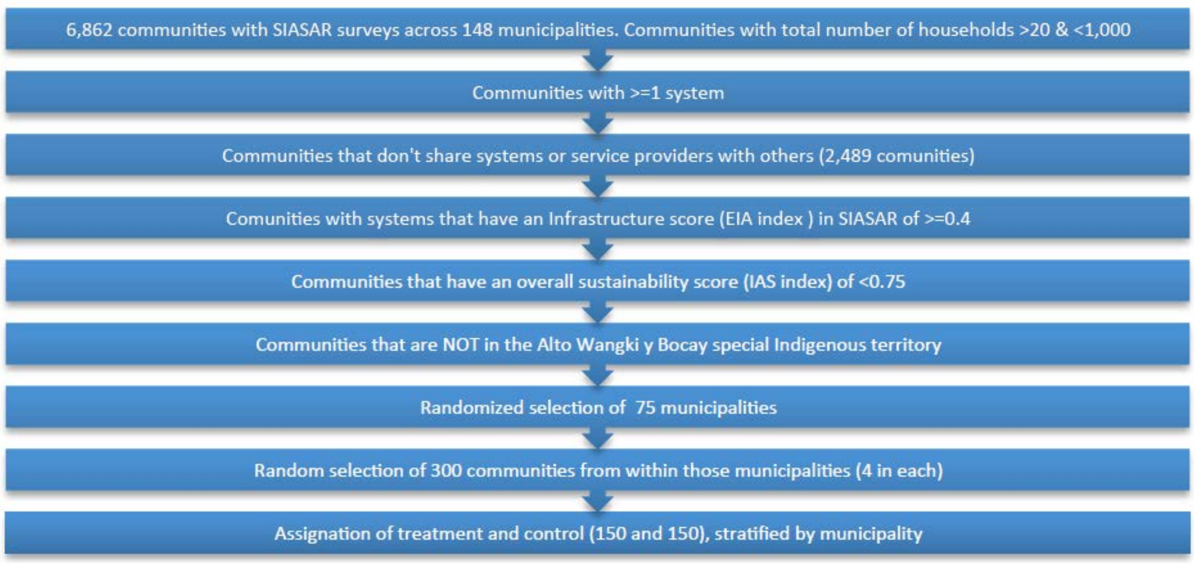

Figure 5-2 Community eligibility and sample selection for impact evaluation study

5.3.3.Data collection and Ethics Procedures

The fieldwork was designed to be conducted to a total of 300 communities (4 per municipality). Baseline community level surveys were designed to be applied to each CAPS or existing informal committee if a CAPS was not formally established. Surveys consisted of several questions from SIASAR as a means of ensuring data validation, as well as selected questions chosen by the Bank team, slightly more qualitative in nature, so as to better measure the impacts of the PROSASR intervention on the WSS service provision, including WSS system's administration, the CAPS' organization, water quality and the community´s sanitation and hygiene practices. The SIASAR questions were often tweaked to make the expression operationally clearer and accompanying survey manuals were put together to ensure that surveyors understood the motivation behind each question asked. These SIASAR surveys consisted of three component surveys – one community, one WSS infrastructure system and one service provider/CAPS, totalling 3-4 hours for surveying per community, excluding travel time. Building on the SIASAR questions also allowed for the construction of the IAS Index for each community visited.

The surveys were designed to include the following elements, among others:

a. Number of residents

b. Characteristics of their source of drinking water

c. Time to collect drinking water

d. Costs of drinking water

e. Perceptions of their drinking water

f. Are they connected to the community system

g. Perceptions of the community system

h. Type of latrine/sanitation facility available to the household

i. Interactions and impressions of community service providers

j. Other households' characteristics, including sanitation facilities

Finally, field work also included water quality tests collected for e-coli and chlorine. These are elements of the SIASAR survey that until now have not been collected as part of SIASAR fieldwork. Resources were provided to the survey firm for 1,000 samples to be taken of e-coli across the 150 communities and 460 samples to be taken for chlorine using commercially available kits (see annex of this chapter). Since Water Quality testing is costly and complex to organise it was confined to a sub set of the study communities – samples were taken in a random selection of half of the entire community selection[48]. The purpose of the water quality sampling was both to examine the ultimate quality of water consumed at the household level but also to provide information about the most common or probably causes of water contamination as water is processed and delivered. The samples for e-coli were therefore taken at the following strategic points:

a. In the system: one prior to treatment (at the source) and another following treatment (if applicable). Where there was no treatment, the survey firm simply took one sample at the storage tank before it entered the network;

b. In the households: one sample in a storage facility from which the last glass of water was drunk by the respondent and one sample directly from the tap in the household. In communities of 140 households or less, these samples were taken in two households. In communities of greater than 140 households, these samples were taken in 3 households;

c. In a subset of these communities there was one additional chlorine sample taken in the household furthest from the system and one additional e-coli sample taken in a household not connected to the system. Due to changes in FISE's management team in early 2015, the activities linked to the Project suffered significant delays. These delays affected the timeline of the impact evaluation as the design was fully reviewed with the new FISE management team in order to ensure they agreed with the objectives and research questions. As such, baseline data collection started in November 2015 and was concluded in January 2016. As part of Project implementation, the Bank team and FISE just concluded the revision of the guiding documents for the AVAR process. The AVAR is scheduled to be launched at the end of February 2016. The next chapter summarizes the results of the baseline surveys.

The ethics procedures will follow first all University of Leeds Policy. The data collection followed the confidentiality and data registry of the university and the funders of the research (World Bank-SIEF). The procedures also involved consultations with the experts of SDDU (Dr Alice Temple) and because the IE surveys will not entail any intromission into human subjects (biomarkers, blood tests, stool tests), the compliance with the University policy is less complicated and straightforward. The only requisite is

[48] Communities were randomly assigned to the intervention. The for the sampling of the survey at the household level, the households to be interviewed in the survey were randomly selected.

to proof the IRB clearance for basic household survey confidentiality (see appendix letter of the local IRB in Nicaragua CIRA-UNAN for baseline and endline). I conducted during the last year a series of certifications and survey registries required for the impact evaluation. This process followed World Bank's Strategic Impact Evaluation Fund (SIEF). Finally, in the appendix there are the international registry of the IE survey and the NIH certificate obtained.

5.4. Conclusions

The evaluation and survey designs were closely collaborated with FISE and heavily based on SIASAR. We adapted question phrasing based on pilots to ensure clear expression and understanding on the part of surveyors, elaborating field manuals and providing training with support from a seasoned SIASAR's expert. New household surveys were also closely debated with FISE so that only jointly agreed questions were taken to the field.

During implementation of the fieldwork, in addition to quality control checks by the survey firm's own team, the research team hired with FISE an external Field Coordinator that carried out several field visits to the country to assess comprehension and quality of the evaluation design and data being collected and provide instructions for communications and protocols where necessary. The Field Coordinator required the Survey Firm to fill in a monitoring sheet, which reported the number of surveys and water samples being collected in each community visited.

5.5. Annex

REPUBLICA DE NICARAGUA
MINISTERIO DE SALUD
CENTRO NACIONAL DE DIAGNOSTICO Y REFERENCIA
COMITÉ INSTITUCIONAL DE REVISIÓN ETICA
IRB 00005231 y FWA 00009658

ACTA DE NOTIFICACIÓN DE DECISION DEL CIRE

Estimados investigadores:
Sr. Christian Borja-Vega, Economista Banco Mundial
Sr. Helmis Cárdenas Villalobos – Gerente General ESA Consultores, Honduras.

El Comité Institucional de Revisión Etica (**CIRE**), del Centro Nacional de Diagnóstico y Referencia del Ministerio de Salud de Nicaragua, se reunió el día 30/09/2015, con el objetivos de revisar el protocolo y anexos recibidos con 07/09/2015 de la investigación que lleva por nombre **"Proyecto de Sostenibilidad del Sector de Agua y Saneamiento Rural de Nicaragua (PROSARS)"**; registrado con el código **# NIC-MINSA/CNDR CIRE-07/09/15-063.Ver1.** En el futuro, usted debe plasmar este código a cualquier correspondencia relacionada con este estudio y el CIRE.

EL CIRE HA DECIDIDO APROBAR SU PROYECTO PRESENTADO EN SU FORMA ACTUAL, SIN OBSERVACION ALGUNA.

La fecha de expiración de éste aprobación es hasta el **01 de Octubre del 2016**. *Si, su estudio o proyecto de investigación se prolongará más de esta fecha usted (es) deben solicitar una nueva aprobación,* (aproximadamente 6 semanas antes de la fecha de su vencimiento). Usted (es) deben solicitar al CIRE el formulario de renovación de estudios y/o protocolos de investigación, para acceder a una nueva aprobación, se pide cumpla con el llenado y entrega en las fechas estipuladas.

Es importante mencionar, que aunque el CIRE ha aprobado su proyecto de investigación en su forma actual, si usted (es) realizan cambios tanto estructurales como en el diseño de investigación en el que de alguna forma se afecte a los sujetos humanos incluidos en estudio, usted tiene la obligación de notificar inmediatamente al CIRE, en caso contrario usted (es) estarían cayendo en desacato y sujeto a sanciones administrativas o penales, según lo amerite el caso. O bien, si uno de sus sujetos incluidos en estudio presenta un evento adverso durante el transcurso de la investigación, usted también debe notificar lo más tardar en los primeros 10 días subsiguiente al evento.

Durante el transcurso del estudio y/o proyecto de investigación El CIRE puede realizar sin previo aviso revisión del cumplimiento de las actividades contempladas en su protocolo de investigación.

Cordialmente,

Dr. Alberto Montoya Pérez
Coordinador del CIRE
CNDR- MINSA

CENTRO NACIONAL DE DIAGNOSTICO Y REFERENCIA COMITE DE ETICA MINSA Nicaragua

cc: Archivo.

COMPLEJO NACIONAL DE SALUD, DRA. CONCEPCION PALACIOS
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ACTA DE NOTIFICACIÓN DE DECISION DEL CIRE

Estimados investigadores:

Sr. Christian Borja–Vega, Economista Senior y PGR Universidad de Leeds.

El Comité Institucional de Revisión Etica (**CIRE**), del Centro Nacional de Diagnóstico y Referencia del Ministerio de Salud de Nicaragua, se reunió el día 20/11/2018, con el objetivo de revisar el protocolo y anexos recibidos con 14/11/2018 de la investigación que lleva por nombre **"Proyecto de Sostenibilidad del Sector de Agua y Saneamiento Rural de Nicaragua (PROSARS)"**; registrado con el código **# NIC-MINSA/CNDR CIRE-07/09/15-063.Ver2.** En el futuro, usted debe plasmar este código a cualquier correspondencia relacionada con este estudio y el CIRE.

EL CIRE HA DECIDIDO APROBAR RENOVACION DE SU PROYECTO PRESENTADO EN SU FORMA ACTUAL, SIN OBSERVACION ALGUNA.

La fecha de expiración de éste aprobación es hasta el **01 de Octubre del 2019**. *Si, su estudio o proyecto de investigación se prolongará más de esta fecha usted (es) deben solicitar una nueva aprobación, (a*proximadamente 6 semanas antes de la fecha de su vencimiento). Usted (es) deben solicitar al CIRE el formulario de renovación de estudios y/o protocolos de investigación, para acceder a una nueva aprobación, se pide cumpla con el llenado y entrega en las fechas estipuladas.

Es importante mencionar, que aunque el CIRE ha aprobado su proyecto de investigación en su forma actual, si usted (es) realizan cambios tanto estructurales como en el diseño de investigación en el que de alguna forma se afecte a los sujetos humanos incluidos en estudio, usted tiene la obligación de notificar inmediatamente al CIRE, en caso contrario usted (es) estarían cayendo en desacato y sujeto a sanciones administrativas o penales, según lo amerite el caso. O bien, si uno de sus sujetos incluidos en estudio presenta un evento adverso durante el transcurso de la investigación, usted también debe notificar lo más tardar en los primeros 10 días subsiguiente al evento.

Durante el transcurso del estudio y/o proyecto de investigación El CIRE puede realizar sin previo aviso revisión del cumplimiento de las actividades contempladas en su protocolo de investigación.

Cordialmente,

Dr. Alberto Montoya Pérez
Coordinador del CIRE
CNDR- MINSA

CENTRO NACIONAL DE DIAGNOSTICO Y REFERENCIA
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MINSA, Nicaragua

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4/4/2017 Nicaragua - Sustainable Water Supply and Sanitation Project Impact Evaluation 2015-2016, Baseline Survey - Data Access

IHSN
International Household Survey Network

IHSN Survey Catalog

SHARE

HOME › IHSN SURVEY CATALOG › NIC_2015_SWSSPIE-BL_V01_M › DATA ACCESS

Nicaragua - Sustainable Water Supply and Sanitation Project Impact Evaluation 2015-2016, Baseline Survey

Reference ID	NIC_2015_SWSSPIE-BL_v01_M
Year	2015
Country	Nicaragua
Producer(s)	Joshua Gruber - Centre for Effective Global Action (CEGA), University of Berkeley, California Christian Borja Vega (World Bank Group)
Sponsor(s)	Strategic Impact Evaluation Fund - SIEF - Main Funder of the Impact Evaluation Fondo de Inversión Social de Emergencia - FISE - PROSASR implementing agency, in kind contributions through mobilization and facilitation of government contacts. Sp

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DOCUMENTATION | STUDY DESCRIPTION | DATA DESCRIPTION

Overview
Sampling
Data Collection
Data Processing
Data Appraisal
Data Access
Export Metadata

Data Access

Access Authority

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Confidentiality

We are stripping all identifiers from the dataset.

Access Conditions

Licensed dataset

Citation Requirements

Use of the dataset must be acknowledged using a citation which would include:
- the Identification of the Primary Investigator
- the title of the survey (including country, acronym and year of implementation)
- the survey reference number
- the source and date of download

Joshua Gruber, University of Berkeley, California, Christian Borja Vega, Lilian Pena Weiss, Clementine Marie Stip and Sophie Ayling, World Bank Group. Nicaragua Sustainable Water Supply and Sanitation Project Impact Evaluation, Baseline Survey (SWSSPIE-BL) 2015-2016, Ref. NIC_2015_SWSSPIE-BL_v01_M. Dataset downloaded from [url] on [date].

Disclaimer

The user of the data acknowledges that the original collector of the data, the authorized distributor of the data, and the relevant funding agency bear no responsibility for use of the data or for interpretations or inferences based upon such uses.

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5.5.1.Survey Instruments

The questionnaires of the baseline survey can be downloaded at:

https://catalog.ihsn.org/index.php/catalog/6520/related-materials

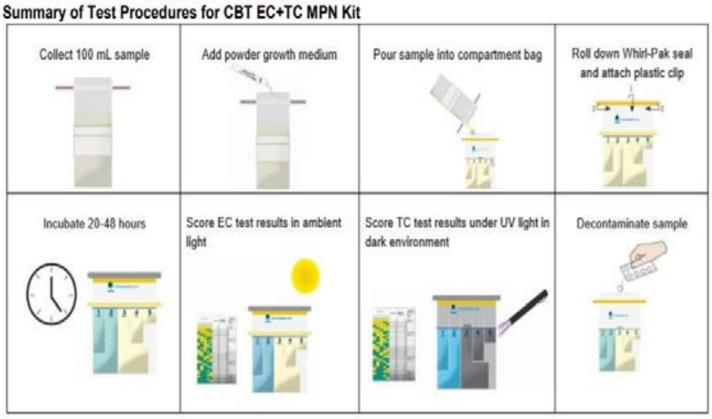
The questionnaires of the endline survey are available at:

https://worldbankgroup-my.sharepoint.com/:f:/g/personal/cborjavega_worldbank_org/EhsDCmy3Vf1Cj0yVjI4pEV0BoXVqmBy82EwJoYa1zwIjOQ

5.5.2.Water Quality Test and Protocols[49]

The test utilized for measuring water quality Aquagenx® basic field kit that simultaneously detects and quantifies E. coli (EC) and Total Coliforms (TC) in a 100 mL sample. It uses a proprietary powder growth medium with a glucose substrate called X-Gluc. When E. coli metabolize this substrate in Aquagenx's growth medium, the color of the water turns blue, indicating the presence of E. coli. The process of collecting samples of this test are shown below.

Summary of Test Procedures for CBT EC+TC MPN Kit



How to Interpret Color-Change Test Results

Color of compartment in Compartment Bag	Yellow/Yellow Brown in ambient light and does not fluoresce blue under UV light	Yellow/Yellow Brown that ... fluoresces blue under UV light	Blue/Blue Green in ambient light	Blue/Blue Green that... fluoresces blue under UV light
E. coli	Negative	Negative	Positive	Positive
Total Coliforms	Negative	Positive	Positive	Positive

Figure 5-3 Procedure of Aguagenx test utilised in the water samples of the Impact Evaluation

The Aquagenx® thresholds of water pollution is based on the World Health Organization "Guidelines for Drinking Water Quality," 4th Edition. MPN of E. coli per 100 mL is estimated from the combination of positive (blue color) and negative (no blue color) compartments in the Aquagenx® Compartment Bag. MPN of Total Coliforms per 100 mL is estimated from the combination of positive (blue fluorescence under UV light) and negative (no blue fluorescence under UV light) compartments in the Aquagenx® Compartment Bag. Based on these protocols from the kit, the test was piloted in Nicaragua at both baseline and endline survey with training to surveyors with specific protocols to identify potential sources of errors committed in the field for capturing and collecting tests. These pilot activities were then reflected in a protocol

[49] The full procedure of test application is available at: https://www.aquagenx.com/wp-content/uploads/2019/06/MPN-CBT-ECTC-Instructions-DrinkingWater-June2019.pdf

process in Spanish to help surveyors understand what sort of issues can emerge if the test was not collected properly according to the protocol.

Figure 5-4 Testing Protocol for the Surveyors in Nicaragua

Chapter 6. Impact Evaluation Baseline Results[50]

6.1. Publications and Awards

This chapter contains edited relevant highlights of work that has also been presented in *Borja-Vega, Christian; Gruber, Joshua Sean; Spevack, Alexander Matthew. 2017. Increasing the sustainability of rural water service: findings from the impact evaluation baseline survey in Nicaragua (English). Policy Research working paper; no. WPS 8283; Impact Evaluation series. Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/291431513690985209/Increasing-the-sustainability-of-rural-water-service-findings-from-the-impact-evaluation-baseline-survey-in-Nicaragua*. The publication of the baseline study has been recognized in recent systematic reviews, such as: *Miller, M., Cronk, R., Klug, T., Kelly, E.R., Behnke, N., Bartram, J., 2019. External support programs to improve rural drinking water service sustainability: A systematic review. Sci. Total Environ. 670, 717–731. https://doi.org/10.1016/j.scitotenv.2019.03.069*. Furthermore, this baseline study was recognized in the last water and sanitation conference, LATINOSAN (2019). The co-authors are Josh S. Gruber[51] University of California, Berkeley (co-author) and Alexander Spevack policy officer USAID (co-author). As stated in the publication, the paper received comments from the following: Barbara Evans (University of Leeds) and Miller Camargo (University of Leeds), Lilian Pena, Sophie Ayling, Clementine Stip, and Maria Eliette Gonzalez Perez (World Bank). The paper also benefited from the following for valuable comments: Vincenzo Di Maro (World Bank), Richard Damania (Chief Economist, World Bank), Victor Orozco (Development Impact Evaluation Initiative-DIME), Alaka Holla (SIEF), Luis Andres (World Bank).

[50] Based on Borja-Vega, Gruber, J. and Spevack, A. (2017) Increasing the sustainability of Rural Water Service: Findings from the Impact Evaluation Baseline Survey in Nicaragua. Policy Paper Series (WPS8283) World Bank, Washington D.C. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/29071/WPS8283.pdf?sequence=1&isAllowed=y

[51] See list of publications of Dr Josh Gruber: https://academictree.org/epidemiology/publications.php?pid=267877

POLICY RESEARCH WORKING PAPER 8283

Increasing the Sustainability of Rural Water Service

Findings from the Impact Evaluation Baseline Survey in Nicaragua

Christian Borja-Vega
Joshua Gruber
Alexander Spevack

WORLD BANK GROUP
Water Global Practice Group
December 2017

6.2. Cover Sheet: Relevance for Thesis

This baseline published showed the statistical comparison of treatment and control communities of the impact evaluation. The approach was based on an RCT methodology for assessing the institutional strengthening, the AVAR (*Aprendizaje Vinculado a Resultados*) or "Results Oriented Learning," carried out through a series of capacity building sessions to the UMAS (or equivalent unit at the municipal level in charge of WSS support to communities through CAPS), which include practical training activities directly between the UMAS and the communities/CAPS within the territory of each UMAS. The baseline study helped assessing the validity and proper implementation of the random assignment of AVAR and a secondary set of trainings to CAPS (ARAS). Both training programs aimed at improving the provision and quality of WSS services at the community level through a chain of activities: enhancing the UMAS' ability to provide better technical assistance to their communities/CAPS, thereby improving the CAPS ' ability to manage their WSS systems, ultimately resulting in better WSS services to the communities at the household level.

6.3. Abstract (as appears in publication)[52]

This report presents the descriptive statistics and analytics of a baseline survey conducted in 2016 for an impact evaluation that aims to measure the causal impact of a large-scale rural water supply and services program (PROSASR) in Nicaragua. The objective of the overall evaluation is to assess the causal impact between the provision of technical assistance packages and improvements in functionality and durability of water supply systems at the community level in rural areas of Nicaragua. At baseline, data was gathered to assess current levels of functionality and durability of water supply and sanitation (WSS) services, including an assessment of the structure and preparedness of the WSS system providers and information related to the rural communities (households) they serve, prior to the implementation of the intervention in both treatment and control groups. By exploiting and analysing the baseline survey, our results suggest that the randomisation of the program assignment into treatment and control groups resulted in balanced characteristics. In addition, several indicators were used to identify key determinants of rural water systems' sustainability. These

[52] This chapter is one of the core components of my research thesis and it is reproduced as it is published with just some adaptations in language and length. This facilitated the adaptation of the chapter into the thesis and the presentation of relevant results.

results help determine the roadmap for constructing a consistent end-line survey (2018) to conclude the evaluation and obtain practical policy and program recommendations to improve its effectiveness.

6.4. Introduction

Despite improvements in poverty alleviation and increased equality in recent years, Nicaragua remains one of the poorest countries in Latin America. Approximately 42% of its 5.9 million inhabitants live below the poverty line and nearly 15% live in extreme poverty.[53] Poverty in Nicaragua is disproportionately rural,[54] with about half of rural Nicaraguans poor compared to 15 percent of the urban population, as of 2014. In rural areas, access to basic services, like Water Supply and Sanitation (WSS), is constrained by a combination of poor infrastructure and poor institutional capacity. In fact, as of 2011, improved water source and improved sanitation[55] coverage levels stood at 85% and 52%, respectively, up from 80% and 48% in 2000.[56] As of 2011, relative to the MDG targets for improved water and sanitation coverage (88% and 75%, respectively), Nicaragua appeared likely to achieve the improved water coverage goal, yet further away from its improved sanitation objective.[57] At the same time, there is also a geographic dynamic to WSS coverage with significantly greater coverage gaps in rural areas in comparison to urban areas. While water coverage and sanitation coverage in urban areas are at 98% and 68%, respectively, in rural areas, they are significantly lower at just 63% and 37%. Nationally, the regions exhibiting the lowest relative percentages of coverage are the Caribbean Coast (North Caribbean Coast Autonomous Region, or RACCN, and South Caribbean Coast Autonomous Region, or RAACS) regions, as well as Alto Wangki and Bokay.[58]

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[53] Source: INIDE (2009)

[54] The World Bank Group's Poverty Reduction Strategy Paper for Nicaragua (Report No. 53710-NI) states that general poverty is 2.5% higher than the national average in rural areas and 3.2% higher on the Caribbean coast.

[55] An improved drinking-water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter. An improved sanitation facility is defined as one that hygienically separates human excreta from human contact (source: JMP/WHO website 2013).

[56] UNICEF/WHO (2013), "United Nations Joint Monitoring Program, 2013 Update".

[57] The most recent improved water and sanitation percentages are available as of 2011. As such, is not possible to verify the extent to which Nicaragua achieved WASH-related MDGs.

[58] The RAACN, RAACS, and Alto Wangki and Bokay have traditionally been marginalized with respect to access to basic goods and services.

Existing research shows that the construction of WSS infrastructure on its own is not enough for sustainable rural WSS service delivery (Parker, 1997; Taylor, 2013; Marks et al., 2014). Evidence demonstrates the importance of complementing WSS infrastructure investments with capacity-building of local water authorities to ensure the sustainable operation of rural WSS systems (WSSCC, 2010; WSP, 2011; Raman and Tremolet, 2009). However, rigorous evidence on the relationship between rural WSS system sustainability and the timeliness and quality of technical assistance provided to municipalities and communities is limited.

In Nicaragua, rural WSS systems are managed by water boards[59] known as *Comités de Agua Potable y Saneamiento* (CAPS).[60] Post-construction WSS systems and CAPS have traditionally received unreliable technical and organizational support from municipal or national authorities, undermining the sustainability and functionality of systems. Despite proposals for municipal and national government entities to provide CAPS with support, only 29% of CAPS reported receiving technical assistance from municipal technical support providers (*Unidades Municipales de Agua y Saneamiento*, or UMAS) (World Bank, 2014). As a result, just 64% of communities with community water systems received more than 16 hours of water service daily, as of 2013 (World Bank, 2014).[61]

An increase in WSS access is a pillar of Nicaragua's 2012-2016 National Plan for Human Development. In recognition of the need to complement WSS access with sustainable and high quality WSS services, the Government of Nicaragua and the World Bank have identified a need to strengthen CAPS' support structure at the municipal, regional, and national levels. In 2013, the Nicaraguan government developed a national plan to this effect (the *Programa Integral Sectorial de Agua y Saneamiento*), officially naming the *Fondo de Inversión Social de Emergencia* (FISE) as the government institution in charge of rural WSS at the national level. In 2014, the World Bank and the Government of Nicaragua began implementing a project with the objective of increasing access to sustainable WSS services in poor rural areas in

[59] In some cases, water boards are made up of volunteers; in others, members are compensated monetarily for their services. According to data at baseline, 43% of CAPS received some sort of monetary remuneration for their services.
[60] At the local level, CAPS have the mandate for both rural water and sanitation services.
[61] Based on data collected by the *Fondo de Inversión Social de Emergencia* (FISE), the national government entity in charge of overseeing the country's CAPS, using the rural water and sanitation information system (SIASAR).

Nicaragua by way of the consolidation of rural WSS institutions and the construction of adequate system infrastructure. This project is expected to run through 2019. A core component of this project, the Sustainable Water Supply and Sanitation Sector Project, or PROSASR in Spanish, is the provision of technical assistance to FISE with the objective of improving its capacity to provide technical assistance to municipal water authorities (UMAS) responsible for supporting local water boards (CAPS), and the ultimate goals of increasing access to and improving the quality of rural WSS services.

In the following paper, we analyse baseline data from a randomised and controlled impact evaluation (IE) of the UMAS capacity-building component of PROSASR. In the context of rural water systems, there is some evidence regarding the factors contributing to the long-run sustainability of water systems, including, for example, water board technical capacity and organization, financial management, community participation, the condition of water system infrastructure, and the provision of technical assistance by external actors (Walter and Chinowsky, 2016; Moriarty et al., 2013). However, rigorous evidence, such as through random control trials (RCTs), on the relative contributions of different factors is currently lacking. As such, a more robust exploration of the causes of WSS service sustainability is necessary.

Besides providing descriptive statistics from IE baseline data collection, this paper investigates the correlates of water system sustainability, described in this context in terms of (i) water service continuity (e.g., hours of service) and (ii) water quality. No causal link should be drawn from the results of bivariate regressions investigating the relationship between system and CAPS independent variables with water service continuity and water quality. Nonetheless, the analyses we present may provide some insight to PROSASR going forward, as well as to other projects aimed at increasing the sustainability of rural WSS services in the developing world.

This publication presented as a chapter of this Thesis is organized in the following way. Section 6.5 describes the context of the Nicaraguan WSS sector, the PROSASR project. Section 6.6 shows data collection. Section 6.7 presents the validation of the impact evaluation design by briefly comparing baseline data with the most recent National Demographic and Health Survey (DHS) in Nicaragua from 2011 to evaluate the representativeness of the IE sample. Section 6.8 reports descriptive statistics, of baseline surveys at the household, community, service provider, and water system levels, including microbiologic water quality tests (Section 6.9). Section 6.10 briefly assesses the balance of key household, system and community characteristics across treatment and control groups. Section 6.11 makes use of baseline data to show correlates and explore the determinants of water service continuity and quality by way or bivariate regressions in an effort to contribute to the empirical knowledge of factors contributing to water system sustainability. Section 6.12 offers a discussion of the results presented in this paper and their implications. Section 6.13 provides a brief discussion and conclusion.

6.5. Nicaragua's Context of Rural Water Sector

Nicaragua has significant coverage gaps in WSS service provision, particularly in poor rural areas. In 2011, at the national level, the country had 85% coverage of improved water and 52% coverage of improved sanitation, up from 80% and 48%, respectively, in 2000, putting it on track to achieve its MDG improved water target (97%), but not its sanitation goal (72%). There are also significant disparities in access between urban and rural households for both water (98% and 68% in urban and rural areas, respectively) and sanitation (63% and 37%, respectively).

The largest territorial unit in Nicaragua is the department, of which there are 17, including two self-governing autonomous regions (the RAACS and RAACN). Thereafter, departments are sub-divided into municipalities, of which there are 153, with municipalities subsequently sub-divided into communities.

The rural WSS sector is governed by institutions stretching from the national level, where water and sanitation policymaking and planning occurs, to the community level, where local WSS systems are managed by community water boards. Institutional infrastructure begins at the national level with the *Fondo de Inversión Social de Emergencia* (FISE). In 2013, the Government of Nicaragua developed a National Water and Sanitation Sector Strategy Plan (*Programa Integral Sectorial de Agua y Saneamiento Humano*, PISASH) and put FISE in charge for ensuring sustainable rural WSS service provision at the national level.[62] FISE is responsible for general

[62] The urban WSS sector is covered by the national WSS utility, ENACAL (*Empresa Nicaragüense de Acueductos y Alcantarillados Sanitarios*)

coordination of the rural WSS sector, policymaking, planning, contracting and implementing works,[63] and capacity-building at the municipality and community level.

It is important to note that even though FISE is recognized as the sole institution in charge of the rural WSS sector by several presidential decrees, officially, the legal framework still attributes responsibility for rural WSS service provision to ENACAL, the national WSS utility. However, ENACAL has gradually withdrawn from the rural sector and now provides WSS services exclusively in urban areas with no overlap with FISE's intervention areas.

6.6. Baseline Data Collection

Baseline data collection began in November 2015 and concluded in January 2016. It included surveys at the household, system, CAPS, and UMAS levels, assessing current levels of functionality and durability of WSS services, including an assessment of system infrastructure, CAPS institutional capacity, as well as water access and use characteristics of the communities and households they supply water to. PROSASR's near-term objective is to strengthen institutional capacity at the municipality level. However, in the long-term, it is expected that project impacts are felt at the community and household levels in the form of increased WSS coverage and continuity, as well as a decreased prevalence of waterborne diseases.[64]

The first survey was directed at the CAPS president or another individual with knowledge of the community water system (in the case that there was no formal CAPS in the community). It included (i) community, (ii) system infrastructure, and (iii) service provider modules. Questions were aimed at measuring key indicators which will ultimately be used to gauge the extent of PROSASR's impact on WSS service

[63] In the context of PROSASR, FISE investments are implemented through a participatory project cycle. Contracting of works is delegated to municipalities, while the preparation of technical studies and engineering designs is led by FISE (due to higher relative technical capacity) in coordination with municipalities to build local capacity and ownership. In some cases, technical studies and engineering designs are delegated to municipalities with high technical capacities. In some cases, municipalities may delegate works to communities. WSS infrastructure projects are implemented through transfers from FISE to municipalities, and, in some cases, from municipalities to communities. In the case of Alto Wangki and Bokay, given that there are no municipal governments, implementation of WSS works is centralized in FISE. Nonetheless, communities are to be involved in decision-making as it relates to service level and technical options, participating in construction, and managing completed systems (World Bank, 2014).

[64] This was not included in the analysis because of the usual temporal challenges to doing so.

provision, system administration, CAPS organization, water quality, as well as community water and sanitation practices.

Second, a household survey was carried out in 4,850 households in 300 communities with questions assessing where households collect drinking water, access to and use of sanitation facilities, and needs, perceptions, and expenses related to WSS services in their community.[65] Questions regarding ownership of a variety of household assets allowed for the creation of an asset wealth index, using principal component analysis (PCA) (included in the Annex). Said index allows us to assess the relative distribution of wealth across the sample, as well as compare the wealth distribution across control and treatment households.

Additionally, one municipal-level survey was conducted in each of the 75 municipalities included in the sample frame with the UMAS or equivalent municipal water institution.

6.6.1.Water Quality Tests

Water samples were collected at the system and household level to test for the presence of *Escherichia coliform* (*E. coli*) and chlorination as indicators of water quality and confirmation of reported water treatment. Tests were conducted at different points throughout water systems and households to understand if and how water quality deteriorates from a system's source(s) to individual households. *E. coli* samples were taken using Aquagenx CBT II Kits, which detect and quantify the most probable number (MPN) of E. coli in a 100 mL water sample according to World Health Organization recommendations for water quality testing. Chlorination samples were taken using Lamotte Insta-Test Strips for Free Chlorination. Survey field team members were trained in how to collect both types of samples in anticipation of fieldwork.

E. coli samples were taken in a random selection of 57% of all communities at the following strategic points:

- *System.* Samples were collected from source storage tanks, after treatment, if applicable. In cases in which no treatment infrastructure exists, a sample was collected at the storage tank before it entered the network.

[65] A sampling strategy was utilized to ensure that the number of households surveyed per community was representative of the distribution of the number of households per community.

- *Household.* Two samples were collected at the household level: One sample was taken from the tap; a second sample was collected from the storage container from which the respondent last drank water – water for the sample was collected in a glass or serving utensil the respondent would have used to take a drink, just prior to consumption.

Following water quality tests, samples were assigned a risk category based on *E. coli* counts: samples with 0 MPN were deemed “safe,” samples with between 1 and 10 MPN “intermediate,” samples with between 10 and 100 “high” and above 100 “very high.” Water quality kits had a detection limit of 101 MPN *E. coli*.

6.7. Validation of Baseline Survey Representativeness with Demographic and Health Survey (DHS)

The context of the impact evaluation is necessarily rural given the objective to understand the factors contributing to the sustainability of rural WSS systems. Municipalities (and communities) from all 15 of Nicaragua’s departments and two autonomous regions are included in the sample, with the exception of the department of Masaya in the Central Region. **Table 6-1** compares baseline data with the most recent Demographic and Health Survey (DHS) from 2011. The IE sample includes a greater number of households in the Central Region and fewer households from the Atlantic Region compared to the 2011 DHS national rural sample. **Table 6-2** shows the age distribution of households included in the IE sample compared the DHS sample. Households in our sample are generally representative of the age distribution in the national rural sample from 2011 DHS.

Table 6-3 exhibits the distribution of floor and roof household materials, as indicators of living conditions. Evaluation households appear to have a higher percentage of concrete/tile floors and a lower percentage of earth/dirt floors, compared to the rural DHS sample; roof materials appear to be generally comparable.

Table 6-4 shows descriptive statistics from the DHS and from the evaluation sample for head of household demographic and education characteristics. The proportion of male household heads in the IE sample is just 54% compared to 76% in the rural DHS sample. Furthermore, a much greater percentage of sample household heads have no primary education than in the rural-only 2011 DHS (37% versus just 3%, respectively); our sample was restricted to communities with poorly-functioning water systems, which may be correlated with lower levels of education.

Table 6-5 provides a comparison of the IE sample and the 2011 DHS with respect to variables relevant to the impact evaluation, including sanitation, household water sources, time to retrieve water, household water treatment frequencies, and the prevalence of childhood diarrhoea. Like differences in household infrastructure across surveys, data on WSS service provision is indicative of increases in WSS coverage. A greater proportion of households in the sample have access to a sanitation facility (89%) than for rural households in the 2011 DHS (80%). Similarly, 62% of households are connected to a community water system in the evaluation sample, more than twice the proportion of rural households with water system connections according to the 2011 DHS (29%). Interestingly, households in the IE sample spend less time retrieving water—just 8 minutes on average—relative to 17 for rural households in the 2011 DHS. However, fewer households in the IE sample treat their water (24%) than households included in the 2011 DHS (31%), perhaps due to increased confidence in water quality, or the belief that water is being treated through community systems. Children in households covered by the evaluation exhibit diarrhoea symptoms in 7% of households, the same percentage as for households in the 2011 DHS.[66] The results described in this section indicate that the IE sample is fairly representative of poor rural households in Nicaragua; however, there is evidence that the PROSASR intervention sample probably differs from the national rural sample in important ways, likely related to the target population and eligibility constraints of the intervention study.

	2011 DHS Data			**Evaluation**
	Nicaragua N = 19,918	**Rural Sample N = 9,481**	**Common Municipalities[1] N = 5,680**	**Baseline Sample N = 4,850**
Region				
Pacific	45%	30%	20%	33%
Central	40%	50%	68%	58%
Atlantic	15%	21%	12%	9%

[1] Households in the third column represent the municipalities covered by the impact evaluation that were also included in the 2011 Nicaragua DHS.

Table 6-1 Geographic Representativeness of Baseline Survey (2015) Relative to DHS 2011

[66] In the baseline survey, respondents were asked whether a child had diarrhoea symptoms in the last week. In the 2011 DHS, households were asked whether a child showed diarrhoea symptoms in the last two weeks. Percentages presented for diarrhoea prevalence from the DHS sample were divided in two to enable a comparison with the percentage from the baseline survey, which assumes that prevalence and prevalence reporting remain constant over both time periods.

	2011 DHS Data			Evaluation
	Nicaragua N = 19,918	Rural Sample N = 9,481	Common Municipalities[1] N = 5,680	Baseline Sample N = 4,850
Age Group				
HH members, 5 and under	12%	14%	14%	13%
HH members, 6-13	17%	20%	20%	17%
HH members, 14-30	34%	34%	34%	34%
HH members, 31-65	31%	28%	28%	31%
HH members 65+	6%	5%	5%	5%

[1] Households in the third column represent the 69 municipalities covered by the impact evaluation that were also included in the 2011 Nicaragua DHS.

Table 6-2 Age distribution of baseline survey (2015) and DHS (2011)

	2011 DHS Data			Evaluation
	Nicaragua N = 19,918	Rural Sample N = 9,481	Common Municipalities[1] N = 5,680	Baseline Sample N = 4,850
Floor Material				
Concrete/tile	54%	31%	28%	42%
Wood	5%	6%	3%	3%
Earth/dirt	41%	63%	68%	56%
Roof Material				
Zinc sheet	87%	84%	84%	88%
Tiled	9%	11%	14%	10%
Fiberglass/asbestos	2%	1%	1%	1%
Palm or non-permanent	2%	3%	2%	1%

[1] Households in the third column represent the 69 municipalities covered by the impact evaluation that were also included in the 2011 Nicaragua DHS.

Table 6-3 Distribution of household infrastructure in Baseline Survey (2015) and DHS (2011)

	2011 DHS Data			Evaluation
	Nicaragua N = 19,918	Rural Sample N = 9,481	Common Municipalities[1] N = 5,680	Baseline Sample N = 4,850
Household Head				
Average age	47.47	45.75	45.55	46.39
% male	65%	76%	78%	54%
Household Head Education				
No Primary	2%	3%	3%	37%
Primary	55%	75%	78%	44%
Secondary	26%	17%	14%	12%
Post-secondary	16%	4%	3%	3%
Other	1%	2%	2%	5%

[1] Households in the third column represent the 69 municipalities covered by the impact evaluation that were also included in the 2011 Nicaragua DHS.

Table 6-4 Distribution of Household's Head Characteristics and Education Levels in Baseline Survey (2015) and DHS (2011)

	2011 DHS Data			Evaluation
	Nicaragua N = 19,918	Rural Sample N = 9,481	Common Municipalities[1] N = 5,680	Baseline Sample N = 4,850
Water and Sanitation Access				
Has a Sanitation Facility	89%	80%	79%	89%
Connected to comm. system	61%	29%	23%	62%
Public or private source	3%	6%	7%	2%
Well	16%	27%	27%	20%
Surface water	16%	32%	37%	9%
Other	4%	6%	6%	7%
Water and Sanitation Use and Health				
Minutes to fetch water	16.78	17.54	18.91	8.18
Treats water	26%	31%	30%	24%
Treats water through chlorination	23%	28%	27%	20%
Child with diarrhoea symptoms[2]	7%	7%	7%	7%

[1] Households in the third column represent the 69 municipalities covered by the impact evaluation that were also included in the 2011 Nicaragua DHS. [2] In the baseline survey, respondents were asked whether a child had diarrhoea symptoms in the last week. In the 2011 DHS, households were asked whether a child showed diarrhoea symptoms in the last two weeks. Percentages presented for diarrhoea prevalence from the DHS sample were divided in two to enable a comparison with the percentage from the baseline survey, which assumes that prevalence and prevalence reporting remain constant over both time periods.

Table 6-5 Selected impact evaluation variables of interest from Baseline Survey (2015) and DHS (2011)

Source: Own elaboration based on DHS and impact evaluation baseline survey data

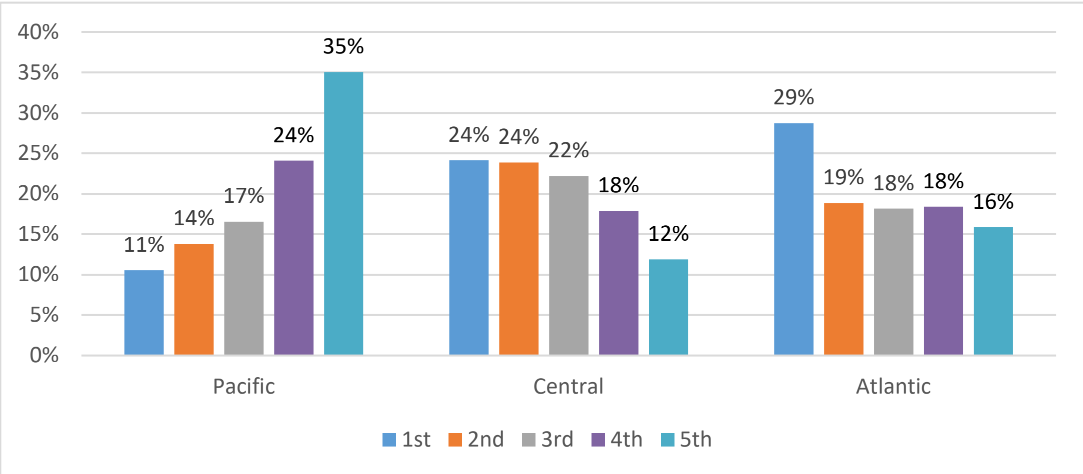
6.8. Descriptive statistics

The following section exploits baseline data from the present impact evaluation of PROSASR in Nicaragua to describe the current state of WSS services in rural Nicaragua.

6.8.1. Household asset ownership

The survey did not include any questions on income or household revenues; however, it did include questions about asset ownership. The answers to these questions were the basis of wealth score calculations, subsequently utilized to construct household wealth quintiles as a proxy for socioeconomic status. Descriptive statistics for household asset ownership is displayed in **Table 6-6**. The most frequently owned assets are cell phones (65%), televisions (64%), and radios (60%). There is a general tendency for ownership of a majority of assets (i.e., television, refrigerator, iron) to increase with household wealth quintile, given that these and other assets were those used to construct the wealth index. Interestingly, cell phone ownership is relatively widespread, with only the poorest quartile significantly less likely to own a cell phone (27%) with respect to an overall average of 65%. In terms of household building material, earth/dirt floors are the most common (56%) with concrete/tile floors concentrated among households in wealthier wealth quintiles (42%, overall, but 85% among the wealthiest wealth quintile of households). With regards to roof material, zinc sheets are present in a clear majority of households (88%), while tiled roofs are more common among the poor (10% overall, but 17% in the poorest wealth quintile).

Figure 6-1 below shows the distribution of households by region and household wealth quintile. Overall, Pacific Region households are wealthier than Central and Atlantic households with Atlantic households exhibiting the highest levels of poverty, based on household wealth scores, of any region.



Note: represents data from the entire baseline sample

Figure 6-1 Distribution of Households by Household Wealth Quintile and Region

		Household Wealth Quintile[1]				
	Whole Sample N = 4,850	**1st N = 970**	**2nd N = 972**	**3rd N = 968**	**4th N = 970**	**5th N = 970**
% of Households:	Mean	Mean	Mean	Mean	Mean	Mean
Radio	60%	66%	65%	61%	52%	57%
Television	64%	7%	51%	72%	94%	99%
Refrigerator	25%	0%	2%	7%	35%	81%
Iron	34%	1%	8%	22%	50%	86%
Grinding Machine	35%	41%	38%	34%	31%	31%

Cassette Recorder	6%	1%	3%	5%	7%	14%
Stereo	20%	0%	3%	9%	27%	59%
Fan	21%	0%	1%	9%	28%	67%
Blender	17%	0%	0%	2%	17%	66%
Sewing Machine	7%	0%	4%	5%	8%	16%
Bicycle	28%	7%	18%	25%	34%	56%
Motorcycle	14%	2%	5%	8%	18%	37%
CD Player/DVD Player	19%	0%	1%	9%	26%	60%
Cell Phone	65%	27%	61%	68%	79%	92%
Computer	2%	0%	0%	0%	1%	10%
Household Infrastructure						
Floor Material						
Concrete/tile	42%	0%	10%	51%	62%	85%
Wood	3%	1%	3%	5%	2%	1%
Earth/dirt	56%	98%	86%	45%	36%	14%
Roof Material						
Zinc sheets	88%	79%	87%	91%	90%	93%
Tiled	10%	17%	12%	8%	8%	6%
Fiberglass/asbestos sheets	1%	1%	1%	1%	1%	1%
Palm or non-permanent	1%	3%	1%	0%	0%	0%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-6 Distribution of Household's Assets by Household Wealth Quintile

6.8.2.Water source, sanitation, and hand/environmental hygiene conditions

Table 6-7 presents descriptive statistics for the project sample with regards to water source characteristics, household sanitation, as well as hand and environmental hygiene conditions, by region.[67] 81% of all households in the sample have an improved water source, with 62% of households connected to a community water system. See **Figure 6-2** for comparisons of the relative levels of WSS coverage across regions. Households in the Pacific Region exhibit higher proportions of households with an improved water source[68] and connected to a community system[69] (88% and 66%, respectively) in comparison to households in the Central (78% and 59%) and

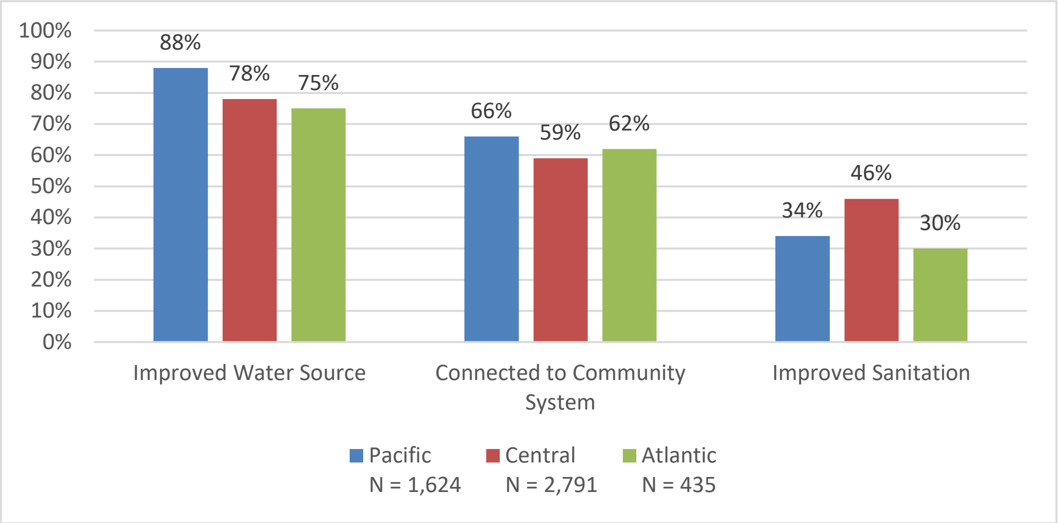
[67] The definitions for improved sanitation and improved water source are based on that of the WHO/UNICEF (2008) Joint Monitoring Programme for Water Supply and Sanitation (JMP). Improved sanitation includes (i) a flush toilet that empties into a sewer, septic tank, or pit; (ii) a ventilated improved pit (VIP) latrine; and (iii) an ecological dry latrine. Improved water sources include (i) systems connected to the community water system; (ii) protected springs; (iii) protected wells; and (iv) rainwater harvesting systems.

[68] Means differences are significant at the 1 percent level for the Pacific versus both the Central and Atlantic Regions (p-value of 0.000 in both instances).

[69] Means differences are significant at the 1 percent level for the Pacific versus the Central (p-value of 0.000); Pacific-Atlantic means differences exhibit a p-value of 0.108.

Atlantic (75% and 62%). 89% of all sample households have a sanitation facility; however, just 40% have improved sanitation. The Central Region exhibits the highest level of improved sanitation of the three regions (46% versus 34% and 30% in the Pacific and Atlantic Regions, respectively).[70] Open defecation is also the highest in the Central Region (13%) in comparison to the Pacific (8%) and Atlantic (9%).

Households were asked whether they have sufficient water to attend to their daily water needs (i.e. bathing, washing clothing, preparing food) in the wet and dry seasons, respectively. Overall, 81% of households report having sufficient water in the wet season compared to just 61% in the dry season. Households in the Atlantic region report having enough water in the wet and dry seasons with greater frequency than households in either the Pacific or Central regions.[71]



Note: represents data from the entire baseline sample

Figure 6-2 Proportion of HH with improved water sources and improved sanitation, by region

[70] Means differences are significant at the 1 percent level between the Central and Pacific and the Central and Pacific (p-value of 0.000). Atlantic-Pacific means differences exhibit a p-value of 0.093.

[71] Means differences for the dry season are significant at the 1 percent level, with the exception that differences between the Atlantic and Pacific coasts exhibit a p-value of 0.080. Means differences for the wet season are also significant at the 1 percent level, except for Pacific-Central Region differences.

	Whole Sample N = 4,850	Household Wealth Quintile[1] 1st N = 970	2nd N = 972	3rd N = 968	4th N = 970	5th N = 970
% of Households:	Mean	Mean	Mean	Mean	Mean	Mean
Radio	60%	66%	65%	61%	52%	57%
Television	64%	7%	51%	72%	94%	99%
Refrigerator	25%	0%	2%	7%	35%	81%
Iron	34%	1%	8%	22%	50%	86%
Grinding Machine	35%	41%	38%	34%	31%	31%
Cassette Recorder	6%	1%	3%	5%	7%	14%
Stereo	20%	0%	3%	9%	27%	59%
Fan	21%	0%	1%	9%	28%	67%
Blender	17%	0%	0%	2%	17%	66%
Sewing Machine	7%	0%	4%	5%	8%	16%
Bicycle	28%	7%	18%	25%	34%	56%
Motorcycle	14%	2%	5%	8%	18%	37%
CD/DVD Player	19%	0%	1%	9%	26%	60%
Cell Phone	65%	27%	61%	68%	79%	92%
Computer	2%	0%	0%	0%	1%	10%
Household Infrastructure						
Floor Material						
Concrete/tile	42%	0%	10%	51%	62%	85%
Wood	3%	1%	3%	5%	2%	1%
Earth/dirt	56%	98%	86%	45%	36%	14%
Roof Material						
Zinc sheets	88%	79%	87%	91%	90%	93%
Tiled	10%	17%	12%	8%	8%	6%
Fiberglass/asbestos	1%	1%	1%	1%	1%	1%
Non-permanent	1%	3%	1%	0%	0%	0%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-7 Distribution of Household Assets by Household's Wealth Quintile (2015)

6.8.3.General Household Characteristics

This section reviews a range of household socio-demographic characteristics, including household socio-demographic characteristics, head of household education level and participation in economic activities. **Table 6-8** exhibits descriptive statistics of socio-demographic characteristics for households in the sample. At the top, we see the breakdown of individuals in different age brackets across household wealth quintiles. Thereafter, descriptive statistics for household size are displayed, with 4.7 family members in the average household. There do not appear to be many differences in household age profile or household size across wealth quintiles. On average, household heads are 46 years old and male in 54% of households. Broadly, the proportion of male household heads decreases with increases in household wealth.

Table 6-9 shows descriptive statistics for household heads in the sample. Overall, 3% of household heads self-identify as indigenous, with a higher proportion of poor households led by individuals identifying as indigenous compared to wealthier households. With respect to economic activity, 81% of household heads report active employment with 73% reporting income from economic activities during the last month. Frequencies of active employment, income in the last month, and income from employment are relatively homogenous across wealth quintiles, with the exception that household heads in the top wealth quintile report having income during the prior month with greater frequency than the first four wealth quintiles (88% versus 83% overall). **Table 6-9** also indicates that a large percentage of household heads have attended school and are literate, at 69% and 70%, respectively. However, just 44% of household heads have completed their primary education, and 12% their secondary education. When broken out by wealth quintile, the relationship between poverty and education, or a lack thereof, becomes clear with households in the bottom wealth quintile more than 2.5x more likely to not have attended any primary school than households in the top wealth quintile (53% versus 21%). Similar patterns are found with respect to completion of primary, secondary, and post-secondary school with wealthier household heads more likely to have completed higher levels of education.

6.8.4.Water Source and Safe Water-Use Behaviour

Baseline data collection included several questions about the source of water for households and the extent of household water treatment activities. Descriptive statistics for these variables are exhibited in **Table 6-10** 62% of households in the IE sample have a system connection and the same percentage of all households collected their last drink of water from the community system. Additionally, a significant majority of households took their last drink of water from a storage container inside of their home (84%) compared to just 14% of households taking their last drink of water directly from the tap; drinking water quality deteriorates during storage in the household and consumption of stored water is considered a risk factor for waterborne diseases (Wright et al., 2004; Trevett et al., 2004; Clasen and Bastable, 2003). Just 24% of households reported treating their last drink of water -- 20% reported treating their water through chlorination. 51% of households did not treat water because they did not believe it was necessary, either because someone had told them so or because their local CAPS had told them that water had already been treated. Wealthier households are more likely to report treating their water than less wealthy households, with 28% of households in the highest wealth quintile having treated water and just 17% of households in the lowest wealth quintile having done so. Nonetheless, samples from households reporting that they treated their currently available drinking water ("last glass") provided evidence of chlorination in only three out of 29 households for samples taken from storage containers; just one in 29 household tap samples from systems that reported treating drinking water showed evidence of chlorination (data not shown).[72]

Table 6.11 shows descriptive statistics for the extent to which households said that they had enough water to attend to their daily water needs. 82% of households with a water connection stated that they had enough water in the wet season compared to 81% without a connection. As for the dry season, 66% of households with a system connection had enough water relative to just 53% of households without a connection. In both the wet and dry seasons, wealthier households respond that they have sufficient water with greater frequency than poorer homes.

Table 6.12 shows descriptive statistics for continuity of water service for connected households in the wet and dry seasons. As expected, households have more hours of service in the water-abundant wet season than during the dry season, averaging 15.2 and 13.3 hours, respectively. Regional breakouts show that the Atlantic has more hours of service in both the wet and dry seasons, followed by the Central and Pacific regions. There is a significant amount of variance in service level both across wealth quintiles, as well as across regions with a broad trend towards increased service levels among lower wealth quintiles. Sixty-two percent and 48% percent of households state that they experience daily or weekly service interruptions during the dry and wet seasons, respectively. Similar to the trend in hours of service, wealthier households tend to experience service interruptions with greater frequency than the poor. Notwithstanding, wealthier homes also use more water than poorer households, consuming 241 litres of water per capita compared to an average of 186 litres overall and 154 litres on average for households in the bottom wealth quintile. They also spend more on water, with homes in the wealthiest quintile spending just shy of 3x as much on water than households in the bottom wealth quintile on a per-month basis.

[72] In the case of the tap samples, the sample with a positive chlorine reading was positive for free chlorine; no tap samples were positive for residual chlorine.

		Household Wealth Quintile[1]				
	Whole Sample N = 4,850	**1st N = 970**	**2nd N = 972**	**3rd N = 968**	**4th N = 970**	**5th N = 970**
	Mean	Mean	Mean	Mean	Mean	Mean
% of sample						
HH members, 5 and under	13%	3%	3%	2%	3%	2%
HH members, 6-13	17%	4%	4%	4%	3%	3%
HH members, 14-30	34%	6%	7%	7%	7%	7%
HH members, 31-65	31%	5%	6%	6%	6%	7%
HH members 65+	5%	1%	1%	1%	1%	1%
All ages	100%	20%	20%	20%	20%	20%
Number of household members						
Average HH size	4.7	4.58	4.74	4.76	4.72	4.69
HH members, 5 and under	0.60	0.65	0.61	0.58	0.62	0.55
HH members, 6-13	.82	.88	.87	.83	.78	.76
HH members, 14-30	1.58	1.52	1.61	1.62	1.59	1.57
HH members, 31-65	1.46	1.26	1.41	1.47	1.53	1.61
HH members 65+	0.25	0.29	0.27	0.27	0.22	0.2
Household size						
1	3%	4%	2%	3%	2%	2%
2	9%	10%	8%	8%	9%	9%
3	19%	20%	21%	19%	19%	18%
4	23%	23%	22%	22%	22%	24%
5	18%	16%	17%	18%	20%	20%
6	12%	11%	13%	12%	12%	12%
7	7%	6%	6%	8%	7%	7%
8+	10%	10%	11%	10%	10%	8%
Household head						
Average age, HH head	46.39	46.56	46.46	47.2	46.12	45.63
HH heads, % male	54%	56%	58%	55%	53%	48%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-8 Socio-demographic characteristics of the household by wealth quintile

% of household heads:	Whole Sample N = 4,850 Obs.	Mean	Household Wealth Quintile[1] 1st N = 970 Mean	2nd N = 972 Mean	3rd N = 968 Mean	4th N = 970 Mean	5th N = 970 Mean
Identifies as Indigenous	4,437	3%	5%	3%	2%	2%	3%
Reports Active Employment	4,850	81%	82%	80%	79%	80%	82%
Any Income Prior Month	4,842	83%	81%	82%	82%	82%	88%
Income from Employment	4,842	73%	73%	71%	71%	73%	76%
Education							
No Primary	4,846	37%	53%	43%	39%	29%	21%
Primary	4,846	44%	37%	43%	45%	46%	47%
Secondary	4,846	12%	6%	7%	10%	15%	20%
Post-Secondary	4,846	3%	1%	2%	2%	5%	8%
Is literate	4,850	70%	53%	65%	68%	78%	86%
Ever attended school	4,846	69%	52%	63%	67%	78%	86%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-9 Distribution of Household Head's Demographic and Education Characteristics by Household's Wealth Quintile

% of Households:	Whole Sample N = 4,850 Mean	Household Wealth Quintile[1] 1st N = 970 Mean	2nd N = 972 Mean	3rd N = 968 Mean	4th N = 970 Mean	5th N = 970 Mean
Water source characteristics						
Connected to Comm. System	62%	39%	58%	61%	71%	80%
Potable water						
Comm. System	62%	42%	59%	62%	71%	76%
Collected: from tap	14%	9%	10%	14%	18%	19%
Collected: from storage	84%	91%	89%	85%	80%	76%
Treated	24%	17%	23%	24%	25%	28%
Treated chlorination	20%	14%	19%	21%	22%	23%
Treatment not necessary[2]	51%	49%	51%	48%	54%	55%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). [2] "Treatment not necessary" is a dummy variable for which households were assigned a 1 if they did not treat water because they did not think treatment was necessary, someone told them that it was not necessary, or their CAPS told them that it was already treated.

Table 6-10 Distribution of Household's Water Source Characteristics by Household's Wealth Quintile

		Whole Sample N = 4,850	Household Wealth Quintile[1] 1st N = 970	2nd N = 972	3rd N = 968	4th N = 970	5th N = 970
Percentage of Households:		Mean	Mean	Mean	Mean	Mean	Mean
Sufficient Water: Dry	With system	66%	63%	64%	64%	67%	69%
	Without system	53%	50%	51%	56%	54%	54%
Sufficient Water: Wet	With system	82%	80%	80%	81%	83%	83%
	Without system	81%	76%	83%	83%	85%	87%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-11 Sufficiency of water supply by system connection status and household's wealth

		Sample N = 4,850	Household Wealth Quintile[1] 1st N = 970	2nd N = 972	3rd N = 968	4th N = 970	5th N = 970
% of Households:	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
Water Use							
Sufficient Water (Dry)	4,850	61%	55%	58%	61%	64%	66%
Sufficient Water (Wet)	4,850	81%	78%	81%	82%	83%	84%
Hours of service per day (Dry)	2,990	13.27	14.8	13.35	13.42	13.47	12.2
Pacific	1,076	11.57	12.78	11.28	11.73	12.62	10.69
Central	1,643	13.67	14.15	13.43	13.58	13.42	14.05
Atlantic	271	17.61	20.71	17.33	19.17	17.56	14.47
Hours of service per day (Wet)	2,990	15.21	17.62	15.56	15.63	15.29	13.42
Pacific	1,076	12.93	15.28	13.08	14.15	13.63	11.58
Central	1,643	15.93	17.35	15.76	15.72	15.94	15.18
Atlantic	271	19.94	22.3	19.6	21.17	19.21	18.31
Difference in Hours (Wet - Dry)[2]	2,981	2.11	2.92	2.24	2.25	1.82	1.34
Service interruptions (Dry)[3]	2,990	62%	56%	61%	63%	61%	65%
Service interruption (Wet)[3]	2,990	48%	40%	48%	49%	47%	53%
Monthly payment	2,737	74.5	39.4	47.0	58.4	81.6	112.2
Amount of water used (Litres)	4,850	185.52	154.32	154.02	179.51	199.08	240.72
Amount of time to retrieve water (minutes)	4,797	8.18	8.83	7.98	8.16	7.53	8.4
Who Manages Household Water?							
Female Member	4,797	86%	86%	84%	85%	87%	88%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). [2] Difference in Hours (Wet - Dry) represents the total difference in hours of service for households by subtracting the number of hours of service in the dry season from the number of service hours in the wet season. [3] Service interruptions for the wet and dry seasons is a dummy variable for which households were assigned a 1 if they said that they experienced daily or weekly interruptions in water service in the wet and dry seasons and a 0 if they did not.

Table 6-12 Distribution of households' water use by Household Wealth Quintile

6.8.5.Waterborne Illness Prevalence

Tables 6-13 through 6-15 present descriptive statistics with respect to diarrhoea prevalence in households, with a disaggregation for children five years and younger. Overall, 9% and 7% of households have had family members with diarrhoea symptoms in the last week and 2 days, respectively. Similarly, children in 7% of households with children under the age of 5 have had diarrhoea symptoms in the last week. As Table 15 indicates, diarrhoea prevalence is the highest in the Pacific and the Atlantic, at 10% in both regions, and 8% in the Central Region. As shown in Table 16, there does not seem to be a strong relationship between reported diarrhoea prevalence and household wealth, with no clear trend in diarrhoea prevalence across wealth quintiles. Diarrhoea prevalence segmented by whether homes have improved sanitation, a water connection, and soap and water available at a handwashing station is displayed in **Table 15**. While having improved sanitation and a water connection are both related to a decreased prevalence of diarrhoea, simply having soap and water at a handwashing station is not. In fact, households with soap and water exhibit higher levels of diarrhoea prevalence; since the survey could not assess temporality, it is possible that households with existing cases of diarrhoea are more likely to be practicing proper hand hygiene, as opposed to soap and water being the cause of diarrhoea.

6.8.6.Community Characteristics

Table 6.16 displays characteristics for the 300 communities (150 treatment and 150 control) at baseline, using data collected from the community-level survey. For **Table 6-16**, as well as other tables displaying information across wealth quintiles for community, system, CAPS, and UMAS data, household wealth scores were averaged across the communities, systems, CAPS or UMAS – yielding average wealth scores aggregated to the unit of interest. Thereafter, aggregate wealth scores were used to classify units (e.g. community, system) into one of the five wealth quintile categories based on the quintile cut-offs established for the household distribution.

Each community is home to an average of 115 households, with a positive relationship between the quintile of the average wealth quintile of a community and the number of households in that community. In relation to WSS infrastructure, 86% of communities have improved sanitation and 97% of communities are covered by at least one water system.[73] Nonetheless, more than half of households are covered by improved sanitation in less than half of all communities. Overall, wealthier communities tend to have access to improved sanitation more frequently than poorer communities. Wealthier communities are also more likely to report having sufficient water throughout the entire year, with 85% of communities in the highest wealth quintile responding in the affirmative compared to just 53% of communities in the lowest wealth quintile.

With respect to non-WSS infrastructure, the community survey included questions regarding whether a community had electricity, fixed and mobile phone infrastructure, and internet. In general, 69% of communities have electricity, with electricity frequencies significantly lower among the bottom two wealth quintiles relative to wealthier communities. Cell phone infrastructure is the only infrastructure category in which all communities have relatively high coverage, on average. 93% of communities have a school, while significantly fewer communities (22%) have a health post. Wealthier communities are more likely to have schools and health posts with water system connections and improved sanitation. For instance, no communities in the lowest wealth quintile have a health post, in comparison with 42% of communities in the top wealth quintile.

In addition to community infrastructure characteristics, the community survey included several questions about household water hygiene. In just 43% and 36% of communities do more than half of all households have a handwashing station and a handwashing station with soap and water within 10 meters from the toilet, respectively.

			Region		
		Whole Sample N = 4,850	**Pacific N = 1,624**	**Central N = 2,791**	**Atlantic N = 435**
Percentage of Households:	Obs.	Mean	Mean	Mean	Mean
Any family member					
Symptoms in the last week	4,850	8.7%	10.1%	7.7%	9.9%
Symptoms in the last 2 days	4,850	6.8%	7.6%	6.2%	7.4%
Child less than five years old					
Symptoms in the last week	2,183	6.9%	7.7%	6.4%	7.8%

Table 6-13 Distribution of Diarrhoea Prevalence (self-reported) by Region

[73] Just 8 communities in our baseline data have no community water system.

		Sample	Household Wealth Quintile[1]				
		Sample N = 4,850	1st N = 970	2nd N = 972	3rd N = 968	4th N = 970	5th N = 970
% of Households:	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
Any family member							
Symptoms in the last week	4,850	8.7%	7.5%	9.9%	7.7%	10.7%	7.7%
Symptoms in the last 2 days	4,850	6.8%	6.2%	8%	6.5%	7.5%	5.6%
Child less than five-year old							
Symptoms in the last week	2,183	6.9%	4.8%	9.9%	5.4%	7.4%	7.1%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-14 Distribution of Diarrhoea Prevalence by Household Wealth Quintile

	Improved Sanitation		Water Connection		Soap and Water		
Percentage of HHs with:	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	
Any family member							
Symptoms in last week	9.0%	8.3%	9.3%	8.4%	7.8%	9.3%	
Symptoms in last 2 days	7.2%	6.2%	7.9%	6.6%	5.8%	7.3%	**
Children							
Symptoms in last week	7.2%	6.6%	7.3%	6.5%	5.2%	8.0%	***

[1] Respondents were asked whether someone living in the household had diarrhoea in the last week and in the last two days. They were asked to identify the number of households in each age range experiencing diarrhoea symptoms.
*** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-15 Distribution of Diarrhoea Prevalence by Water, Sanitation and Hygiene Conditions

		Whole Sample	Quintile of Average Household Wealth Score[1]				
			1st	2nd	3rd	4th	5th
	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
General community characteristics							
No. HH	294	115	43	90	103	144	208
Indigenous community	294	7%	12%	7%	8%	3%	8%
Has improved sanitation	283	86%	82%	77%	84%	94%	96%
>50% HH have improved sanitation	300	49%	44%	40%	54%	60%	31%
Has electricity	294	69%	18%	25%	84%	99%	100%
Has cell phone connection	294	89%	94%	84%	88%	93%	96%
Has internet	294	17%	6%	6%	13%	28%	42%
School characteristics							
Has a school with water connection	274	79%	56%	68%	80%	88%	100%
Has a school with improved sanitation	274	66%	50%	75%	61%	68%	68%
Health post characteristics							
Community has a health post with water connection	294	19%	0%	7%	17%	30%	42%

Community has a health post with improved sanitation	294	16%	0%	7%	13%	24%	38%
Hands washed	293	20%	0%	10%	20%	30%	38%
Handwashing station with soap and water	291	14%	0%	5%	15%	17%	35%
Household Hygiene Practices							
>50% HH have hand-washing station >10m of toilet	280	43%	13%	33%	45%	49%	58%
. . . with water and soap	276	36%	33%	27%	33%	46%	42%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). Household wealth scores were then averaged across communities, after which each community was assigned to a wealth quintile based on thresholds utilized to group households into wealth quintiles. Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-16 Community-level Characteristics by Quintile of Average Household Wealth Score

6.8.7.Water System Characteristics

Of principal importance in data collection were questions related to water systems and CAPS. **Table 6-17** exhibits descriptive statistics for the 316 systems in the sample, by the quintile of the average household wealth quintile for system-users.[74]

It should be noted that even though several communities had more than three systems, a decision was made during data collection to limit the number of systems for which system-level data was collected to three given resource and time constraints. Systems are an average of 12.4 years old, and cover an average of 76 users, representing an average of 62% of the total population on a per-community basis for communities in the sample. Systems covering wealthier households cover more users and a higher percentage of potential users. With regard to system technology, the most frequently found system technologies are gravity systems, with 47% of systems being of this type. Nonetheless, pumped systems are more frequent among systems at the top two wealth quintiles (46% and 65%, respectively).

With respect to sources, the average system draws from 1.4 sources. More than half of a system's sources have sufficient water for 91% and 69% of systems in the wet and dry seasons, respectively. Respondents were asked about the condition of key WSS system infrastructure components. Any of a water system's sources are reported

[74] Due to miscoding during data collection and entry, it was not possible to match households to water systems for 15 of 331 systems. Data for these systems is included in descriptive statistics shown for the entire sample, but is not included in descriptive statistics shown for the quintile of the average household wealth score associated with systems.

to be in poor condition for 21% of systems, while any source is contaminated by garbage/sewage and chemicals for 22% in both cases. Contamination by garbage/sewage and chemicals from industrial activities can put households' drinking water at an increased risk of contamination. Some of a system's sources are not protected for 35% of systems. There is a tendency for any source to be in poor condition and to not be protected more frequently for systems serving poorer households than wealthier households.

Just 26% of systems have treatment infrastructure, with a strong relationship between the wealth level of households served by a system and the existence of treatment infrastructure. For systems with treatment infrastructure, any treatment infrastructure is in poor condition for 15% of systems. With respect to actual treatment, respondents for just 33% of systems claimed that water was treated with chlorination with only 10% having applied chlorination in the last 10 days. However, chlorination analyses conducted by the survey firm detected positive levels of total chlorination in just four of 15 instances, with residual chlorination showing up in just two cases (not exhibited). Almost 78% of systems have distribution infrastructure, with any distribution infrastructure in poor condition for 8% of systems that have associated infrastructure. 71% of systems have storage infrastructure, with any storage infrastructure in poor condition for 15% of systems. Again, there is evidence of a possible relationship between the relative wealth of households served by a system and the likelihood that distribution and storage infrastructure is in poor condition.

6.8.8.Service Provider Characteristics

6.8.8.1. Institutional Strength

Much of the research on rural water system sustainability emphasizes the importance of the institutional aspects of service providers in addition to water system infrastructure. In many contexts, like that of rural Nicaragua, water systems are frequently managed by local water boards with varying levels of institutionalism. A rich survey of CAPS service providers was included in PROSASR baseline data collection to understand the extent to which institutional capacity exists in the context of CAPS (*Comité de Agua Potable y Saneamiento*), ultimately benefiting by way of the Project from increased capacity to support them on the part of municipal technical assistance providers (UMAS). Tables displaying descriptive statistics for the 299 CAPS included in the baseline data are included in **Tables 6-18 through 6-22**.[75]

Table 6-18 provides descriptive statistics with respect to the education level of CAPS leadership.[76] 57% of CAPS presidents completed primary school with 25% and 14% having completed secondary and a university education, respectively. Similar to data on household head education, there is evidence of a relationship between community wealth level and education level of CAPS leadership, with the highest level of education completed by a CAPS president increasing with the wealth level of CAPS users.

Table 6-19 provides information with respect to the institutionalism, professionalism, and mechanisms for community participation in CAPS. Overall, the data tends to show that service providers serving wealthier households exhibit higher levels of institutionalism. In total, just 35% of water committees are legalized; however, about half of CAPS in the top two wealth quintiles are legal versus 0% and 28% in the bottom two wealth quintiles, respectively. CAPS in wealthier areas also hold more meetings on average than those in poorer areas, with CAPS in the top wealth quintile holding 3.5 meetings on average over the last six months versus 1.5 and for CAPS in the bottom wealth quintile. With respect to the democratic nature of service providers, 62% are fully elected. Regarding female participation in CAPS, just 37% of CAPS have women in leadership roles. Granted female participation improves with wealth level, even in the top wealth quintile, less than half of CAPS have women in leadership roles.

Increased professionalism of CAPS could allow service providers to respond quickly and effectively to technical problems related to water systems. Based on the system survey, 67% and 44% of CAPS have technical and paid technical staff, respectively, with systems in wealthier areas more likely to employ technical and paid technical staff than systems in less well-off areas. With respect to community participation, about half of all CAPS have complaint- receiving mechanisms and are accountable to system users.[77] Again, systems serving wealthier households exhibit higher frequencies for community participation variables than systems serving poorer households.

[75] Again, due to miscoding during data collection and data entry, CAPS were matched to the households they provide water service to for 223 of 299 CAPS for which data was collected at baseline.
[76] Surveyors sought to identify the CAPS president, or other individual with knowledge of CAPS. The surveyor then asked about the highest level of education achieved by said individual.
[77] "Accountable to users" is a dummy variable for which system providers were assigned a 1 if they report back to users at least one every six months and have meeting minutes to demonstrate it.

			Quintile of Average Household Wealth Score[1]				
		Whole Sample N = 316	1st N = 6	2nd N = 53	3rd N = 64	4th N = 65	5th N = 31
% of Systems:	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
Infrastructure							
System age (years)	287	12.4	11.5	10.0	13.4	12.5	13.6
No. system users	223	76	24	38	50	108	187
% of HHs Connected to System	220	62%	64%	52%	60%	77%	78%
Water System Technology							
Drilled Well	305	12%	0%	0%	2%	13%	6%
Dug Well	305	5%	0%	2%	0%	3%	3%
Pumped system	305	25%	0%	14%	11%	46%	65%
Manual well	305	11%	0%	0%	3%	0%	3%
Gravity system	305	47%	100%	84%	84%	38%	23%
Source Characteristics							
No. sources	302	1.4	1.5	1.2	1.2	1.2	1.2
Sources have sufficient water: Dry[2]	300	69%	50%	71%	66%	75%	71%
Sources have sufficient water: Wet[2]	300	91%	100%	92%	95%	94%	87%
Any Source . . .							
. . . in poor condition	251	21%	20%	19%	27%	7%	10%
. . . contaminated by garbage/sewage	297	22%	0%	22%	16%	16%	23%
. . . contaminated by chemicals	289	22%	20%	27%	26%	16%	23%
. . . not surrounded by green areas	294	14%	0%	6%	15%	14%	10%
. . . surrounded by eroded areas	289	23%	20%	20%	21%	29%	23%
. . . not protected	289	35%	40%	43%	32%	24%	29%
Treatment Characteristics							
Has treatment infrastructure	303	26%	33%	24%	37%	33%	42%
Water treated with chlorine	298	33%	17%	27%	40%	41%	35%
Chlorine applied in last 15 days	303	10%	0%	8%	13%	13%	19%
Other Infrastructure Condition							
Has distribution infrastructure	299	78%	83%	100%	94%	98%	100%
Any distr. infra in poor condition	229	8%	0%	13%	14%	2%	6%
Has storage infrastructure	299	71%	83%	90%	90%	95%	90%
Any storage infra in poor condition	210	15%	20%	20%	22%	8%	7%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). Household wealth scores were then averaged across water systems, after which each water system was assigned to a wealth quintile based on thresholds utilized to group households into wealth quintiles. Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). [2] Sources have sufficient water is a dummy variable for which systems for which more than half of sources were said by respondents to have sufficient water in a given season received a 1, while systems for which fewer than half of sources have sufficient water in a given season received a 0.

Table 6-17 Water system characteristics by quintile of average household wealth score

6.8.8.2. Financial Sustainability

In addition to institutional capacity, the literature highlights the importance of adequate financial management of CAPS operations. With respect to financial management, of interest are the extent to which CAPS charge for their services, whether they cover costs, and how well they manage funds, which are detailed for CAPS in the sample in Table 22. Overall, three-quarters of CAPS have a monthly tariff with the monthly tariff variable for just 21% of service providers. Variable tariffs permit CAPS to charge users for the amount of water they draw from the system, obliging users consuming more to pay more than those using less water. An average monthly tariff among tariff-charging CAPS is USD 3.09; however, there is significant variability with CAPS in the highest wealth quintile charging 3 times more than CAPS in the second-to-last wealth quintile. On average, 72% of users are current on payments with some evidence that poorer communities are delinquent more often. At the same time, just more than 60% of CAPS cover costs, indicating that CAPS may not be charging enough or that their financial management is inefficient. There is limited evidence that CAPS serving poorer households cover costs more frequently than CAPS serving wealthier households.

			Quintile of Average Household Wealth Score[1]				
		Whole Sample N = 299	**1st N = 6**	**2nd N = 53**	**3rd N = 65**	**4th N = 67**	**5th N = 33**
% of CAPS:	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
Less than primary	269	5%	20%	9%	10%	2%	0%
Primary	269	57%	80%	65%	65%	48%	23%
Secondary	269	25%	0%	15%	16%	29%	45%
University	269	14%	0%	11%	10%	22%	32%

[1] The survey firm was asked to locate the CAPS president or other individual with knowledge of the CAPS. The above table describes the distribution of the education level of these individuals. [2] Wealth scores were averaged across service providers, after which each service provider was assigned to a wealth quintile based on thresholds utilized to group households into wealth quintiles. Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-18 Education level of CAPS leadership1 by average household wealth score quintiles

% of CAPS:	Obs.	Whole Sample N = 299 Mean	Quintile of Average Household Wealth Score[1] 1st N = 6 Mean	2nd N = 53 Mean	3rd N = 65 Mean	4th N = 67 Mean	5th N = 33 Mean
Institutionalism							
Service Provider is a CAPS	276	70%	40%	74%	86%	84%	64%
CAPS age	165	6.8	3.0	7.5	7.6	5.8	7.4
CAPS legalized	276	35%	0%	28%	38%	52%	45%
CAPS fully-elected	277	62%	20%	70%	84%	75%	58%
No. meetings last 6 months	184	2.8	1.5	2.9	2.8	3.2	3.5
No. CAPS committee members	240	5.4	5.4	5.5	6.0	5.4	5.6
% women in CAPS leadership	230	37%	26%	24%	32%	42%	47%
Professionalism							
Has technical staff	258	67%	60%	67%	72%	81%	82%
Technical staff paid	257	44%	0%	36%	53%	57%	67%
Participation							
Has complaint-receiving mechanism	262	45%	20%	52%	58%	48%	67%
Accountable to users[2]	251	52%	0%	55%	71%	63%	58%
Women participate in meetings	258	89%	60%	84%	97%	98%	97%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). Household wealth scores were then averaged across CAPS, after which each CAPS was assigned to a wealth quintile based on thresholds utilized to group households into wealth quintiles. Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). [2] "Accountable to users" is a dummy variable for which system providers were assigned a 1 if they report back to users at least one every six months and have meeting minutes to prove it.

Table 6-19 Institutionalism professionalism, and participation characteristics of CAPS by average household wealth score quintiles

		Whole Sample N = 299	Quintile of Average Household Wealth Score[1]				
			1st N = 6	2nd N = 53	3rd N = 65	4th N = 67	5th N = 33
% of CAPS:	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
Has monthly tariff	265	73%	60%	74%	87%	92%	94%
Monthly tariff is variable	265	21%	2%	9%	15%	47%	34%
Average monthly tariff (USD)	192	3.089	.242	2.293	3.078	2.403	6.372
% of HH current on payments	176	72%	47%	68%	66%	79%	70%
Accounting books to date	252	56%	20%	53%	70%	71%	72%
CAPS cover costs (e.g., solvent)	147	62%	100%	64%	68%	59%	52%
Has bank account	231	26%	0%	20%	16%	47%	37%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). Household wealth scores were then averaged across CAPS, after which each CAPS was assigned to a wealth quintile based on thresholds utilized to group households into wealth quintiles. Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-20 Financial Sustainability Characteristics of CAPS by Quintile of Average Household Wealth Score

6.8.8.3.Operations & Management and Government Assistance

A third determinant of water system sustainability from the perspective of service providers has to do with the extent to which CAPS perform Operations & Maintenance and receive government assistance to do so. Preventative care, for instance, can increase system sustainability in that systems receiving preventative care may be less likely to break down. Corrective care would be necessary in the case of an unanticipated system problem. Descriptive statistics for CAPS in the baseline data are exhibited in **Table 6-21** 74% of CAPS provide corrective care versus just 53% providing preventative care. Indeed, CAPS serving wealthier users are more likely to apply preventative care, with CAPS in the top wealth quintile providing preventative care 4 times more than CAPS in the bottom wealth quintile. There is a corresponding negative relationship with respect to corrective care with CAPS in poorer wealth quintiles providing corrective care more frequently than CAPS in wealthier quintiles. Less than 50% of all CAPS have materials for providing O&M. Nonetheless, 81% and

90% of CAPS report promoting environmental sanitation and protect areas around system sources, respectively, actions that may enhance system sustainability and water quality.

At the municipal level, UMAS are responsible for providing technical assistance to CAPS. They are frequently the ones called upon by CAPS in the case of doubts or for technical and training needs. According to the survey, 54% of CAPS requested government support, with 38% requesting and ultimately receiving it. 16% of CAPS requested but did not receive support from UMAS. 36% of CAPS report system problems to UMAS with UMAS responsive in the case of 24% of CAPS. There is some evidence that CAPS report service issues and that UMAS are responsive more often for CAPS in wealthier areas than poorer areas.

6.8.8.4.Community interaction with CAPS

In addition to questions in the CAPS survey aimed at learning about the institutional aspects of CAPS, the household survey included several questions to gauge the extent to which households interact with CAPS. CAPS engaging more frequently with community members may have an increased ability to detect and respond faster to service and system problems than CAPS engaging to a lesser degree. Additionally, they may have the social capital necessary to convince system users to pay tariffs on time, increasing the likelihood that funds are available for timely preventative and corrective system care. The household survey included questions about the extent to which households had interacted with CAPS in the previous two months. **Table 6-22** exhibits descriptive statistics for household interaction with CAPS.

Overall, 55% of households had at least some contact with their local CAPS[78] in the two months before the survey, with contact higher for wealthier households than for the less well-off. The most popular types of contact are attending a meeting (30%) and making a payment to CAPS (28%). Overall, females attended CAPS meetings more frequently than males, although marginally.

When asked about the last time a household or someone in the community encountered an issue with water service, about half of households said that a local CAPS resolved the service issue, with CAPS resolving the service issues of wealthier

[78] CAPS is the term for a formal community water board; however, in communities without CAPS, other institutions such as religious organizations, local government, or another community organization or committee are responsible for ensuring system functionality.

homes more frequently than the poor. Higher relative rates of CAPS resolving water among issues may be related to higher relative institutional capacity. Finally, 13% of households reported that their community had received a training by their CAPS in the last year.

6.8.9.Municipal WSS Units

In addition to household and system-level surveys, baseline data was also collected at the level of the municipal WSS units providing technical assistance to CAPS, known as *Unidades Municipales de Agua y Saneamiento*, or UMAS. The component of PROSASR for which the present impact evaluation is being performed has the objective of building the institutional capacity of UMAS. Thereafter, it is expected that UMAS will provide better technical assistance to CAPS, improving the performance of rural water systems and increasing the long-term sustainability of said systems. One survey was conducted for each of the 77 municipalities in the baseline data; however, due to errors in coding, one of the municipalities was unable to be matched to household data. **Table 6-23** displays descriptive statistics for the entire UMAS sample, as well as by household wealth quintile for the 76 UMAS successfully matched to households from the household survey.

Overall, an average of 54 communities are assigned to each UMAS. Of the total number of communities assigned to a given UMAS, on average, 44% of communities solicit the support of UMAS and 41% of communities are ultimately attended to by UMAS. Consistent with the level of institutional development of CAPS, communities in municipalities with wealthier households tend to request and receive support from UMAS with increased frequency in comparison to poorer municipalities. With respect to financial resources with which to attend to CAPS, slightly less than half of all UMAS are assigned funds from the municipal budget. However, budget support is reported to be sufficient for supporting CAPS for just 20% of UMAS.

With respect to resources with which to provide technical assistance, the UMAS survey asked about the extent to which UMAS had equipment on hand for CAPS support. Even though 61% of UMAS have their own transportation and 74% have their own IT equipment, just 42% of UMAS have equipment to measure water quality. Lastly, UMAS were asked about the extent to which they would like to receive more training, alluding to the AVAR-component of PROSASR. 76% of UMAS responded that more training was necessary from the national government. However, 67 of the 77 UMAS, or 87% in the baseline data had received at least one training from the national government.

			Quintile of Average Household Wealth Score[1]				
		Whole Sample N = 299	**1st N = 6**	**2nd N = 53**	**3rd N = 65**	**4th N = 67**	**5th N = 33**
% of CAPS:	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
O&M							
Provides preventative care	266	53%	20%	53%	65%	55%	81%
Provides corrective care	266	74%	100%	96%	90%	67%	78%
Has materials for O&M	260	46%	20%	47%	51%	54%	75%
Promotes environmental sanitation	267	81%	80%	83%	84%	87%	70%
Protects area around source	267	90%	100%	91%	95%	92%	88%
Government Assistance							
Requested gov't support	270	54%	40%	57%	47%	57%	61%
Requested and received government support	269	38%	40%	43%	35%	43%	48%
Requested, but did not receive government support	269	16%	0%	15%	11%	14%	12%
Reports problem to UMAS	261	36%	0%	37%	30%	37%	47%
UMAS responsive	261	24%	0%	20%	18%	32%	41%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). Household wealth scores were then averaged across CAPS, after which each CAPS was assigned to a wealth quintile based on thresholds utilized to group households into wealth quintiles. Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-21 Service provider O&M and government assistance characteristics of CAPS by quintile of average household wealth score

			Household Wealth Quintile[1]				
		Whole Sample N = 4,850	1st N = 970	2nd N = 972	3rd N = 968	4th N = 970	5th N = 970
	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
% of Households:							
Community has CAPS	4,850	75%	65%	73%	73%	79%	86%
Contact with CAPS	4,844	55%	44%	52%	54%	61%	62%
Membership contact	4,844	6%	4%	6%	6%	7%	5%
Payment contact	4,844	28%	20%	24%	27%	34%	34%
Attended meeting contact	4,844	30%	27%	30%	28%	32%	31%
Woman attended CAPS meeting	4,849	17%	12%	14%	18%	20%	21%
Man attended CAPS meeting	4,849	15%	16%	17%	13%	15%	13%
Man and woman attended meeting	4,849	2%	2%	3%	2%	3%	3%
Knowledge of CAPS meeting	4,849	57%	47%	54%	57%	64%	65%
CAPS resolved last service problem	4,849	49%	35%	45%	47%	56%	60%
Time to resolve service problem (Days)	3,658	8.4	4.4	5.9	5.7	9.6	15.1
CAPS training in last year	4,849	13%	8%	12%	14%	16%	15%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-22 Distribution of household interaction with service providers by household wealth quintile

			Quintile of Average Household Wealth Score[1]				
		Whole Sample N = 77	1st N = 1	2nd N = 18	3rd N = 27	4th N = 27	5th N = 3
% of UMAS	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
No. communities assigned to UMAS	76	53.8	26.0	55.7	68.8	43.7	16.7
% communities soliciting support	76	44%	35%	35%	44%	47%	55%
% of communities attended	76	41%	23%	29%	40%	46%	80%
Annual budget assigned to UMAS	76	47%	0%	33%	50%	48%	100%
% Budget / Total Budget	30	26%	.%	4%	24%	46%	0%
Budget sufficient for CAPS support	35	20%	.%	20%	15%	31%	0%

Has own transportation	76	61%	0%	72%	69%	44%	67%
Has water-quality measurement equip.	76	42%	0%	50%	54%	30%	33%
Has IT equipment	76	74%	0%	83%	81%	59%	100%
Budgeted travel expenses	76	54%	0%	61%	62%	37%	100%
Budgeted gasoline	76	66%	0%	67%	69%	59%	100%
More nat. government training needed	75	76%	100%	67%	80%	74%	100%
Received training from FISE/ARAS	77	87%	100%	83%	78%	100%	67%

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). Household wealth scores were then averaged across UMAS, after which each UMAS was assigned to a wealth quintile based on thresholds utilized to group households into wealth quintiles. Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th).

Table 6-23 Municipal Technical Assistance Provider (UMAS) Characteristics by Quintile of Average Household Wealth Score

6.9. Water Quality

6.9.1. Household Samples

Water quality tests were conducted at different points throughout water systems. Results for samples taken at the household level are exhibited in **Table 6-24** Analyses were conducted for 373 households in 146 communities for 147 systems. 335 samples were taken from a storage container in the household and 171 from household taps. When duplicate samples were taken in households and the results differed (n = 5) the average *E. coli* count was preserved for analysis. Mean *E. coli* counts for storage samples across all households (regardless of the source from which the last glass of water was taken) was 24.1 (“high risk”).[79] Mean *E. coli* counts across all tap samples was 21.5 (also “high risk”). In order to further assess differences between tap and storage water quality, that controlled for other household factors, we utilized paired tap-storage samples from the 121 households for which paired samples were available. On average, paired storage samples were more contaminated than tap samples (Tap: 16.8 MPN *E. coli*; Storage 23.1 MPN *E. coli,* difference of means t-test being 6.2), with means differences significant at the 1 percent level (p-value of 0.001). Table 26 also shows *E. coli* counts for households based on the source from which

[79] A cap of 100 was placed on the *E. coli* count detectable by water quality analyses.

their last drink was taken. On average, the *E. coli* counts for storage samples for households taking their last glass from the storage container was 25.3. For households taking their last glass from the tap, the *E. coli* count for tap samples was 18.0.

Table 6-25 exhibits the distribution of household samples by contamination risk category. The risk level of water taken from storage containers and from the tap is "safe" in 27% and 26% of households, respectively. With respect to the quality of water in storage containers in households for which the last glass of water was taken from a storage container water is "safe" in just 25% of households, while tap water is "safe" for 31% of households for which the last glass was taken from the tap.

			Household Wealth Quintile[1]				
		Whole Sample N = 4,850	**1st N = 970**	**2nd N = 972**	**3rd N = 968**	**4th N = 970**	**5th N = 970**
	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
% of Households:							
All Samples							
E. coli MPN, storage	325	24.1	27.2	24.5	27.6	19.6	19.2
E. coli MPN, tap	169	21.5	26.4	23.0	17.2	18.8	21.8
Paired Samples[2]							
E. coli MPN: storage	121	23.1	34.3	22.3	24.5	15.1	12.4
E. coli MPN: tap	121	16.8	26.6	16.1	11.1	12.4	16.7
Difference (Storage - Tap)[3]	121	6.2	7.8	6.2	13.4	2.7	(4.4)
Last Drink[4]							
E. coli MPN, storage	276	25.3	28.7	25.3	26.9	23.7	18.9
E. coli MPN, tap	36	18.0	16.3	19.6	15.4	18.6	25.4

[1] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). [2] Represents the E. coli counts for households for which both a storage container and tap sample were taken. [3] Means differences are significant at the 1 percent level (p-value of 0.001). [4] Represents *E. coli* counts for the source (storage or tap) from which the household specified that they had taken their last drink of water.

Table 6-24 E. Coli counts for Households by wealth quintile

	Risk Level[2]			
% of samples:	Safe	Inter.	High	Very High
Source (N = 139)	59%	17%	6%	17%
Tank (N = 89)	58%	25%	10%	7%
Tap (N = 169)	26%	38%	22%	14%
Storage (N = 325)	27%	33%	30%	10%
Last Drink				
Tap (N = 36)	31%	36%	25%	8%
Storage (N = 276)	25%	33%	32%	10%

[1] Descriptive statistics for tap, storage, and last drink samples shown at the household level; statistics for source and tank samples shown at the system level. [2] Risk categories correspond to the following E. coli counts: Safe (0), Intermediate (1 to 10), High (10 to 100), Very High (100 and above).

Table 6-25 E. Coli Risk Levels for Samples—Source: Tank, tap and storage facilities

6.9.2.System Samples

In addition to *E. coli* analyses conducted in households, *E. coli* analyses were conducted at the system level, taking samples from the storage tank, as well as from system sources. 307 samples were taken for 169 systems, with 24 samples dropped from the dataset due to miscoding during data entry. After dropping miscoded samples, there is data for 141 system sources and 89 system tanks. In the 18 cases for which more than one sample was taken for a given system-source or system-tank combination, like for household samples, the mean *E. coli* count was kept for the purposes of descriptive statistics and subsequent analyses.

Table 6-26 shows *E. coli* counts at the system level for source, tank, tap, and storage container samples, as well as for paired source-tank, tank-tap, tap-storage, and source-storage samples. In the case of tap and storage container samples, the mean *E. coli* count across all households receiving water for a given system was kept for the purpose of showing how these descriptive statistics and analysis are distributed. Overall, average *E. coli* counts tell a story of deteriorating water quality as water moves from source to a household storage container. The mean *E. coli* count for systems at the source is 19.5, corresponding to a “high” water quality risk. Interestingly, the mean *E. coli* count for system samples taken from the tank is just 10.6, which may be indicative of improved water quality in the case of treatment by CAPS; however, the frequency of water treatment from CAPS, as gauged by chlorination tests, is very low. An alternative explanation could be reduction in *E. coli* counts associated with settling in the tank, or indicator die off (Levy et al., 2008). From there, water quality deteriorates significantly with average *E. coli* counts at the tap and storage 23.5 and 22.7, respectively. Also displayed in Table 28 are differences in *E. coli* counts between different points in water systems for systems in which paired source-tank, tank-tap, and tap-storage samples exist. The greatest one-step difference (i.e., source to tank represents one step, while source to tap represents two steps) in water quality is between tank and tap samples, with a gap of 7.0 *E. coli* MPN, with means differences statistically significant at the 5 percent level (p-value of 0.048). The difference in water quality from source to storage containers is 7.2 *E. coli* MPN, on average. Means differences are also significant at the 5 percent level (p-value of 0.037). Paired storage-tap differences are negligent. While we see that more than half of source and tank samples are classified as safe (**Table 6-25**), there is a clear deterioration of water quality as it makes its way through the system. In the regressions displayed in Section 6.12, we explore the determinants "safe" water quality at the system level.

			Quintile of Average Household Wealth Score[3]				
		Sample N = 331	**1st N = 6**	**2nd N = 53**	**3rd N = 69**	**4th N = 71**	**5th N = 35**
	Obs.	Mean	Mean	Mean	Mean	Mean	Mean
E. coli MPN: source	139	19.5	3.5	33.0	13.3	19.2	20.2
E. coli MPN: tank	89	10.6	0.8	12.9	12.7	9.4	10.2
E. coli MPN: tap	82	23.5	2.0	23.6	23.0	27.9	12.4
E. coli MPN: storage	139	22.7	12.4	29.7	26.2	15.6	18.9
Differences\2							
Tank - Source	60	-3.7	-1.1	-9.9	8.4	-10.9	0.0
Tap – Tank**	63	7.0	.	5.6	4.1	9.2	1.4
Storage - Tap	75	-0.2	6.6	9.8	5.5	-13.0	-5.4
Storage – Source**	108	7.2	12.8	1.9	19.8	4.3	1.4

[1] E. coli counts represent the average count for a system, averaged across all systems for which E. coli analyses were conducted. [2] Risk categories correspond to the following E. coli counts: Safe (0), Intermediate (1 to 10), High (10 to 100), Very High (100 and above). [2] Households were assigned to wealth quintiles based on self-reported possession of assets, sanitation/water source, and household infrastructure (i.e., roof and floor materials). Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). Household wealth scores were then averaged across water systems, after which each water system was assigned to a wealth quintile based on thresholds utilized to group households into wealth quintiles. Wealth quintiles are ordered from poorest (e.g., 1st) to wealthiest (e.g., 5th). *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level \2*Paired Samples Only.*

Table 6-26 System-level E. Coli counts by quintiles of average household wealth score

6.10. Baseline Balance Check

In order for the impacts detected for a random control trial to be valid, both the treatment and control groups must be similar with respect to observable and unobservable characteristics that could potentially impact the outcomes of interest. To assess the effectiveness of randomisation at creating balanced treatment arms we evaluated the balance of measured baseline characteristics. **Tables 6-27-6-34** present baseline balance checks for key household, community, system, and CAPS variables. We rely on randomisation to provide overall balance across all characteristics but conducted tests of differences in means for specific variables, and report resulting test statistics.

The results of balance checks suggest that treatment and control group households are relatively well-balanced, increasing the likelihood that we will be able to detect the impacts of the PROSASR intervention with respect to key final and intermediate outcome variables, consistent with the initial IE design.

Overall, 176 variables are presented in the aforementioned tables. Across all characteristics there is evidence of good balance between treatment and control arms. For key outcome variables, such as the proportion of households with access to an improved water source and improved sanitation, as well as indicators of the sustainable operation of CAPS, show equivalence between arms. Similarly, there are no significant differences in most demographic, socio-economic, and water use characteristics across treatment and control households. The null hypoThesis of means equality at the 5 percent level was rejected for 11 indicators suggesting means differences between treatment and control groups for 6.2% of variables; if we exclude differences in CAP committee members, which is likely not meaningful (5.16 vs. 5.66) then 5.6% variables have evidence of statistical differences.[80]

One difference that does stand out is that control households are more likely to have taken their last drink from the tap, while treatment households are more likely to have taken their last drink from a storage container. Furthermore, control households are more likely to experience daily or weekly service disruptions in the wet season relative to households in the treatment group. Given that we expect to observe a reduction in service disruptions as a result of the intervention, this difference is potentially problematic. However, according to the community survey, communities in the control group are more likely to report having enough water all year long compared to treatment communities. Control group communities are also more likely to have a health post in the community, with means differences significant at the 1 percent level. With respect to differences between treatment and control service providers, treatment CAPS tend to keep accounting books to date more frequently than CAPS in the control group. Regarding water quality, the only notable differences in means is that the average *E. coli* MPN for tap samples among treatment homes taking their last glass of water from the tap was higher than for control group households. These characteristics will be controlled for in the endline analyses to assess whether these apparent imbalances impact interpretation of results.

6.11. Correlates of Continuity of Water Service and Water Quality

This section exhibits and discusses the implications of bivariate regressions exploring the correlates of water service continuity and water quality. These analyses are purely informative and exploratory; no interpretation of causal link should be drawn between the independent variables included in our analysis and the dependent variables we attempt to explain. However, utilizing baseline data from the IE detailed in this paper to offer some insight into factors that may contribute to sustainable water systems, and these analyses may or may not offer insight to the PROSASR project going forward.

[80] Finding that one of 20 indicators exhibits means differences that is statistically significant is expected by chance alone under a normal distribution assumption.

6.11.1.Methodology

Given the need for evidence on the factors contributing to water system sustainability, we dedicate much of our analysis to the correlates of water system continuity and microbial contamination. The variable used to proxy water system continuity is the average number of hours of water service per day for households during the dry season. This variable was calculated by averaging households' answers to the question of how many hours of water service they received from the system they receive service from, during the dry season (rather than the wet season), across systems. Intuitively, more pressure is put on water systems during the dry season than the wet season; as such, water is more likely to be in shorter supply in the dry season than the wet season (see **Table 6-12**). Given difficulties matching households to water systems due to miscoding during data collection, this analysis was conducted using data for 233 of the 316 systems (73.7%) for which data was collected.

Next, we investigate the correlates of water quality at the system and household levels. We consider two measures of water quality: (i) *E. coli* MPN and (ii) a dummy variable for "safe water" (defined as 0 MPN *E. coli* per 100 ml of water). The first set of bivariate regressions investigates the correlates of water quality at the system level. Water quality at the system level in this context is gauged by averaging across all household tap samples linked to a given system.[81] Water quality at the tap is most representative of the impact of the system on water quality before water is handled by system end-users.

Alternatively, water quality in the source and tank may improve or deteriorate depending on the state of water system infrastructure and the application of chlorination treatment (or a lack thereof) closer to the end user (e.g., distribution infrastructure). At the household level, we look at the water quality of household storage container samples. Storage container samples offer insight into the quality of water once it has been handled by the end user, and is influenced by household practices. In situations in which more than one storage container sample was taken, a household is assigned the average *E. coli* MPN across all of that household's samples for the purpose of this analysis. Just as for the system dummy variable,

[81] In cases in which more than one tap sample was taken for a given household, the value assigned to that household for the purpose of this analysis is the average of all tap samples.

households were assigned a 1 for the household dummy variable if *E. coli* MPN was 0 and a 1 if average *E. coli* MPN was above 0.

For water system continuity and quality at the system level, our independent variables of interest include water system and CAPS characteristics. System-level independent variables of interest include dummy variables for the following:

a. water system type (pumped versus gravity systems)
b. whether any water system source is:
    i. contaminated by garbage or sewage
    ii. contaminated by chemicals
    iii. *not* surrounded by a green area
    iv. surrounded by an eroded area
    v. *not* protected
    vi. in poor condition
c. whether a water system has:
    i. treatment infrastructure
    ii. storage infrastructure
    iii. distribution infrastructure
d. whether any treatment, storage, and distribution infrastructure is in poor condition (with dummy variables for each case) for systems with associated treatment, storage, and distribution infrastructure (e.g., systems without treatment infrastructure were assigned a missing value and were not considered in associated bivariate regressions)

For all dummy variables other than water system type, a system was assigned a 1 in the case of an affirmative instance (e.g., a system *was* contaminated with chemicals) and a 0 in the case of a negative instance (e.g., a system *was not* contaminated by chemicals). System-level variables were chosen based on the likelihood of their impacting water quality and/or water service continuity. The rational for creating dummy variables based on whether *any* component is in poor condition or contaminated, not protected, etc. is that any water system weakness, regardless of the magnitude, may have an adverse impact on water quality and/or water service continuity.

CAPS variables were taken into consideration to measure the extent to which the relative strength or weakness of a local CAPS impacts the quality and continuity of the associated water system's water. Variables proxying the level of administrative and fiscal strength, as well as the level of service provided to water systems were incorporated into bivariate regressions. Dummy variables for whether the CAPS associated with a system fit the following criteria were taken into consideration:

a. is legalized
b. has professional staff
c. has a verified complaint mechanism in place
d. is accountable to system users
e. charges a variable tariff
f. has accounting books that are to date
g. provides preventative care to water systems
h. applies a chlorination treatment and confirms that it works
i. applied a chlorination treatment in the 15 days preceding the survey
j. has received assistance from a municipal or national government entity

In addition to water system and CAPS variables, we look at means differences by (i) the quintile of the average household wealth score for systems and (ii) region, utilizing Pacific, Central, and Atlantic region dummy variables.

Given the richness of the household survey and the fact that storage container *E. coli* samples were taken during data collection, we incorporate a series of bivariate regressions to investigate the correlates of water quality at the household level. For bivariate regressions, we used dummy variables for the characteristics of household water source, household head characteristics, several proxies of wealth (e.g., floor and roof material), as well as behaviours related to water and sanitation. The specific dummy variables we utilize for our analysis include the following:

a. Whether the household:
    i. has an improved water source
    ii. is connected to community system
    iii. claims to have treated their last drink through chlorination
    iv. practices open defecation
b. Whether the household head:
    i. has studied some secondary school or more

ii. that manages the household's water is female
iii. that manages the household's water is female and has some secondary school or more

c. Household physical infrastructure characteristics
   i. Floor type (firm versus earth)
   ii. Roof type (zinc versus tiled/fiberglass/palm)
d. Whether the enumerator observed:
   i. faeces in the yard
   ii. a handwashing station available
   iii. a handwashing station in a convenient location
   iv. water and soap at the handwashing station
e. Whether the container used to store water had a wide mouth (e.g., one's hand can fit into it) rather than a small mouth.

Regional and household wealth quintile dummy variables were also included in household water quality bivariate regressions.

Baseline Characteristic	**Baseline - Overall N = 4,850**		**Control Arm N = 2,466**	**Treatment Arm N = 2,384**	**Ttest**
	Obs.	Mean (sd)	Mean (sd)	Mean (sd)	p-value[1]
Number of household members					
Average HH size	4,850	4.7 (2.17)	4.73 (2.21)	4.67 (2.13)	0.41
HH members, 5 and under	4,847	0.6 (0.82)	0.62 (0.84)	0.58 (0.8)	0.16
HH members, 6-13	4,847	0.82 (0.95)	0.85 (0.97)	0.79 (0.93)	0.09
HH members, 14-30	4,847	1.58 (1.32)	1.58 (1.36)	1.58 (1.29)	0.98
HH members, 31-65	4,844	1.46 (.98)	1.44 (.95)	1.47 (1)	0.38
HH members 65+	4,842	0.25 (0.57)	0.25 (0.59)	0.25 (0.56)	0.81
Average age, HH head	4,850	46.39 (15.74)	46.46 (15.78)	46.32 (15.69)	0.82
HH heads, % male	4,850	54% (50%)	52% (50%)	56% (50%)	0.07
Head of Household					
Ethnicity					
Identifies as indigenous	4,437	3% (17%)	3% (18%)	3% (17%)	0.89
Employment					
Reports Active Employment	4,850	81% (39%)	79% (41%)	82% (38%)	0.13
Any Income Prior Month	4,842	83% (38%)	82% (39%)	84% (37%)	0.36
Income from Employment	4,842	73% (44%)	72% (45%)	74% (44%)	0.35
Education					
No Primary	4,846	37% (48%)	36% (48%)	38% (48%)	0.4
Primary	4,846	44% (50%)	44% (50%)	43% (50%)	0.47
Secondary	4,846	12% (32%)	12% (33%)	11% (31%)	0.24

Post-Secondary	4,846	3% (18%)	3% (17%)	3% (18%)	0.67
Is literate	4,850	70% (46%)	70% (46%)	70% (46%)	0.85
Ever attended school	4,846	69% (46%)	69% (46%)	69% (46%)	0.75
Health (Diarrhoea Incidence)					
Last week: any family member	4,850	9% (28%)	9% (29%)	8% (27%)	0.34
Last 2 days: any family member	4,850	7% (25%)	7% (26%)	6% (25%)	0.53
Last week: child (<5 years)	2,182	7% (25%)	7% (25%)	7% (26%)	0.87

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-27 Assessment of Baseline Balance on demographics, health and head of household characteristics

Baseline Characteristic	**Baseline - Overall N = 4,850**		**Control Arm N = 2,466**	**Treatment Arm N = 2,384**	**Ttest**	
	Obs.	Mean (sd)	Mean (sd)	Mean (sd)	p-value[1]	
Water						
Source Characteristics						
Improved Water Source	4,850	81% (39%)	80% (40%)	82% (39%)	0.71	
Connected to Community System	4,844	62% (49%)	64% (48%)	60% (49%)	0.39	
Sufficient Water (Dry Season)	4,850	61% (49%)	61% (49%)	61% (49%)	0.95	
Sufficient Water (Wet Season)	4,850	81% (39%)	80% (40%)	83% (38%)	0.27	
Last Drink of Water						
Last Drink Source: Community System	4,797	62% (49%)	64% (48%)	59% (49%)	0.31	
Last Drink Direct from Tap	4,850	14% (35%)	16% (37%)	12% (33%)	0.09	
Last Drink from Storage Container	4,850	84% (36%)	82% (38%)	87% (34%)	0.05	**
Last Drink Treated	4,797	24% (42%)	23% (42%)	24% (43%)	0.53	
Last Drink Treated with Chlorine	4,797	20% (40%)	18% (39%)	21% (41%)	0.19	
Water Use						
Believe treatment is Not Necessary	4,797	51% (50%)	52% (50%)	50% (50%)	0.51	
Hours of service per day (Dry Season)	2,990	13.27 (10.13)	12.71 (10.13)	13.9 (10.09)	0.37	
Hours of service per day (Wet Season)	2,990	15.21 (10)	14.26 (10.13)	16.27 (9.74)	0.13	
Difference (Wet - Dry)	2,981	2 (5.45)	1.65 (4.73)	2.38 (6.12)	0.19	

Service interruption (Dry)	2,990	62% (49%)	65% (48%)	59% (49%)	0.25	
Service interruption (Wet)	2,990	48% (50%)	54% (50%)	42% (49%)	0.02	**
Monthly payment (córdobas)	2,737	74.45 (92.06)	81.4 (92.25)	66.82 (91.29)	0.13	
Amount of water used (Liters)	4,850	185.52 (164.11)	185.14 (163.96)	185.91 (164.29)	0.94	
Amount of time to retrieve water	4,797	8.18 (29.03)	8.42 (35.37)	7.92 (20.59)	0.76	
Who Manages Household Water?						
Female Member	4,797	86% (35%)	87% (34%)	85% (36%)	0.17	
Sanitation						
Has Sanitation Facility	4,849	89% (31%)	90% (30%)	89% (31%)	0.48	
Private Facility	4,849	82% (39%)	82% (38%)	82% (39%)	0.89	
Improved Sanitation	4,849	40% (49%)	39% (49%)	42% (49%)	0.45	
Open defecation	4,849	11% (31%)	10% (30%)	11% (31%)	0.59	
Hand Hygiene						
Reports Handwashing Station	4,850	70% (46%)	71% (46%)	70% (46%)	0.9	
Station Convenient Location	4,849	67% (47%)	68% (47%)	67% (47%)	0.85	
Water and Soap Available	4,849	62% (48%)	63% (48%)	62% (49%)	0.81	
Environmental Hygiene						
Trash in Yard	4,849	41% (49%)	39% (49%)	42% (49%)	0.43	
Feces in Yard	4,849	36% (48%)	33% (47%)	38% (49%)	0.11	

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-28 Assessment of baseline balance of water sources, environmental and hygiene conditions

Baseline Characteristic	**Baseline - Overall N = 4,850**	**Control Arm N = 2,466**	**Treatment Arm N = 2,384**	**Ttest**
	Mean (sd)	Mean (sd)	Mean (sd)	p-value[1]
Assets				
Radio	60% (49%)	60% (49%)	60% (49%)	0.92
Television	64% (48%)	64% (48%)	64% (48%)	1
Refrigerator	25% (43%)	26% (44%)	24% (43%)	0.34
Iron	34% (47%)	34% (47%)	33% (47%)	0.81
Grinding Machine	35% (48%)	34% (48%)	35% (48%)	0.83
Cassette Recorder	6% (24%)	6% (24%)	6% (24%)	0.73
Stereo	20% (40%)	20% (40%)	19% (39%)	0.7
Fan	21% (41%)	22% (42%)	20% (40%)	0.49
Blender	17% (38%)	17% (38%)	17% (37%)	0.77
Sewing Machine	7% (25%)	7% (26%)	6% (24%)	0.17
Bicycle	28% (45%)	29% (45%)	27% (44%)	0.49
Motorcycle	14% (35%)	15% (35%)	14% (34%)	0.49
CD Player/DVD Player	19% (39%)	20% (40%)	18% (39%)	0.45
Cell Phone	65% (48%)	65% (48%)	66% (47%)	0.61
Computer	2% (15%)	2% (14%)	2% (15%)	0.66
Wealth Quintile				

Poorest Quintile	20% (40%)	20% (40%)	20% (40%)	0.89	
Second Wealth Quintile	20% (40%)	19% (39%)	21% (41%)	0.37	
Third Wealth Quintile	20% (40%)	18% (39%)	22% (41%)	0.05	**
Fourth Wealth Quintile	20% (40%)	21% (41%)	19% (39%)	0.34	
Richest Quintile	20% (40%)	21% (41%)	19% (39%)	0.35	
Infrastructure					
Floor Material					
Concrete/tile	42% (49%)	43% (50%)	40% (49%)	0.39	
Wood	3% (16%)	2% (15%)	3% (17%)	0.51	
Earth/dirt	56% (50%)	55% (50%)	57% (50%)	0.49	
Roof Material					
Zinc sheet	88% (32%)	88% (33%)	88% (32%)	0.89	
Tiled	10% (30%)	10% (30%)	10% (30%)	0.88	
Fiberglass/asbestos	1% (9%)	1% (10%)	1% (9%)	0.89	
Palm or non-permanent	1% (10%)	1% (10%)	1% (10%)	0.84	

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-29 Assessment of baseline balance for household assets, income and household materials

Baseline Characteristic	Baseline - Overall N = 300		Control Arm N = 150	Treatment Arm N = 150	T-test	
	Obs.	Mean (sd)	Mean (sd)	Mean (sd)	p-value[1]	
General community characteristics						
No. HH	294	115.2 (121.06)	116.48 (105.55)	113.93 (135.15)	0.86	
No. systems	291	3.23 (15.6)	4.97 (22.03)	1.52 (1.49)	0.06	
No. systems: 1	291	74% (44%)	75% (43%)	73% (45%)	0.67	
No. systems: 2	291	12% (33%)	13% (34%)	11% (31%)	0.55	
No. systems: 3	291	6% (23%)	3% (18%)	8% (27%)	0.09	
Indigenous comm.	294	7% (25%)	7% (26%)	6% (24%)	0.64	
Improved sanitation	283	86% (35%)	83% (38%)	88% (33%)	0.23	
>50% of HH have improved sanitation	300	49% (50%)	46% (50%)	53% (50%)	0.25	
Water-related epidemic in community	294	35% (48%)	33% (47%)	37% (49%)	0.47	
% of communities with waste collected/treated	290	61% (49%)	62% (49%)	61% (49%)	0.86	
% of communities with sufficient water	290	63% (48%)	71% (46%)	56% (50%)	0.01	***
School characteristics						
Has a school	294	93% (25%)	92% (27%)	95% (23%)	0.36	
Has a school with water connection	274	79% (41%)	79% (41%)	78% (41%)	0.87	
Has a school with improved sanitation	274	66% (47%)	67% (47%)	66% (47%)	0.93	

Good hand washing practices taught	271	95% (22%)	93% (25%)	96% (19%)	0.24	
Adequate water manipulation practices taught	268	93% (25%)	92% (28%)	95% (22%)	0.27	
School bathroom has handwashing station w/soap and water	271	37% (48%)	35% (48%)	39% (49%)	0.5	
Health post characteristics						
Community has a health post	294	22% (42%)	29% (45%)	16% (37%)	0.01	***
Community has a health post with a water connection	294	19% (39%)	24% (43%)	13% (34%)	0.01	***
Community has a health post with improved sanitation	294	16% (36%)	19% (39%)	12% (33%)	0.11	
Hands washed at health post	293	20% (40%)	25% (44%)	15% (36%)	0.03	**
Health post has handwashing station with soap and water	291	14% (34%)	15% (36%)	12% (33%)	0.45	
Community infrastructure						
Community has electricity	294	69% (46%)	69% (47%)	69% (47%)	1	
Community has fixed phone lines	294	7% (26%)	8% (27%)	6% (24%)	0.5	
Community has mobile phone connection	294	89% (31%)	90% (30%)	88% (32%)	0.71	
Community has internet	294	17% (38%)	17% (38%)	17% (38%)	1	
Household water use characteristics						
>50% of HHs w/ hand-washing station < 10m of latrine with water and soap	280	43% (50%)	41% (49%)	44% (50%)	0.62	
>50% of HH have hand-washing station < 10m of latrine/toilet	276	36% (48%)	33% (47%)	38% (49%)	0.41	
>50% of HHs in which entire family using hand-washing station	264	48% (50%)	45% (50%)	50% (50%)	0.45	
>50% of HHs practicing safe water storage practices	281	86% (35%)	89% (32%)	83% (38%)	0.17	
% of HH utilizing hygiene and water management practices	293	78% (41%)	79% (41%)	78% (42%)	0.86	

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-30 Assessment of Baseline balance of community's water, sanitation, and conditions

Baseline Characteristic	Baseline - Overall N = 331		Control Arm N = 159	Treatment Arm N = 157	Ttest	
	Obs.	Mean (sd)	Mean (sd)	Mean (sd)	p-value[1]	
Infrastructure						
System age (Years)	287	12.4 (8.08)	12.37 (7.78)	12.44 (8.41)	0.94	
No. system users	223	76.17 (110.19)	81.32 (98.88)	71.07 (120.59)	0.49	
% of HHs connected to the system	220	62% (35%)	64% (35%)	60% (35%)	0.49	
Drilled Well	305	12% (33%)	12% (33%)	13% (33%)	0.95	
Dug Well	305	5% (21%)	6% (24%)	3% (18%)	0.29	
Pumped system	305	25% (43%)	25% (44%)	24% (43%)	0.77	
Manual well	305	11% (32%)	7% (26%)	16% (37%)	0.03	**
Gravity system	305	47% (50%)	49% (50%)	44% (50%)	0.39	
Source characteristics						
Number of sources	302	1.41 (1.11)	1.36 (.83)	1.47 (1.33)	0.43	
Any source in poor condition	251	21% (41%)	19% (40%)	22% (42%)	0.6	
Any source contaminated by garbage/sewage	297	22% (42%)	25% (44%)	19% (39%)	0.22	
Any source contaminated by chemicals	289	22% (42%)	18% (39%)	26% (44%)	0.13	
Any source not surrounded by green areas	294	14% (34%)	15% (36%)	12% (33%)	0.55	
Any source surrounded by eroded areas	289	23% (42%)	21% (41%)	25% (44%)	0.36	
Any source not protected	289	35% (48%)	35% (48%)	35% (48%)	1	
Sources have sufficient water: summer	300	69% (46%)	72% (45%)	66% (47%)	0.26	
Sources have sufficient water: winter	300	91% (28%)	89% (32%)	94% (24%)	0.11	
Treatment characteristics						
Treatment infrastructure exists	303	26% (44%)	23% (42%)	29% (45%)	0.23	
Any treatment infra in poor condition	78	15% (36%)	17% (38%)	14% (35%)	0.71	
Water treated with chlorine	298	33% (47%)	36% (48%)	29% (46%)	0.23	
Receive assistance with chlorine treatment	108	46% (50%)	49% (50%)	43% (50%)	0.56	
Residual chlorine analysis performed	120	20% (40%)	23% (42%)	17% (38%)	0.48	
Chlorine applied in last 15 days	220	82% (39%)	83% (38%)	80% (40%)	0.6	
Other infrastructure characteristics						
Storage infrastructure exists	299	71% (46%)	73% (45%)	68% (47%)	0.43	
Any storage infra in poor condition	210	15% (36%)	12% (33%)	19% (39%)	0.19	
Distribution infrastructure exists	299	78% (41%)	79% (41%)	77% (42%)	0.61	
Any distr. infra in poor condition	229	8% (28%)	8% (28%)	8% (27%)	0.92	
No. public water intakes	296	1 (5.85)	1.26 (8.13)	.74 (1.41)	0.44	

>75% public water intakes >100m from HH	111	32% (47%)	25% (44%)	39% (49%)	0.12

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-31 Assessment of Baseline Balance for system's conditions of water, sanitation and hygiene

Baseline Characteristic	Baseline - Overall N = 299		Control Arm N = 150	Treatment Arm N = 149	Ttest	
	Obs.	Mean (sd)	Mean (sd)	Mean (sd)	p-value[1]	
Institutionalism						
Service Provider is a CAPS	276	70% (46%)	69% (46%)	71% (45%)	0.68	
System age (Years)	287	12.4 (8.08)	12.37 (7.78)	12.44 (8.41)	0.94	
CAPS is legalized	276	35% (48%)	33% (47%)	37% (48%)	0.49	
CAPS fully-elected	277	62% (49%)	60% (49%)	64% (48%)	0.45	
No. meetings last 6 months	184	2.84 (2.68)	2.61 (2.42)	3.06 (2.91)	0.25	
No. CAPS committee members	240	5.4 (1.7)	5.16 (1.83)	5.66 (1.52)	0.02	**
Women in CAPS leadership	230	37% (24%)	38% (24%)	36% (23%)	0.58	
Professionalism						
Has technical staff	258	67% (47%)	63% (48%)	72% (45%)	0.13	
Technical staff is paid	257	44% (50%)	42% (49%)	46% (50%)	0.51	
Participation						
Has complaint mechanism	262	45% (50%)	41% (49%)	49% (50%)	0.18	
Has accountability mechanism	251	52% (50%)	48% (50%)	56% (50%)	0.19	
Women speak in meetings	258	89% (31%)	87% (34%)	92% (28%)	0.22	
Finances						
Has tariff	265	73% (44%)	71% (45%)	75% (43%)	0.47	
Tariff is variable	265	21% (41%)	20% (40%)	22% (41%)	0.79	
Average monthly tariff (USD)	192	3.09 (10)	2.92 (9.48)	3.24 (10.49)	0.82	
% HH on time with payment	176	.72 (.27)	.71 (.27)	.72 (.28)	0.86	
Accounting books to date	252	56% (50%)	51% (50%)	62% (49%)	0.07	
Solvent	147	62% (49%)	61% (49%)	62% (49%)	0.91	
Has savings account	231	26% (44%)	23% (42%)	29% (46%)	0.25	
O&M and government assistance						
Provides preventative care	266	53% (50%)	51% (50%)	55% (50%)	0.55	
Provides corrective care	266	74% (44%)	77% (42%)	72% (45%)	0.33	
Has materials for O&M	260	46% (50%)	42% (50%)	50% (50%)	0.22	
Requested government support	270	54% (50%)	57% (50%)	52% (50%)	0.47	
Requested and received government support	269	38% (49%)	35% (48%)	41% (49%)	0.31	
Requested, did not receive government support	269	16% (37%)	21% (41%)	11% (32%)	0.02	**
Reports problems to UMAS	261	36% (48%)	34% (48%)	38% (49%)	0.52	
UMAS responsive	261	24% (43%)	26% (44%)	22% (42%)	0.54	
CAPS promotion activities						
Promotes environmental sanitation	267	81% (39%)	84% (36%)	78% (42%)	0.18	
Protects area around water source	267	90% (31%)	92% (27%)	87% (34%)	0.21	

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-32 Assessment of baseline balance for water, sanitation and hygiene (service provider)

Baseline Characteristic	Baseline - Overall N = 4,850		Control Arm N = 2,466	Treatment Arm N = 2,384	T-test	
	Obs.	Mean (sd)	Mean (sd)	Mean (sd)	p-value[1]	
E. coli MPN, last drink: storage	276	25.3 (30.33)	23.89 (30.02)	26.78 (30.69)	0.59	
E. coli MPN, last drink: tap	36	18 (26.33)	5.77 (13.83)	30.23 (30.32)	0.01	***
E. coli MPN, storage	325	24.09 (30.09)	21.3 (29.07)	27.07 (30.96)	0.26	
E. coli MPN, tap	169	21.48 (32.18)	17.73 (32.02)	25.66 (32.04)	0.25	
E. coli MPN, storage less tap	121	6.24 (20.8)	5.37 (18.62)	7.36 (23.43)	0.73	

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-33 Assessment of baseline balance for households' water, sanitation and hygiene variables

Baseline Characteristic	Baseline - Overall N = 331		Control Arm N = 159	Treatment Arm N = 157	T-test
	Obs.	Mean (sd)	Mean (sd)	Mean (sd)	p-value[1]
E. coli MPN: source	139	19.54 (37.08)	19.47 (37.13)	19.63 (37.3)	0.98
E. coli MPN: tank	89	10.58 (26.76)	8.11 (24.82)	13.47 (28.9)	0.35
E. coli MPN: Tank - Source	60	-3.72 (32.46)	-2.06 (30.91)	-5.75 (34.75)	0.67
E. coli MPN: Tap - Tank	63	7.04 (27.71)	7.16 (28.4)	6.91 (27.45)	0.97

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-34 Assessment of baseline balance for water, sanitation and hygiene for system's water quality

6.12. Results

This section summarizes findings for the correlates of water service levels and water quality based on bivariate regressions. For each table, the independent variable of interest is found in the first column and is followed by the number of observations and the mean for the two dummy variable comparison groups (e.g., DV = 0 and DV = 1). The p-value for means differences is found in the final column. Means differences significant at the 1 and 5 percent levels are highlighted with three and two asterisks, respectively.

6.12.1.System-level water service

Tables 6-35 through 6-37 exhibits the results of bivariate regressions for the number of hours of water service during the dry season, e coli and other characteristics. Overall, these results demonstrate that significant differences exist at the regional level, whereby the greatest number of hours of service is observed in the Atlantic (17.8), followed by the Central and Pacific regions (14.1 and 10.9, respectively). All region-versus-region differences are significant at the 1 percent level with only Atlantic-Central differences significant at the 5 percent level. See **Figure 6-3** for a graphical representation of hours of service during the dry season, by region. With respect to differences across wealth quintiles, there is a tendency for systems serving poorer households to exhibit higher service levels than systems serving wealthier homes. **Figure 6-4** shows system service levels by wealth quintile. Importantly only 2nd-5th wealth quintile means differences are significant, with means differences significant at the 5 percent level (p-value = 0.04).

With regards to means differences for system-level variables, no variables are significant at the 5 percent level or higher. Nonetheless, we note that service levels are higher for gravity systems relative to pump systems (14.6 hours versus 12.2 hours, p-value = 0.06). Indeed, gravity systems are found in the Central and Atlantic regions (81.5% and 92.6%, respectively) more frequently than in the Pacific (19.7%) (not exhibited). With respect to other system-level variables, in general, systems for which system components are in better condition (e.g., that *are* protected, that *are* surrounded by green areas) exhibit higher levels of water service, though, means differences are not significant at conventional levels. In particular, systems with any distribution infrastructure in poor condition demonstrate lower levels of service than systems for which no distribution infrastructure is in poor condition (14.1 hours versus 10.0 hours, p-value = 0.06)[82].

[82] With respect to CAPS variables, one would expect CAPS that possess more technical capacity to exhibit higher levels of service. Results indeed provide limited evidence for a link between sound CAPS administration and water service continuity. However, in just one case are means differences significant at conventional levels. Systems administered by CAPS with a monthly tariff for which the variable is variable demonstrate a higher level of service in comparison to systems administered by CAPS without a variable monthly tariff (16.9 hours versus 12.5), with means differences significant at the 1 percent level. Also, of note is the fact that CAPS with accounting books to date demonstrate higher levels of service than do CAPS for which this is not the case (14.4 hours versus 12.3, p-value = 0.10).

6.12.2. System-level water quality

Table 6-35 exhibits results for bivariate regressions for which the dependent variable is *E. coli* MPN. **Table 6-36** exhibits results for bivariate regressions for which the dependent variable is the “safe” dummy variable. Dummy variables for which a 1 has been assigned can be interpreted as having “safe” water.

Broadly, with regards to regional differences, there is some evidence for the Atlantic region having “safe” water with greater frequency than either the Pacific or Central Regions. 55% of Atlantic samples were deemed “safe,” while this was the case for just 20% of Central and 35% of Pacific Region systems. Nonetheless, only Atlantic-Central means differences for the “safe” dummy variable regressions suggest a statistically significant difference (p-value = 0.02) (**Table 6-37**).

With respect to differences by the quintile of the average household wealth score for systems, there seems to be an overall trend towards higher water quality for systems serving higher-wealth users. This is confirmed using *E. coli* MPN (**Figure 6-5**) and the dummy variable for samples for which water is deemed “safe”. Nonetheless, means differences are only significant for 5th-3rd and 4th-3rd bivariate regressions, with just 12% of 3rd wealth quintile systems having “safe” water, relative to 56% and 40% of 5th and 4th wealth quintile systems, respectively.

System characteristics and the condition of system infrastructure are found to impact water quality in several instances. For one, pump systems are associated with “safe” water more frequently than gravity systems (53% versus 21%), granted the two types of systems exhibit similar mean *E. coli* MPN levels. Secondly, at least some of a system’s sources being contaminated by chemicals or industrial revenue is associated with a higher *E. coli* MPN and a lower prevalence of “safe” water, with means differences significant for both variables.[83] Additionally, systems with sources surrounded by eroded areas exhibited higher *E. coli* MPN and a lower prevalence of “safe” water vis-à-vis systems for which this was not the case, even though means differences are only significant for the *E. coli* MPN variable (37.7 versus 19.6, p-value = 0.05). Other system variables support the premise that systems with sources and infrastructure in poor condition are associated with “safe” water with less frequency than systems with sources and infrastructure for which this is not the case (**Figure 6-**

[83] Also of note is the fact that just 8% of systems for which at least some sources were contaminated by garbage or sewage were deemed to have “safe” water relative to 31% of systems for which this was not the case (p-value = 0.09).

6). Means differences are, however, significant in few cases. Bivariate regressions for which CAPS characteristics are the independent variables demonstrate few consistent trends or significant relationships between the institutional strength of CAPS and water quality.

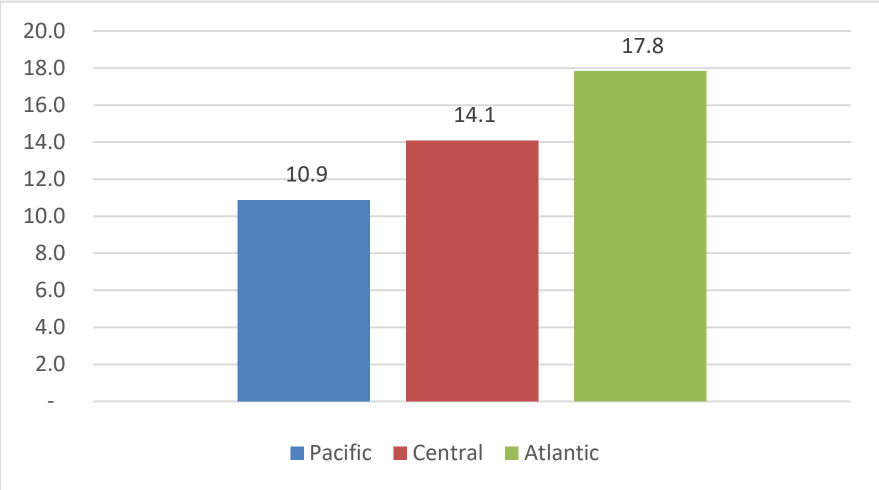


Figure 6-3 Hours of water service in the dry season, system-level

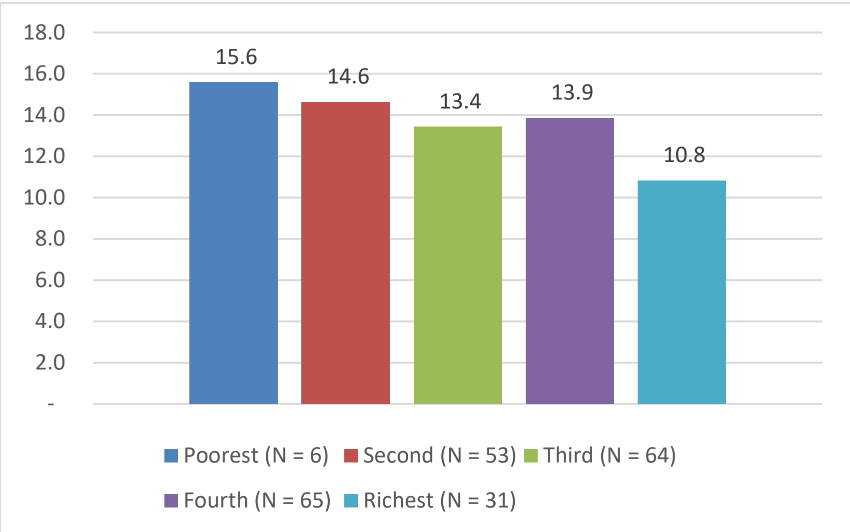


Figure 6-4 Hours of water service in the dry season, by wealth quintile

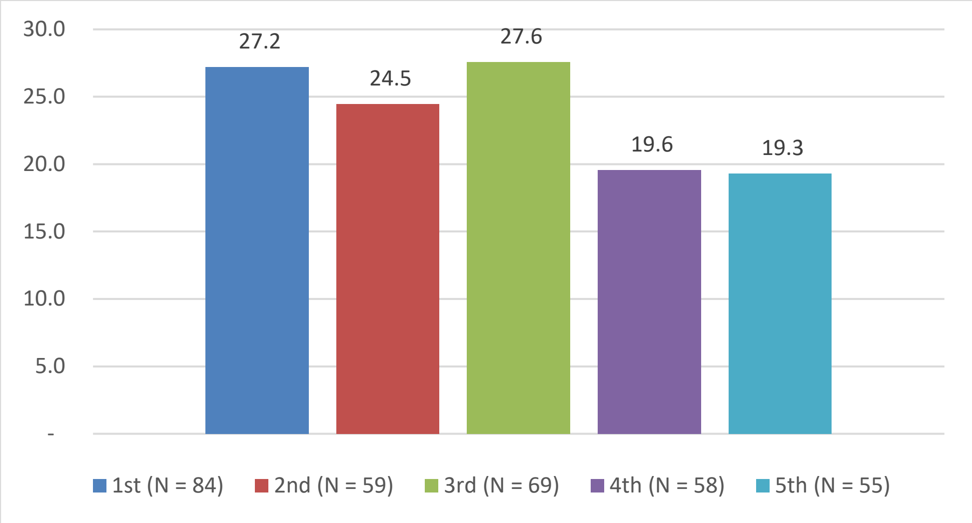


Figure 6-5 E.coli MPN for Household Storage Container Samples by Wealth Quintile

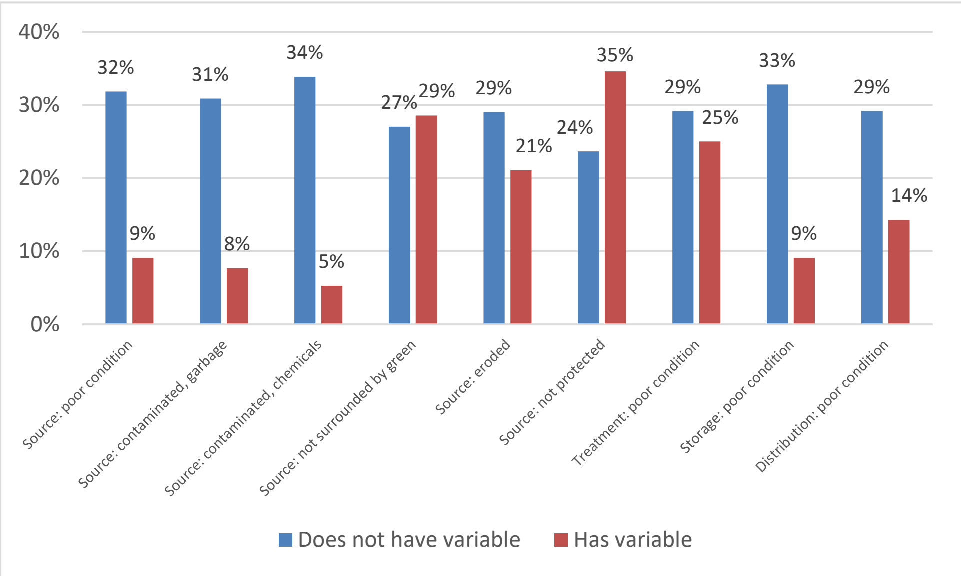


Figure 6-6 % of "safe" tap samples according to infrastructure condition

6.12.3.Household water quality

Results for household water quality regressions using storage container samples are shown for *E. coli* MPN in **Table 6-38** and for the dummy variable for whether water was deemed “safe” in **Table 6-39**. P-values in both cases were adjusted by clustering at the community level.

As for system-level regressions, with respect to regional differences, the Atlantic again has the highest prevalence of “safe” water (41%) granted average *E. coli* MPN was the highest in the Atlantic vis-à-vis the Central and Pacific regions. In no cases were means differences significant.

With respect to differences across wealth quintiles, there is again some evidence for a relationship by which better water quality is observed for households in higher wealth quintiles. But, although some combinations approach significance at the 10 percent level (e.g., 5th-3rd and 4th-3rd wealth quintile differences for *E. coli* MPN and 5th-2nd wealth quintile differences for "safe" water quality bivariate regressions), overall, means differences are not significant at conventional levels. Bivariate regressions of several household variables on the household water quality variable exhibit several interesting trends. For example, households with an improved water source exhibit a higher percentage of "safe" water samples and a lower average *E. coli* MPN than those without an improved water source. Nonetheless, in neither of the two cases are means differences significant. With respect to the profile of the household head, household heads with higher levels of education (in this case, some secondary school or more), exhibit "safe" water and lower *E. coli* MPN than households where household heads have lower levels of education. Whereas 42% of households with "educated" household heads have "safe" water, this is the case for just 24% of households with less educated household heads (p-value = 0.05). Gender may also be a factor in household water quality, with households for which the female is the household member in charge of water exhibiting "safe" water in storage containers less frequently than for male-headed homes (25% versus 39%, p-value = 0.09). However, households for which an "educated" woman oversees water exhibit "safe" water 40% of the time relative to 25% for households in which this is not the case (p-value = 0.11). This interaction variable is negative and significant in a simple regression including gender and education independent variables, indicating that this subgroup may in fact be associated with improved water quality[84].

Variable of interest	**Does not have variable**		**Has variable**		**Ttest**
	Obs.	Mean (sd)	Obs.	Mean (sd)	p-value
Regional differences					
Central = 0, Pacific = 1	54	22.56 (34.32)	17	31.8 (42.43)	0.36
Atlantic = 0, Pacific = 1	11	15.44 (31.61)	17	31.8 (42.43)	0.28
Atlantic = 0, Central = 1	11	15.44 (31.61)	54	22.56 (34.32)	0.53
System variables of interest					
Pumped system = 0, Gravity system = 1	19	23.33 (41.67)	58	23.76 (34.86)	0.97
Any source in poor condition	66	23.2 (34.93)	11	24.46 (40.36)	0.91

[84] With regards to other household variables of interest, we find that, counterintuitively, households claiming that they had treated their last drink of water through chlorination exhibit lower levels of "safe" water than households not treating their last drink through chlorination (p-value = 0.03). At the same time, given that an analysis of the chlorine samples taken at the household level indicated that very few households chlorinated water, there is little reason to read much into this result.

Any source contaminated by garbage/sewage	68	21.94 (34.5)	13	33.59 (42.15)	0.29	
Any source contaminated by chemicals/industrial residue	62	19.35 (33.89)	19	38.37 (38.92)	0.04	**
Any source not surrounded by green areas	74	24 (35.74)	7	21.83 (39.32)	0.88	
Any source surrounded by eroded areas	62	19.55 (32.61)	19	37.72 (42.75)	0.05	**
Any source not protected	55	23.67 (35.42)	26	24.12 (37.32)	0.96	
Treatment infra exists	54	18.16 (32.75)	28	33.87 (39.31)	0.06	
Any treatment infra in poor condition	24	37.59 (40.7)	4	11.54 (20.81)	0.23	
Storage infra exists	7	12.61 (21.48)	73	24.07 (36.39)	0.42	
Any storage infra in poor condition	61	25.86 (38.77)	11	16.24 (19.44)	0.43	
Distribution infra exists	1	1.95 (.)	80	24.09 (35.95)	0.54	
Any distribution infra in poor condition	72	24.96 (36.24)	7	18.17 (36.76)	0.64	
CAPS variables of interest						
CAPS legalized	42	29.29 (39.86)	35	18.38 (31.01)	0.19	
Technical staff paid	34	22.17 (31.56)	43	26.04 (39.93)	0.65	
Has complaint-receiving mechanism	34	17.21 (33.26)	43	29.97 (37.96)	0.13	
Accountable to system-users	23	24.54 (38.76)	52	24.69 (36.12)	0.99	
Has monthly tariff	8	21.59 (33.34)	69	24.65 (36.84)	0.82	
Monthly tariff is variable	56	23.86 (35.31)	21	25.58 (39.69)	0.85	
Accounting books to date	21	17.39 (35.37)	55	26.99 (36.94)	0.31	
Provides preventative care	29	25.3 (39.23)	48	23.75 (34.82)	0.86	
Protects area around source	6	42.74 (48.74)	71	22.78 (35.06)	0.2	
Water treated with chlorine	51	26.8 (36.01)	30	18.74 (35.49)	0.33	
Chlorine applied in last 15 days	70	23.56 (35.78)	12	23.33 (36.65)	0.98	
Receive assistance with chlorine treatment	20	15.43 (26.5)	14	25.94 (43.01)	0.38	

*** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-35 Bivariate regressions for tap sample E. Coli MPN by system and CAPS variables of interest—System level

Variable of interest	Does not have variable		Has variable		Ttest	
	Obs.	Mean (sd)	Obs.	Mean (sd)	p-value	
Regional differences						
Central = 0, Pacific = 1	54	20% (41%)	17	35% (49%)	0.21	
Atlantic = 0, Pacific = 1	11	55% (52%)	17	35% (49%)	0.33	
Atlantic = 0, Central = 1	11	55% (52%)	54	20% (41%)	0.02	**
System variables of interest						
Pumped system = 0, Gravity system = 1	19	53% (51%)	58	21% (41%)	0.01	**
Any source in poor condition	66	32% (47%)	11	9% (30%)	0.13	
Any source contaminated by garbage/sewage	68	31% (47%)	13	8% (28%)	0.09	
Any source contaminated by chemicals/industrial residue	62	34% (48%)	19	5% (23%)	0.01	**
Any source not surrounded by green areas	74	27% (45%)	7	29% (49%)	0.93	
Any source surrounded by eroded areas	62	29% (46%)	19	21% (42%)	0.5	
Any source not protected	55	24% (43%)	26	35% (49%)	0.31	
Treatment infra exists	54	28% (45%)	28	29% (46%)	0.94	
Any treatment infra in poor condition	24	29% (46%)	4	25% (50%)	0.87	
Storage infra exists	7	14% (38%)	73	29% (46%)	0.42	

Any storage infra in poor condition	61	33% (47%)	11	9% (30%)	0.11
Distribution infra exists	1	0% (.%)	80	28% (45%)	0.54
Any distribution infra in poor condition	72	29% (46%)	7	14% (38%)	0.41
CAPS variables of interest					
CAPS legalized	42	29% (46%)	35	26% (44%)	0.78
Technical staff paid	34	24% (43%)	43	30% (46%)	0.52
Has complaint-receiving mechanism	34	35% (49%)	43	21% (41%)	0.16
Accountable to system-users	23	26% (45%)	52	29% (46%)	0.81
Has monthly tariff	8	13% (35%)	69	29% (46%)	0.33
Monthly tariff is variable	56	23% (43%)	21	38% (50%)	0.2
Accounting books to date	21	24% (44%)	55	29% (46%)	0.65
Provides preventative care	29	17% (38%)	48	33% (48%)	0.13
Protects area around source	6	33% (52%)	71	27% (45%)	0.73
Water treated with chlorine	51	24% (43%)	30	33% (48%)	0.34
Chlorine applied in last 15 days	70	26% (44%)	12	42% (51%)	0.26
Receive assistance with chlorine treatment	20	35% (49%)	14	36% (50%)	0.97

*** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-36 Bivariate Regressions for Dummy Variables Measuring Water Safety in systems administered by CAPS

Variable of interest	**Does not have variable**		**Has variable**		**Ttest**	
	Obs.	Mean (sd)	Obs.	Mean (sd)	p-value	
Regional differences						
Central = 0, Pacific = 1	128	14.08 (8.4)	66	10.87 (8.79)	0.01	**
Atlantic = 0, Pacific = 1	25	17.82 (6.68)	66	10.87 (8.79)	0	***
Atlantic = 0, Central = 1	25	17.82 (6.68)	128	14.08 (8.4)	0.04	**
Wealth quintile differences						
5th = 0, 1st = 1	31	10.82 (8.69)	6	15.58 (7.73)	0.22	
4th = 0, 1st = 1	65	13.86 (9.52)	6	15.58 (7.73)	0.67	
3rd = 0, 1st = 1	64	13.42 (8.26)	6	15.58 (7.73)	0.54	
2nd = 0, 1st = 1	53	14.64 (7.64)	6	15.58 (7.73)	0.77	
5th = 0, 2nd = 1	31	10.82 (8.69)	53	14.64 (7.64)	0.04	**
4th = 0, 2nd = 1	65	13.86 (9.52)	53	14.64 (7.64)	0.63	
3rd = 0, 2nd = 1	64	13.42 (8.26)	53	14.64 (7.64)	0.41	
5th = 0, 3rd = 1	31	10.82 (8.69)	64	13.42 (8.26)	0.16	
4th = 0, 3rd = 1	65	13.86 (9.52)	64	13.42 (8.26)	0.78	
5th = 0, 4th = 1	31	10.82 (8.69)	65	13.86 (9.52)	0.14	
System variables of interest						
Pumped system = 0, Gravity system = 1	63	12.19 (9.28)	131	14.64 (7.9)	0.06	
Any source in poor condition	164	14.08 (8.53)	33	12.28 (7.99)	0.26	
Any source contaminated by garbage/sewage	171	13.71 (8.68)	38	13.03 (8.11)	0.66	
Any source contaminated by chemicals/industrial residue	160	14.04 (8.74)	47	12.2 (7.94)	0.2	
Any source not surrounded by green areas	185	13.72 (8.43)	24	12.59 (9.65)	0.54	
Any source surrounded by eroded areas	159	13.71 (8.61)	49	13.17 (8.59)	0.7	
Any source not protected	139	14.23 (8.78)	65	12.3 (7.95)	0.13	
Treatment infra exists	141	13.16 (8.69)	71	14.57 (8.33)	0.26	
Any treatment infra in poor condition	59	14.4 (8.33)	12	15.39 (8.62)	0.71	
Storage infra exists	18	16.44 (8.22)	192	13.32 (8.59)	0.14	
Any storage infra in poor condition	162	13.22 (8.72)	29	13.78 (8.1)	0.75	
CAPS variables of interest						
CAPS legalized	124	13.25 (8.3)	81	14.09 (8.84)	0.49	

Technical staff paid	99	13.83 (8.49)	101	13.36 (8.56)	0.69	
Has complaint-receiving mechanism	91	13.62 (8.38)	110	13.6 (8.62)	0.99	
Accountable to system-users	77	12.4 (8.44)	120	14.23 (8.38)	0.14	
Has monthly tariff	28	15.61 (7.7)	174	13.29 (8.59)	0.18	
Monthly tariff is variable	151	12.51 (8.14)	51	16.88 (8.77)	0	***
Accounting books to date	69	12.32 (8.83)	131	14.4 (8.22)	0.1	
Provides preventative care	80	12.59 (8.6)	123	14.23 (8.42)	0.18	
Water treated with chlorine	135	13.35 (8.75)	76	13.99 (8.26)	0.6	
Chlorine applied in last 15 days	186	13.62 (8.62)	26	13.74 (8.42)	0.94	

*** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-37 Bivariate regressions for hours of water service in dry season by system and CAPS

Variable of interest	Does not have variable		Has variable		Ttest	
	Obs.	Mean (sd)	Obs.	Mean (sd)	p-value[1]	
Regional differences						
Central = 0, Pacific = 1	198	22.01 (28.92)	90	24.61 (28.87)	0.66	
Atlantic = 0, Pacific = 1	37	33.94 (37.24)	90	24.61 (28.87)	0.39	
Atlantic = 0, Central = 1	37	33.94 (37.24)	198	22.01 (28.92)	0.24	
Wealth quintile differences						
5th = 0, 1st = 1	55	19.31 (25.36)	84	27.21 (33.72)	0.18	
4th = 0, 1st = 1	58	19.58 (25.15)	84	27.21 (33.72)	0.17	
3rd = 0, 1st = 1	69	27.58 (30.76)	84	27.21 (33.72)	0.95	
2nd = 0, 1st = 1	59	24.46 (32.08)	84	27.21 (33.72)	0.61	
5th = 0, 2nd = 1	55	19.31 (25.36)	59	24.46 (32.08)	0.4	
4th = 0, 2nd = 1	58	19.58 (25.15)	59	24.46 (32.08)	0.38	
3rd = 0, 2nd = 1	69	27.58 (30.76)	59	24.46 (32.08)	0.6	
5th = 0, 3rd = 1	55	19.31 (25.36)	69	27.58 (30.76)	0.12	
4th = 0, 3rd = 1	58	19.58 (25.15)	69	27.58 (30.76)	0.11	
5th = 0, 4th = 1	55	19.31 (25.36)	58	19.58 (25.15)	0.96	
Household variables of interest						
Improved Water Source	65	26.57 (31.44)	260	23.47 (29.77)	0.52	
Connected to Community System	136	27.04 (32.01)	189	21.97 (28.52)	0.24	
Some Secondary School or more	282	25.28 (30.83)	43	16.31 (23.5)	0.04	**
Female Member Manages Household Water	38	20.86 (28.52)	284	24.41 (30.07)	0.45	
Female with Secondary or more Manages Water	287	24.73 (30.39)	35	17.93 (24.72)	0.16	
Last drink treated through chlorination	252	22.92 (30.79)	70	27.85 (26.14)	0.29	
Firm Floor = 0, Earth Floor = 1	124	22.4 (26.64)	188	25.03 (32.04)	0.52	
Zinc Roof = 1, Other Type of Roof = 0	42	24.62 (29.58)	281	23.74 (29.97)	0.86	
Open defecation	292	24.93 (30.26)	33	16.63 (27.81)	0.12	
Feces in Yard	213	22.29 (27.19)	112	27.52 (34.81)	0.24	
Reports Handwashing Station	88	22.43 (31.36)	237	24.71 (29.65)	0.59	
Station Convenient Location	98	23.3 (31.25)	227	24.43 (29.64)	0.78	
Water and soap avail at handwashing station	109	24.54 (32.17)	216	23.86 (29.06)	0.87	
Wide-mouthed storage container	38	22.77 (29.02)	238	25.71 (30.57)	0.56	

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-38 Bivariate regressions for storage sample of E. Coli MPN by household characteristics

Variable of interest	Does not have variable		Has variable		Ttest	
	Obs.	Mean (sd)	Obs.	Mean (sd)	p-value[1]	
Regional differences						
Central = 0, Pacific = 1	198	26% (44%)	90	22% (42%)	0.63	
Atlantic = 0, Pacific = 1	37	41% (50%)	90	22% (42%)	0.24	
Atlantic = 0, Central = 1	37	41% (50%)	198	26% (44%)	0.33	
Wealth quintile differences						
5th = 0, 1st = 1	55	35% (48%)	84	25% (44%)	0.34	
4th = 0, 1st = 1	58	29% (46%)	84	25% (44%)	0.54	
3rd = 0, 1st = 1	69	28% (45%)	84	25% (44%)	0.74	
2nd = 0, 1st = 1	59	19% (39%)	84	25% (44%)	0.32	
5th = 0, 2nd = 1	55	35% (48%)	59	19% (39%)	0.12	
4th = 0, 2nd = 1	58	29% (46%)	59	19% (39%)	0.16	
3rd = 0, 2nd = 1	69	28% (45%)	59	19% (39%)	0.25	
5th = 0, 3rd = 1	55	35% (48%)	69	28% (45%)	0.5	
4th = 0, 3rd = 1	58	29% (46%)	69	28% (45%)	0.82	
5th = 0, 4th = 1	55	35% (48%)	58	29% (46%)	0.57	
Household variables of interest						
Improved Water Source	65	23% (42%)	260	28% (45%)	0.52	
Connected to Community System	136	27% (45%)	189	26% (44%)	0.91	
Some Secondary School or more	282	24% (43%)	43	42% (50%)	0.05	**
Female Member Manages Household Water	38	39% (50%)	284	25% (44%)	0.09	
Female with Secondary or more Manages Water	287	25% (44%)	35	40% (50%)	0.11	
Last drink treated through chlorination	252	30% (46%)	70	17% (38%)	0.03	**
Firm Floor = 0, Earth Floor = 1	124	27% (45%)	188	26% (44%)	0.83	
Zinc Roof = 1, Other Type of Roof = 0	42	21% (42%)	281	28% (45%)	0.4	
Open defecation	292	26% (44%)	33	33% (48%)	0.47	
Feces in Yard	213	24% (43%)	112	31% (47%)	0.27	
Reports Handwashing Station	88	35% (48%)	237	24% (43%)	0.08	
Station Convenient Location	98	34% (48%)	227	24% (43%)	0.13	
Water and soap avail at handwashing station	109	32% (47%)	216	24% (43%)	0.21	
Wide-mouthed storage container	38	24% (43%)	238	25% (44%)	0.85	

[1] p-values adjusted for clustering at community level; *** Statistically significant at the 1 percent level, ** Statistically significant at the 5 percent level

Table 6-39 Bivariate regressions for dummy variable of safe water by household characteristics

6.13. Discussion and Conclusions

The above analyses of the PROSASR impact evaluation sample lead us to several observations about the impact evaluation, itself, in addition to the general WSS situation in rural Nicaragua at the time baseline data was collected. First, the IE sample we describe in this paper appears to be fairly representative of poor rural households in Nicaragua. However, it differs from the 2011 DHS rural sample in ways possibly related to the target population and eligibility constraints of the impact evaluation. For example, households in our sample appear to have a higher prevalence of concrete/tile floors relative to earth/dirt floors, increased access to a sanitation facility, and increased connectivity to a community water system. This may also be indicative of general improvements in household economy and of efforts on the part of the Nicaraguan government to expand access to WSS services (i.e., temporal changes in living standards since 2011). It may also be due to the fact that PROSASR targets water systems likely to show improvements as a result of the Project's capacity-building efforts. To the extent that less well-off households (e.g., households with an increased prevalence of earth/dirt floors versus concrete/tile) without access to a sanitation facility and/or community water system connection have systems that would be less likely to benefit from PROSASR, these households may have been left out of the impact evaluation sample frame.

Second, results from balance checks indicate that treatment and control households are well-balanced with respect to measurable characteristics. Assessments of baseline balance do suggest specific indicators that are not balanced and could be of importance to endline outcomes. For example, balance checks suggest that control households may be more likely to have taken their last drink from the tap, while treatment households are more likely to have taken their last drink from a storage container. Additionally, average *E. coli* MPN for tap samples for households taking their last glass from the tap was higher among treatment households than control households. Nonetheless, it appears that randomisation was largely successful at ensuring a proper balance across the majority of variables of concern for which data was collected at baseline. At end line, variables for which means differences between the treatment and control group were significant will be controlled for to assess the extent to whether imbalances in these variables impact our interpretation of results.

With respect to the WSS situation in rural Nicaragua, our analysis evidences a significant expansion in access to community water systems, with the prevalence of being connected to a community water system increasing more than two-fold from 29% for the 2011 DHS rural-only sample to 62% in the case of our baseline. Nonetheless, baseline data indicate that access is not uniform across regions and wealth quintiles. The Pacific region exhibits the highest prevalence of connectivity (66%) relative to the Atlantic and Central regions (62% and 59%, respectively). Pacific households are also wealthier, on average, than households in the Atlantic and Central regions. Across all regions, wealthier households exhibited higher levels of access to a community system, as well as access to an improved water source and improved sanitation.

Of interest are the variables correlated with higher levels of water system sustainability, defined here in terms of water system service levels and water quality. With respect to regional variation, our analysis offers some evidence that the Atlantic region exhibits higher levels of both service and water quality. Homes in the Atlantic region report 17.6 hours of service a day during the dry season, on average, relative to 11.6 and 13.7 hours of service a day in the Central and Pacific regions, respectively (see **Table 6-12**). Bivariate regressions for household service levels aggregated at the system level, exhibited in Table 39, confirm that the rain-heavy Atlantic exhibits increased service levels relative to the Pacific and Central regions. Pacific-Central and Pacific-Atlantic means differences are significant at conventional levels for household- and system-level bivariate regressions. Regarding water quality, samples taken from the taps of water systems in the Atlantic were safe in 55% of systems relative to 35% and 20% of systems in the Pacific and Central regions, respectively (see **Table 6-36**). Only Atlantic-Central means were significant at conventional levels (p-value = 0.02); however, Atlantic systems also present the lowest average *E. coli* MPN levels of any region (**Table 6-35**).

Our analysis also provides some evidence that systems serving wealthier households exhibit higher quality water than do systems serving less-wealthy households, but, perhaps counterintuitively, fewer hours of service. In terms of water quality, according to bivariate regressions in Tables 38-39, 56% of systems serving households at the top wealth quintile exhibit safe water relative to 40% and 12% of systems serving households in the fourth and third wealth quintiles, respectively. Top-4th and top-3rd wealth quintile differences are both significant at conventional levels. However, in terms of service levels, households in the top wealth quintile receive just 12.2 hours of service a day during the dry season in comparison to 14.8 hours a day for households in the bottom wealth quintile (**Table 6-12**). Households in the top wealth quintile are also more likely to experience service interruptions than poorer households. Lower levels of service for wealthier households may be due to increased water consumption on their part versus poorer homes (see **Table 6-14**), possibly contributing to increased pressure on water systems. However, it may also have something to do with CAPS serving wealthier households managing water systems efficiently and effectively to ensure that service levels do not vary drastically between the wet and dry seasons: wealthier homes, in fact, exhibit lower differences in service levels between the wet and dry seasons than do poorer homes.

Differences in water quality across wealth quintiles and regions may, in some way, be related to the presence or absence of system infrastructure components, as well as the condition of infrastructure components, with which water quality is also correlated. For example, pump systems, which are more prevalent among systems serving wealthier homes, exhibit safe water with greater frequency than gravity systems, which are more prevalent among systems serving poorer homes (53% and 21%, respectively). Additionally, systems with some sources in poor condition (less common among wealthier households) are less likely to have safe water than systems with no sources in poor condition (9% and 32%, respectively; p-value = 0.13). Further analysis (not shown) demonstrates that any sources are in poor condition for systems with the least frequency in the Atlantic, followed by the Central and Pacific regions, in line with results for bivariate water quality regressions including regional dummy variables. However, other variables correlated with decreased prevalence of safe water (e.g., any source contaminated with garbage/sewage and any source contaminated with chemicals/industrial residue) do not appear correlated with household wealth quintiles. There is also evidence that other variables related to system infrastructure are correlated with water quality (i.e., whether a system has treatment infrastructure; the condition of treatment, distribution, and storage infrastructure).

Bivariate regressions also illuminate correlations between system infrastructure and water system service levels. For one, even though gravity systems are associated with lower prevalence of safe water relative to pump systems, they are associated with higher levels of service. This finding may be related to the fact that gravity systems are more prevalent among systems serving poorer households, which also exhibit higher levels of water service, while pump systems are more prevalent among systems serving wealthier homes. Secondly, even though several variables demonstrate the general relationships we would expect to see between the prevalence of certain infrastructure and infrastructure and service levels (i.e., any sources in poor condition, any sources contaminated by garbage/sewage correlated with lower service levels), means differences are not significant for any of these variables at conventional levels. Only means differences for any sources not being protected (p-value = 0.13) and any distribution in poor condition (p-value = 0.06), whereby a system with said characteristic presents lower service levels, approach conventional levels of significance.

This paper has also exhibited descriptive statistics evidencing low levels of administrative capacity on the part of CAPS, with relative administrative capacity levels increasing with the wealth level of households served by CAPS. For instance, just 35% of CAPS are legalized, even though more than 50% of CAPS serving households at the top two wealth quintiles are legalized vis-à-vis 0% and 28% of CAPS serving the bottom two wealth quintiles, respectively. Trends for the prevalence of technical staff, paid technical staff, CAPS having complaint-receiving mechanisms, and CAPS being accountable to system users indicate that a higher percentage of CAPS serving wealthier homes have these administrative capacity characteristics than CAPS serving poorer households. However, bivariate regressions provide little evidence that these and other CAPS variables impact water quality and water service levels. Just the existence of a variable tariff and accounting books being to date appear correlated with service levels.[85] With respect to water quality, granted relative percentages of systems with safe water are what we would expect in many instances, the only variable for which means differences approach conventional levels of significance is the variable for whether a CAPS provides preventative care (p = 0.13).

In addition to insight into the correlates of water quality at the system level, our analysis also provides some insight into WSS behaviour at the household level. For one, households collect water from storage containers more frequently than from the tap (84% and 14%, respectively). This would be problematic to the extent that household behavior increases the probability that water from storage containers be contaminated. Indeed, water samples from household storage containers exhibited higher levels of *E. coli* MPN and were safe less frequently than water coming from the tap. For paired storage container-tap samples, water from storage containers exhibited 6.2 *E. coli* MPN greater than water from the tap, with means differences significant at the 1 percent level. Water from storage containers was safe less often for households taking

[85] Variable tariffs ensure that incentives are aligned such that tariff amounts are commensurate to water usage (e.g., if a household uses more water, it pays a higher tariff). Decreased water consumption may apply less pressure on water systems, potentially allowing them to provide water for a greater number of hours per day. Accounting books being to date may be reflective of increased administrative capacity on the part of CAPS.

their last glass of water from storage containers than for all storage container samples, in general (25% and 27%, respectively).[86] Poorer relative water quality in storage containers versus the tap would be less of an issue were households treating drinking water through chlorination. However, despite 20% of households claiming to treat water through chlorination, chlorination samples in the context of baseline data collection found little evidence of chlorination in households. More than half of households said that they did not treat water because someone told them that it was not necessary, or their local CAPS told them that water had already been treated. Yet, system chlorination samples indicate that CAPS treat water through chlorination infrequently.

The bivariate regression results for water quality at the household level presented in Tables 40 and 41 do provide us with some insight into the correlates of water quality at the household level. For one, there is some evidence for water quality in storage containers being higher for households in higher wealth quintiles than poorer wealth quintiles (i.e., differences of means between the 5th-3rd and 4th-3rd groups in **Table 6-38**, 5th-2nd and 4th-2nd comparisons in **Table 6-39**). Secondly, there is evidence that households in which the household head has some secondary school education or greater exhibit higher quality water in storage containers. There is also evidence that households for which a female household member manages the water supply exhibit safe water with less frequency than households for which the household member is a male. Nonetheless, the group of female household heads with some secondary school education or more exhibit lower *E. coli* MPN levels and safe water with greater frequency relative to households for which this is not the case. Household sanitation practices may also impact water quality in storage containers: households practicing open defecation exhibit higher *E. coli* MPN levels than households not practicing open defecation (p-value = 0.12). At the same time, there are several variables for which means differences are significant that demonstrate relationships counter to what would be expected (e.g., households treating their last drink of water with chloride and households that report having a handwashing station exhibit lower frequencies of safe water than for households for which that is not the case).

[86] Similarly, water from the tap was safe more often for households taking their last glass of water from the tap than for all tap samples (31% and 26%, respectively).

These results provide possible answers with respect to the variables associated with improved water quality and higher levels of water service continuity for rural water systems in Nicaragua. In the context of PROSASR, they may shed light on areas of emphasis for the capacity-building of UMAS. For example, results indicate that capacity-building may want to emphasize the importance of keeping distribution infrastructure in good condition and providing preventative care to systems to ensure a high quality of service. Additionally, the positive relationship between source condition (i.e. contamination, not being surrounded by eroded areas) and service levels may imply that capacity-building should emphasize the need to protect and maintain system sources. Capacity-building may also want to emphasize the need to transition to variable tariffs as a means of putting into place the incentives for sustainable use of water by households. Implications as to the household behaviors that CAPS should be promoting are less clear.

This analysis leads us to some general lessons with respect to data collection and analysis in the context of water system sustainability. For one, during baseline data analysis, several issues of data quality were discovered, especially as they relate to water quality and chlorine samples taken by enumerators. Reports from the IE field coordinator during baseline data collection point to the possibility that water samples were not taken with the sufficient care to guarantee quality. For example, on one occasion, it was found that *E. coli* MPN levels were consistently higher for one enumerator compared to other enumerators. The reason for this is unclear given that the enumerator rated well on IE field coordinator supervision. As such, it is possible that water quality and chlorine analyses may have been administered incorrectly, with obvious implications for data quality and subsequent analyses. To ensure high quality water samples at IE end line and in the context of other impact evaluations, more emphasis should be put on (i) adequate training of enumerators in the administration of water samples and (ii) monitoring the administration of water sampling to ensure that any errors are corrected early on in data collection efforts. Accordingly, quality assurance will be a focus during end line data collection. A second lesson comes from the lack of clear trends in our results. This may, in part, be related to the relatively “loose” definitions of indicators that come from the SIASAR monitoring system itself. The IE team plans on validating indicator definitions with FISE in anticipation of end line data collection activities. Together, analysis of bivariate regressions and lessons with respect to data collection and indicator definition should increase the likelihood of collecting high quality data during PROSASR end line data collection and IE efforts in the context of other rural water sustainability projects.

This report presented descriptive statistics and analyses as they relate to a baseline survey conducted in 2016 in the context of an impact evaluation which attempts to explain the causal impact of a large-scale rural WSS program in Nicaragua. Data was collected to assess current levels of functionality and durability of community water systems, the capacity of service providers to administer systems sustainably, as well as the current state of WSS services at the community and household level for treatment and control groups. Our results suggest that randomisation of program treatment resulted in an adequate balance across treatment and control groups. Additionally, several indicators were used to identify the correlates of rural water system sustainability, including system characteristics (i.e., source condition, the presence and condition of water system infrastructure components) and service provider characteristics (i.e., variable tariffs, providing preventative care). Analyses were used to inform potential areas which PROSASR capacity-building efforts may want to emphasize in order to positively impact the sustainability of water systems. Lastly, we pointed out several areas of improvement as they relate to data collection and indicator definitions that we hope will inform data collection activities at end line (2018), as well as other impact evaluations in the context of rural water system sustainability.

6.14. References

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Chapter 7. Results of the Impact Evaluation

7.1. Cover Sheet: Relevance for Thesis

This is a draft paper on the final impact evaluation results, using the endline survey collected between the months of May and October 2019. The results presented are already drafted and reviewed to begin the process of application to a an academic journal (Water Policy, Water Journal; or similar). This paper will be submitted to a journal after the completion of the Thesis. My role in this draft has been as principal researcher, covering all the process of verifying quality of data collection, following up and contributing with data preparation, estimates, graphs and tables, and write up of drafts. Additional co-author participated in this process as well. Pavel Luengas (University of Oxford) and Jonathan Grabinsky (World Bank) are part of the research team, as well as Josh Gruber (University of California, Berkeley). The title of this paper will be “The causal impacts of a training program to enhance sustainability of Rural Water Systems in Nicaragua”. This paper represents the conclusion of a 4 year research of evaluating the large-scale program of rural water sustainability in Nicaragua (PROSASR). It reflects the main impacts of one of the core training components for UMAS and CAPS that was part of the PROSASR program. The program started in 2015 and concluded in 2019.

The findings are based on the evaluation design presented in Chapter 5 of this Thesis, a baseline survey presented in Chapter 6 of this study, and the endline survey collected in 2019. The interventions in the 150 treatment communities were completed between 2017 and 2018, and the study is based on more than 4,500 households collected in each survey round and complemented with SIASAR data for communities involved in the study. They results show that in the intervention communities, scores on three out of five attributes of a good water and sanitation system had risen, with statistical significance: financial stability (up 18 percent compared to the control communities), formalization of operation of water systems (13 percent), and quality of system operation and maintenance (11 percent). The two other attributes, protection of the system’s water source and the charging of adequate tariffs for water supplied, showed no significant change.

At the household level, the study found positive impact in four indicators of sanitation: improved sanitation (8 percent higher than the control communities), use of non-shared sanitation facilities (4 percent higher), open defecation (37 percent lower), and diarrhoea (16 percent lower). There was no significant effect on other household indicators including handwashing, latrine use, safe water storage, unsafe disposal of trash, and the presence of faeces or trash in a house's yard. The results presented are consistent with the Thesis format and with an outline compatible with academic rigour.

7.2. Introduction

An increase in water-supply and sanitation (WSS) access is a pillar of Nicaragua's 2012-2016 National Plan for Human Development. In 2013, the Government of Nicaragua (GoN) developed a national plan, the *Programa Integral Sectorial de Agua y Saneamiento*, officially naming the *Fondo de Inversión Social de Emergencia* (FISE) as the government institution in charge of rural WSS at the national level. In 2014, the World Bank and the GoN began implementing a project focused on increasing access to sustainable WSS services in poor rural areas in Nicaragua, through the consolidation of rural WSS institutions and the construction of adequate system infrastructure. Through the Strategic Impact Evaluation Fund (SIEF), research funding was obtained to conduct a rigorous and independent impact evaluation to estimate the effectiveness of this program. This funding helped in the design, survey collection and research of the impact evaluation.

The evidence on factors contributing to the success or failure of rural water services, and on the components determining the institutional capacity of rural water providers, is an area which remains underexplored. Part of the challenge is that the functionality of rural water services is a function of a complex set of connections, which are often difficult to analyze in isolation. Recent literature has revealed that post-construction support and continued local management assistance were key factors for enabling the sustainability of rural water systems over time (Foster et al., 2018; Foster and Hope, 2017; Hutchings et al. 2017; Thomson and Koehler, 2016; Smits et al. 2015; Whittington et al. 2009).

To expand on the evidence on rural water sustainability, this impact evaluation will use an experimental-design to analyze the effect of a rural water institutional-strengthening program in Nicaragua. The aim is to approach a causal estimate of the effects of the program at the level of the community, water-system, and household level. To the best of our knowledge, this is the first impact evaluation conducted on an institutional water-strengthening program in the country, an, as far as we know, one of the few in the existing literature.

A core component of this project is the Sustainable Water Supply and Sanitation Sector Project (PROSASR, by its acronym in Spanish), tasked with providing technical assistance to municipal water authorities (UMAS/UTASH) responsible for supporting local water boards (CAPS) in rural areas of the country. The CAPS are water-sector government authorities tasked with managing the water systems, and water operations, at the community-level. The CAPS are the main point of contact with the communities, and report directly to the UMAS/UTASH. The goal of PROSASR is to increase access to and improve the quality of rural WSS services. The project concluded in the spring of 2019[87].

The central objective of PROSASR is to expand access to WSS services to poor, rural regions of Nicaragua. PROSASR consists of two main components: Component I aims to consolidate, and strengthen, the institutional capacity of the water sector, and Component II seeks to expand the provision of sustainable rural water and sanitation infrastructure. Progress in Component I is framed, and guided by, the metrics outlined in the Rural Water and Sanitation Information System (SIASAR) census, gathered every two years.

This chapter evaluates the impact of Component I of PROSASR. Randomisation for Component I of PROSASR occurred at the community level, so at the CAPS, water-system, and household level, the impact of the program is estimated using the econometric technique of an average treatment effect. The randomisation at the level of the community generated statistically balanced groups (with and without intervention) which allows us to measure the causal attribution of the services offered as part of Component I of PROSASR.

[87] The PROSASR project's intervention (training, component 1) finished in spring 2019. After that, the Impact Evaluation endline survey was conducted in October 2019 to allow close to 6 months after exposure to treatment to generate the data that fed into the evaluation and, hence, observe changes in outcomes

7.3. Description of AVAR and ARAS on improving rural water systems

Additional data was also gathered at the municipality/UMAS level, which allows us to detect non-causal progress in the project through pre-post difference in mean estimates. The findings presented here draw from surveys administered to UMAS, CAPS, water systems and households, as well as data from the SIASAR, which were applied to 300 communities (150 with intervention, 150 without intervention) across 76 municipalities.

Prior to PROSASR, there were large variations in how rural water systems were managed in Nicaragua. Component I of PROSASR provided the first large-scale approach to homogenize the type of water-training delivered to communities in Nicaragua; to level their endowments of management and technical skills, and to improve the overall performance and sustainability (economic, financial and operational) of rural water service providers. Moreover, these interventions also sought to level the knowledge and administrative capacity of the UMAS and of the CAPS, to improve the performance and sustainability of water services.

This study followed an experimental design, which increases the robustness of the results; the research design followed a phased-in approach, which compared outcomes of treatment communities intervened by Component I of PROSASR first with control communities intervened later.

Description of the institutional set up

The rural WSS sector is governed by institutions stretching from the national level, where WSS policies and planning occurs, to the community level, where local WSS systems are managed by formal and informal community water boards. Institutional infrastructure begins at the national level with FISE. In 2013, the GoN developed a National Water and Sanitation Sector Strategy Plan (*Programa Integral Sectorial de Agua y Saneamiento Humano*, PISASH) and placed FISE in charge of ensuring sustainable rural WSS service provision at the national level. FISE is responsible for general coordination, policy making, planning, contracting and implementing works, and capacity-building at the municipal and community level.

At the sub-national level, FISE currently has a large contingent of regional and local staff. UMAS/UTASH are the municipal/territorial WSS units in charge of providing technical assistance to the CAPS, which administer, operate, and provide routine maintenance to rural WSS systems in communities. The municipal and community-level staff is supported by eleven regional WSS technical advisors known as ARAS (*Asesores Regionales de Agua y Saneamiento*).

ARAS are decentralized FISE technical staff, usually water engineers, in charge of shepherding all components of PROSASR to the relevant municipalities and communities. The ARAS started providing support throughout the communities in 2015 and were initially assigned to help with the rollout and administration of the SIASAR. Their role eventually expanded to help guide, oversee and support all components of PROSASR.

The ARAS are responsible for enacting FISE policy at the regional level, as well as building the technical assistance capacities of the UMAS at the municipality level. The ARAS offers technical support to the UMAS/UTASH and the CAPS in the elaboration of operational and maintenance water system plans, and preventive and corrective plans to protect potable water systems. The ARAS also assists in matters of community development and gender inclusion, and spend seventy-five percent of their time in the field, assisting CAPS and UMAS in the implementation of the project, and twenty-five percent of their time in training with FISE in Managua.[88]

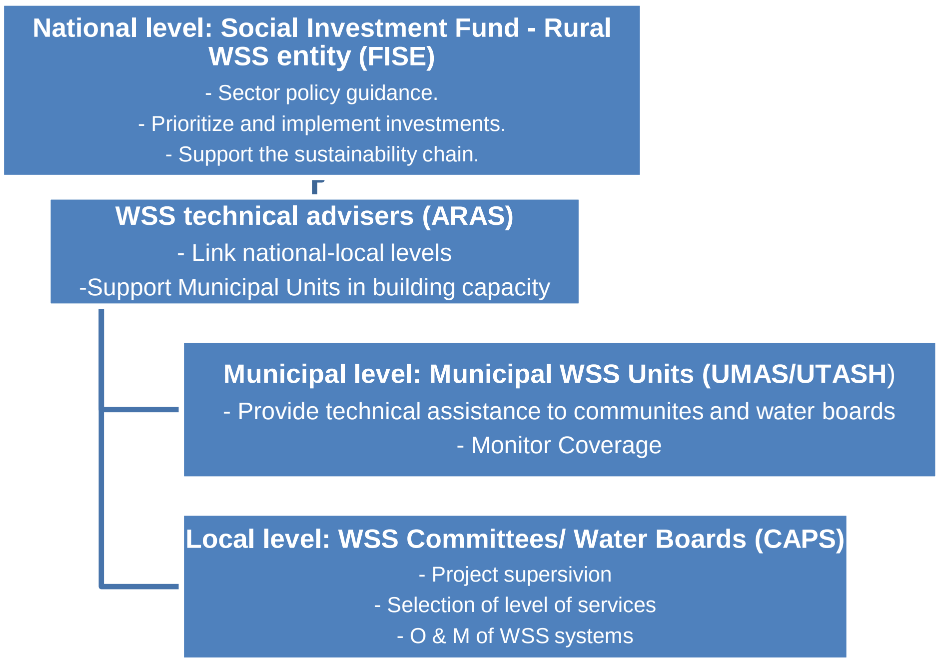


Figure 7-1 Nicaragua Rural Water and Sanitation Sector; Line of Hierarchy

[88] Conversations with FISE, Spring, 2019.

Description of the program and intervention

The central component of this evaluation is to test whether the randomisation of the implementation of Component I of PROSASR, of the implementation of the AVAR, and the ongoing, technical assistance from the ARAS, had any differentiating effects on 300 treatment vs. control communities: zeroing on survey data from CAPS, households, and water systems.

This section describes the different aspects of PROSASR, while focusing primarily on the details of Component I, which are the items of the intervention randomised. It shows how the central objectives of Component I, the *Aprendizaje Vinculado a Resultados* (AVAR), and the technical assistance provided by the ARAS, were guided by the metrics chartered in the SIASAR.[89] This section also offers additional details on how the program was rolled out.

Below is an outline of the different PROSASR project indicators which uniquely map onto each of the components of PROSASR. In addition to the items listed below, there were several transversal components which were applied to all municipalities that received PROSASR. These include support from the ARAS, components on environmental care, community development, and gender training.[90]

Component I – Strengthening the Institutional Capacity of the Water Sector

The technical assistance provided under Component I of PROSASR is directed at strengthening the capacity of the local government water providers and bettering their management of the water systems. The institutional strength of the local government water agencies was first measured with the baseline collection of SIASAR in 2011, with a second round 2015. Each UMAS/UTASH and CAPS was assigned a ranking, based on their performance along a set of indicators (outlined in **Table 7-1** and **Table 7-2** below).

Component I of PROSASR includes the following central elements:

- A series of water training workshops, AVAR, administered in three-different occasions to staff at the UMAS/UTASH, meant to strengthen the institutional and water-management capacity of the local water government sector. The AVAR includes training in water tariff calculation, operation and maintenance

[90] Based on conversations with FISE in Spring, 2019.

(O & M) procedures, water treatment methods, accountability mechanisms, CAPS legislation, and meter reading, among other topics. Support from the AVAR/ARAS was implemented at the municipal level, and, as of April 2019, has been administered in all of Nicaragua's municipalities.[91]

- Periodical, ongoing support from the ARAS engineers to the communities, to help oversee progress of the AVAR, and provide wide-ranging support in strengthening the capacity of local water institutions. The ARAS also offers technical support to the UMAS and CAPS in the elaboration of operational and maintenance water-system plans, and preventive and corrective plans to protect potable water systems.

Since the training occurred at the municipal level, to comply with the experiment's research design, the UMAS/UTASH were instructed to transmit learning from the AVAR trainings to the CAPS and communities in the treatment communities first, and then, starting in the last trimester of 2018, to start rolling-out the capacitation the program in the control communities. The ARAS were also indicated to withhold assistance to the communities in the control group until the last trimester of 2018.

The central component of this evaluation is to test whether the randomisation of the implementation of Component I of PROSASR, of the implementation of the AVAR, and assistance from the ARAS, had any differentiating effects on treatment vs. control communities. The end-purpose is to identify any differentiating effect on the treatment vs. control communities along dimensions linked strictly to the trainings and identified via the baseline and end-line surveys administered to CAPS, households and water systems.

Measures of Progress in Component I – Upgrading UMAS and CAPS to a superior category

The metrics guiding the content of Component I of PROSASR, and used to evaluate whether the UMAS/UTASH are upgraded to a "higher category," are the following: the availability of data UMAS/UTASH have on the communities in their area, how up-to-date the information is, the number of visits administered by UMAS/UTASH to the communities in the last twelve months, the level of support from UMAS to communities

[91] Ibid

in helping control, and improve, the quality of water, and the human resources available in the municipality.

Additional metrics include: the availability, and the quality, of computer, transportation equipment, and educational material used for distribution. Finally, the metrics also consider whether the UMASH/UTASH has: an officially assigned annual budget, access to the internet, and funding to cover car fuel, and travel expenses.**Table 7.1** offers an outline of the different components used to evaluate upgrading UMAS to a higher category: [92]

CATEGORY	CRITERIA
Availability of data	The UMAS/UTASH has information on the communities in their area, and the information is up-to-date.
Visited communities in the last twelve months.	Number of communities in the municipality visited within the last twelve months.
Assistance to communities in water-quality control.	Number of communities in the municipality were water-quality has been properly administered.
Human Resources	Average number of communities within the municipality overseen by technicians.
Transportation Capacity	Ratio of transportation capacity to number of technicians.
Equipment for water- quality control, computer, transportation equipment, printed didactic material for distribution.	Availability and quality of the equipment.
Availability of an annual budget, funding for fuel and out-of-pocket expenses, internet service.	Number of items available.

Table 7-1 Requisites for Upgrading the UMAS to a superior category of PROSASR

The metrics used to determine whether a CAPS is upgraded to a higher category, and the key-elements guiding the AVAR trainings and the assistance from the ARAS, as gathered bi-annually through the SIASAR, are: the institutional strength of the service providers, the existence, and efficacy, of a water-tariff system, the financial solidity of the CAPS, and whether there is sufficient attention being paid to the operation and maintenance of the water basin and the source of water. **Table 7.2** offers a breakdown of the different metrics used to evaluate how a CAPS is upgraded to a higher category[93].

[92] Documento Base III Fase AVAR en AS – 2015 - 2017
[93] ibid

CATEGORY	CRITERIA
Management of the service provider	The CAPS is legalized
	The CAPS board positions are well-defined and assigned.
	CAPS gets together at least four times every six months.
	CAPS provides details on the financial accounts every three months
Water Tariffs	Water Tariff exists
	The water tariff allows for cost-recovery
	The cost-recovery is above eighty-percent
	The tariff is set according to consumption
Financial solidity	CAPS has bank account
	CAPS keeps proper financial records
	CAPS revenue is higher than costs
Attention to operation and maintenance of the water basin	The replenishment fund of the life of the water-system is adequate
	Preventive and corrective maintenance is provided.
	An operator/ plumber is available to assist in operation and maintenance
Attention to the water-source	Community has a clean source of water, and has a program for the reforestation or care of the forest.

Table 7-2 Metrics for upgrading the CAPS to a higher category

AVAR Trainings

The AVAR trainings consisted of three workshops, administered to the UMAS/UTASH. The trainings are meant to help strengthen the local government water agencies, and better their management of water systems. The content of the training is intended to be used by UMAS/UTASH to spill-down the water-sustainability ladder, to the CAPS, water-system providers and, eventually, to the communities. The material of the workshops is guided by the metrics outlined in **Table 7-1** and **Table 7-2** above.

Each of the workshops lasted between two and three days. In its original design, the time between each AVAR workshop was intended to be four months. But, given a series of difficulties: chiefly, problems AVAR technicians faced in reaching the more remote communities of the country, and inadequate local management capacity in some of communities, the time that elapsed between trainings often exceeded four months — in some instances, up to 7 months passed between workshops.[94] Each workshop included between 20 and 36 UMAS/UTASH participants. A total of 244 technicians participated in the trainings.

In the first workshop, the participants developed a Municipal Action plan, which lays out a series of steps to upgrade the institutional capacity of the CAPS and UMASH according to the SIASAR. The feedback and input from the Municipal Action plans helps inform and guide the content of the subsequent workshops. The second workshop focuses on monitoring and following-up on progress made as of the first workshop. The third workshop included additional topics, such as climate change, water quality control, the institutional strengthening of the capacity of the CAPS, and a review of how much progress the UMAS has made in upgrading the CAPS/UMAS to a superior category.

At the end of the third workshop, the UMAS developed a plan of action to identify the remaining bottlenecks, next steps, and to elaborate an operational plan to continue to work on promoting the UMAS/UTASH, and the CAPS. There was a total of eleven AVAR specialists in charge of administering the project across all municipalities in the country.

Training sessions (TS)	
TS I	• Trainings on how to use SIASAR as an instrument for planning. • Overview of the matrix of classification of the CAPS and UMAS/UTASH in the SIASAR baseline. • Laying out concrete actions, via a Municipal Action Plan, to follow in order to upgrade the CAPS/UMAS to a higher category. In the case that they are already in the highest category, possible strategies to remain in the highest category. • Trainings on how to teach the CAPS to understand and structure a plan of operation and maintenance of a potable water system administered by the CAPS.

[94] Conversations with officials from FISE, 2019.

TS II	• Achieve an analysis of the results of the implementation of the municipal action plan for the promotion of the CAPS. • Elaborate a matrix of challenges, limitation, and possible solutions identified during the implementation of the action plans for the promotion of CAPS and UMASH/UTASH from one category to another. Share among members of the CAPS and UMAS their experiences. • Review of the actualized data of the SIASAR in relation to the classification of the CAPS/UMAS at baseline. • SWOT analysis of the strengths, opportunities, weaknesses of the implementation of the plan of action to upgrade de UMAS/UTASH
TS III	• Review of the initial municipal action plan, to look over achievements accomplished. • Review of the actualized data of the SIASAR in relation to the classification of the CAPS/UMAS at baseline. • Identify bottlenecks and develop an operational plan to continue in the promotion of the UMAS/UTASH, and the CAPS, once the AVAR has been finalized. • Look through the fulfilment of the SIASAR criteria established in the matrix for classification for the CAPS and UMAS to a higher “sustainability” category.

Table 7-3 An overview of the AVAR workshops

To prevent contamination of control communities, a detailed timetable for the execution of the training was developed at different stages, where the UMAS/UTASH were asked to withhold transmitting the learnings of the AVAR trainings to control communities until the last trimester of 2018, first trimester of 2019.

ARAS interventions

As mentioned previously, ARAS are water engineers responsible for enacting FISE policy at the regional level, as well as building the technical assistance capacities of the UMAS at the municipality level. The ARAS offer technical support to the UMAS/UTASH and the CAPS in the elaboration of operational and maintenance water system plans, and preventive and corrective plans to protect potable water systems. The ARAS also assist in matters of community development and gender inclusion, and spend seventy-five percent of their time in the field, assisting CAPS and UMAS in the implementation of the project, and twenty-five percent of their time in training with FISE in Managua.

The ARAS helped guide the UMAS/UTASH and the CAPS across all project components of PROSASR, including overseeing the infrastructure component of PROSASR. In terms of Component I, The ARAS provided ongoing support to the CAPS and UMAS in the intervention communities, to help implement the different components of the AVAR trainings, and assist in the overall process of upgrading CAPS and UMAS to a superior category.

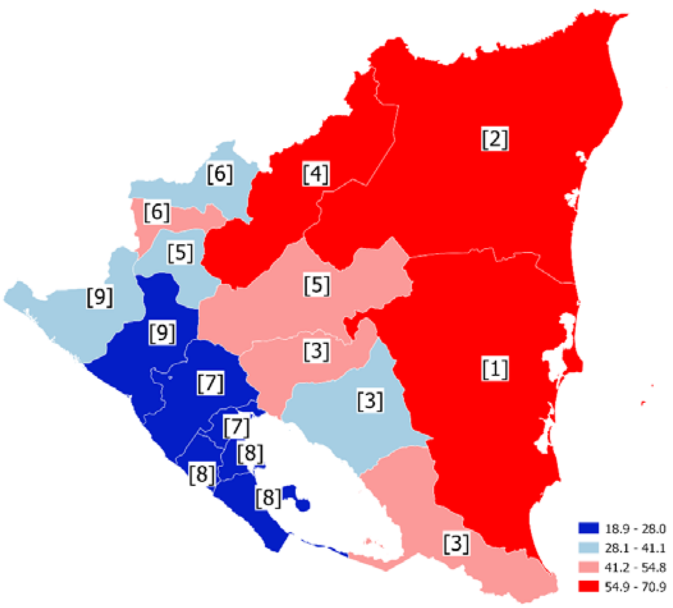
Among other things, to complement the AVAR training, ARAS followed up with targeted assistant in treatment communities on the following:

- Providing the basic information and support to elaborate Action Plans for the promotion of the CAPS to sustainable status.
- Providing further inputs from the elaboration of the Municipal / Territorial Action Plans for the promotion of the UMAS / UTASH
- Providing technical support to develop Preventive and Corrective Maintenance and Operation Plans of the systems.
- Support in bettering community practices relating to sanitation and hygiene.

The eleven ARAS, which, as mentioned previously, provide support to the UMAS and CAPS throughout project implementation, were instructed to withhold visits, and capacity-building, in control communities, until the last trimester of 2018. The listings of treatment groups were shared with municipalities to inform attendance of CAPS for the training sessions, and number of 20 AVAR territorial consultants specialized in water supply and sanitation supported the logistics of CAPS attendance. The support staff for the implementation of the trainings provided coordination with the Regional Water and Sanitation Advisors (ARAS), and delivered technical assistance on the tasks developed by the municipal teams, in order to inform and training both CAPS and UMAS / UTASH in the treatment areas.

Rollout

As of October 2019, the AVAR had been administered across all of Nicaragua's one-hundred and fifty-three municipalities in the country.[95] **Figure 7-2** presents the nine regional groups comprising the AVAR workshops overlapped with the poverty levels for all municipalities. The departments were grouped by region in the country, and the table next to the map shows the municipal groupings. The AVAR workshops were rolled-out progressively, by regional group. The rollout also overlapped with the poverty levels in the country. Rollout by poverty levels has no effect on the impact evaluation, because the evaluation was designed at the level of the municipality, and the interventions were conducted within the periods established in the operational plans of the impact evaluation.



Workshop order	Departments
[1]	ATLANTICO SUR
[2]	ATLANTICO NORTE
[3]	BOACO
	CHONTALES
	RIO SAN JUAN
[4]	JINOTEGA
[5]	MATAGALPA
	ESTELI
[6]	NUEVA SEGOVIA
	MADRIZ
[7]	MANAGUA
	MASAYA
[8]	CARAZO
	GRANADA
	RIVAS
[9]	CHINANDEGA
	LEON

Note: Shaded areas in the map denote departmental extreme poverty levels estimated by the National Statistic Institute (INIDE, in Spanish). Red areas denote high poverty; pink, medium-high; light blue, medium-low; and bl low.

Figure 7-2 AVAR workshop groups overlapped with municipal poverty levels

[95] Ibd

In the seventy-six municipalities included in the impact evaluation, the earliest date in which the first AVAR workshop was administered was in February 2016, and the latest date in which the third workshop was administered was in november 2018.[96] The trainings were administered by region, according to nine-different groups. **Figure 7.3** below shows the AVAR training date for all municipalities.

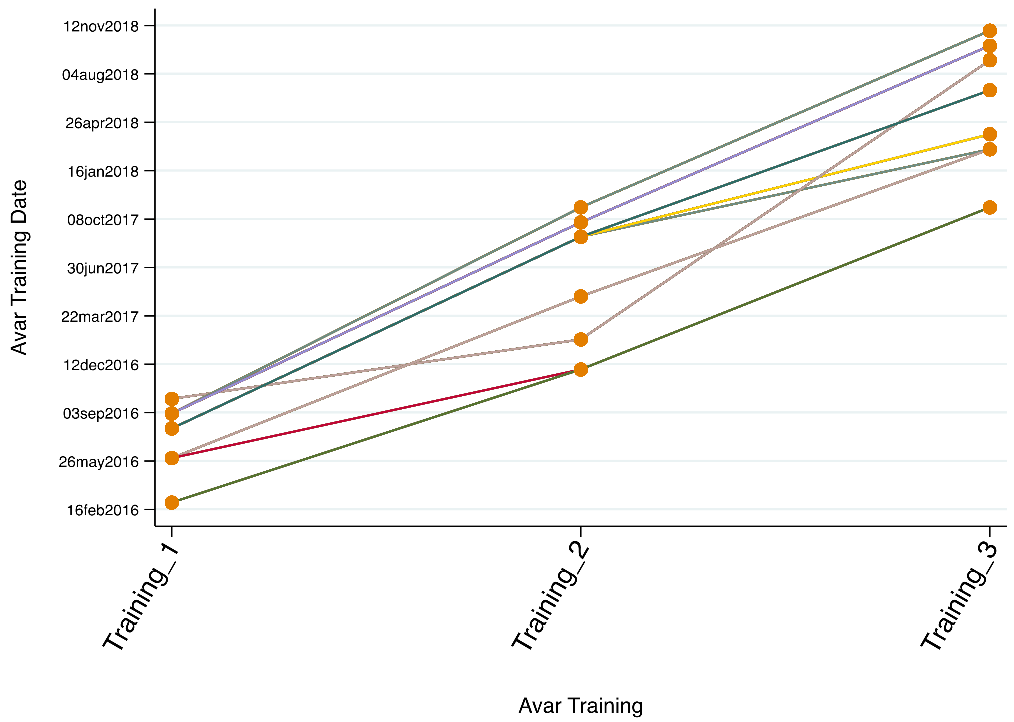


Figure 7-3 AVAR Training Dates for All Municipalities. Each line shows a group of UMAS/UTASH receiving trainings

Note: In general, the graph shows that the dates for the AVAR trainings occurred without much difference in time of exposure across regions.

The ARAS and AVAR interventions

The components of ARAS and AVAR are designed to provide coordinated training to induce changes in the levels of technical and non-technical capabilities, which allow for a better generalized management of rural water systems through CAPS. Without a doubt, the coordination work of the municipal entities for this purpose is critical. In addition, the AVAR methodology takes into account training modules on i) improvement of institutional coordination to respond more efficiently to the problems of supply and operation of rural water systems, ii) improvement in management and

[96] Consultations with FISE, July, 2019.

administrative activities , and periodic reviews of the operation of the systems, iii) improvement in the ability to identify preventive actions for system maintenance, iv) support in the areas of establishment and rate collection strategies, CAPS legalization process, v) support in development of water management plans, and management manuals for operation and maintenance of systems.

It should be emphasized that FISE, as part of its institutional mandate, provides another series of support in these matters. In the specific case of CAPS legalizations, which is essential for improving management and access to other types of financial and non-financial support, generalized support is provided regarding the filling out of legalization forms, which is the last process step However, the tangible contribution of ARAS and AVAR interventions in the matter of CAPS legalization has to do with providing greater technical capabilities to streamline the legalization process, which would not imply that this process results in legalization. Other areas of inclusive and social management also appear as fundamental parts of the technical support structure of ARAS and AVAR interventions. The FISE will carry out induction supervision of these supports, as well as a schedule to know in detail the implementation of the interventions and their temporal structuring according to the impact evaluation design.

In sum, the components of ARAS and AVAR were designed to provide coordinated training to induce changes in the levels of technical and non-technical capabilities, which allow for a better generalized management of rural water systems through CAPS. Without a doubt, the coordination work of the municipal entities for this purpose is critical. In addition, the AVAR methodology takes into account training modules on i) improvement of institutional coordination to respond more efficiently to the problems of supply and operation of rural water systems, ii) improvement in management and administrative activities , and periodic reviews of the operation of the systems, iii) improvement in the ability to identify preventive actions for system maintenance, iv) support in the areas of establishment and rate collection strategies, CAPS legalization process, v) support in development of water management plans, and management manuals for operation and maintenance of systems.

It should be emphasized that FISE, as part of its institutional mandate, provides a series of support in these matters. In the specific case of CAPS legalizations, which is essential for improving management and access to other types of financial and non-financial support to ensure rural water systems sustainability, technical support is rather limited regarding the filling out of legalization forms, which is the last process step to upgrade CAPS into a legalized status. However, the tangible contribution of ARAS and AVAR interventions in the matter of CAPS legalization has to do with providing strong technical capabilities and streamline support for meeting all the steps needed for the legalization process. Other areas of inclusive and social management also are fundamental elements of the technical support structure of ARAS and AVAR interventions, such as developing management plans for sustained service provision and strengthening the governance of CAPS. The FISE carried out induction supervision of these interventions through the program, as well as a schedule to know in detail the implementation of the interventions and their temporal structuring according to the composition of treatment and control areas.

The training provided to the CAPS proved to be essential to achieve the development objectives of the rural water sector in the context of the program. Undoubtedly, there are other interventions that can affect the sustainability chain and that are generally given to the CAPS. However, the evaluation design is typified to only be able to identify the impacts within the Regional Water and Sanitation Advisory (ARAS) and AVAR interventions. In the case of CAPS, these obtained new regional and municipal knowledge provided by the Regional Water and Sanitation Advisors (ARAS) to the comparison group communities according to the evaluation design. The ARAS were selected within the eligible municipalities of the intervention. Subsequently, municipal meetings were held, joining CAPS leaders to generate a lottery to randomly assign the sequence of training delivery in two phases (2014-2015, and 2015-2016). Within the final listings, invitations were made with the integrated dates on the ARAS trainings where they were kept listed with strict control of participation and follow-up.

Because the control communities were potentially exposed to receiving information on the ARAS of the treated CAPS, a detailed timetable for the execution of the training was developed at different stages, where the control CAPS were assigned to the training stage right at the end of the evaluation period (December, 2018 to May, 2019); and where the municipal agreements held during 2015 stipulated the stages that would arise from the randomisation. The control communities maintained close communication with the FISE operational personnel in order to guarantee the preservation of the intact groups regarding the execution of ARAS interventions.

Outside the ARAS, most of the interventions were timely and with prior notification of technical assistance that primarily responded to questions of change of members, notifications of operational updates and participation were kept in record protocols informed to all members in social sessions, that involved health promoters and community meetings.

The action plans of the municipalities that resulted from the training of the AVAR, helped in defining the randomisation sequences in the implementation stage between control and treatment communities of the evaluation study. Since AVAR and ARAS methodology belong to the design of the PROSASR project, other models of technical assistance were left outside the participant communities. The dates and description of the comparison groups receiving the AVAR and ARAS was shared by FISE to the evaluation and survey collection teams to assess data feedbacks and specifying the progress of implementation of both interventions. One of the operational restrictions for the implementation of the interventions was the execution time of the training sessions, since there may be delays of different kinds regarding the achievement of the trainings given almost full participation (90%) of the CAPS in treatment.

When a complete forum of treatment communities was not reached, close follow-up was given to update the number of training participants and identify the rest that needed training. This minimized the lag time of training within the treatment group. Although the training was approved for all participating entities, the final decision on monitoring priorities and activities related to the improvement of management of rural water and sanitation systems was developed with the process of community decision making and the during the CAPS meetings. These steps provided further cohesion to the interventions, given the heterogeneity of communities' and systems' needs on i) the level of assimilation of the information from the training sessions and their needs for subsequent training sessions to the CAPS, and ii) the manner in which training recipients translated that knowledge in concrete actions of change as key points of the management of rural water systems. In the next subsection the results of the characteristics at end-line, along with the main results of the program interventions by treatment and control group are presented.

The geographical coverage of the evaluation designed was developed to guarantee not only statistical representativeness between treatment and control groups, but also to obtain a certain level of external validity to be able to generalize results to the entire rural segment of the country.

Experimental Identification strategy

To gauge project eligibility, Nicaraguan communities registered in SIASAR were assessed using key indicators on the existence and condition of (i) water system infrastructure, (ii) service providers, (iii) general WSS conditions in the community, including water, sanitation, and hygiene practices. These SIASAR indicators allowed for the calculation of a WSS water system sustainability index (Índice de Agua y Saneamiento or IAS).[97]

Even though the intervention happened at the municipality level, as mentioned previously, randomisation was conducted at the community level. After discussions with FISE, for both political and logistical reasons, it was agreed that the community was the best unit of intervention at which UMAS and FISE could reasonably implement the program. Moreover, the community was the smallest independent units at which randomisation could be implemented. Perhaps most importantly, it was advantageous from a power and sample size angle (i.e. increased available sample size and compared to the municipal level, reduced estimates of intra-cluster correlation.)

During data collection, the IE team replaced (i) one full municipality (4 communities), (ii) two communities from a municipality with two communities from another municipality, and (iii) one community with another in the same municipality due to concerns about conflict, logistics, and the safety of enumerators. Hence, by the end of baseline data collection, communities across a total of seventy-six municipalities, as opposed to seventy-five, had been interviewed. Within each community, a proportionate balanced number of households were randomly selected based on community size for the purpose of household data collection responsibilities.

All the 300 communities were randomly selected and assigned to treatment and control arms (150 treatment communities, 150 control communities) using a stratified design across 75 municipalities that were as representative as possible of the national municipal distribution. Within these communities, 5,000 households were targeted for

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The IAS calculation ideally takes into consideration indicators of water quality. However, at the time of eligibilit y determination, water quality data had not yet been collected. Given the importance of water quality in deter mining household health outcomes, water quality tests were included in baseline data collection activities.

recruitment and measurement of household outcomes. The list of treatment and control communities was shared with FISE to allow them to coordinate the implementation of the UMAS capacity-building component of PROSASR.

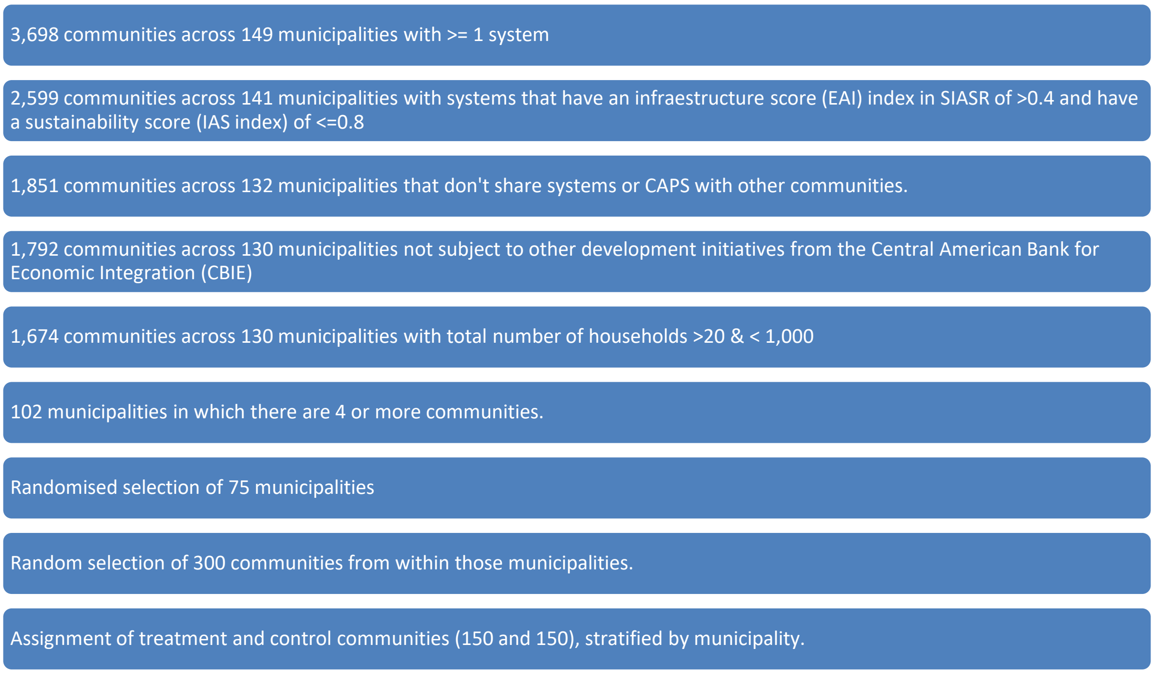


Figure 7-4 Community Sample Selection Process for the Intervention

7.3.1.Compliance and Balance

The overall compliance of the treatment and control groups was preserved relatively well according to the design. From the initial one-hundred and fifty control communities, due to emergency situations, thirty-eight control communities were contaminated with some aspect of Component I of PROSASR -- they received the learnings from the AVAR workshops, and the support from the ARAS -- prior to the third trimester of 2018. Hence, the experiment was left with only 112 non-contaminated treatment communities to analyze.

Moreover, the CAPS legalization component, which is a component of the AVAR trainings and a piece of support offered by the ARAS, was not phased out according to the intervention design, so this indicator is dropped from the analysis.

As mentioned in the next section, balance checks, at the household level, were done excluding the 38 contaminated communities to detect whether the initial design was significantly compromised. The data shows that, when excluding the 38 communities, the initial experiment design was not compromised as the communities remain balanced in treatment and control groups across baseline household characteristics.

The geographical distribution of the communities that were left out of the original impact evaluation design was not skewed towards certain locations. The dropout of the communities and the contamination of the control group did not follow a common factor amongst communities, and hence the balance of characteristics was preserved without those communities included. The overall power preserved for the final sample of communities included in the end-line survey was 85%.

7.4. Data and Specification

Baseline data collection began in November 2015 and concluded in January 2016. Baseline data-collection included surveys at the household, community, system, CAPS, and UMAS levels, assessing current levels of functionality and durability of WSS services, including an assessment of system infrastructure, CAPS institutional capacity, as well as water access and characteristics of the communities and household they supply water to.[98] The piloting and training of enumerators for the end-line data collection was conducted on March, and on May 2019. Collection of the end-line survey occurred between May 22 and October 22, 2019. The rollout of the survey was significantly delayed due to problems importing water tests into the country, and because heavy rainfall affected the capacity of the enumerators to reach some of the more remote areas of the country.

At baseline, 4,850 households, 77 UMAS/UTASH and 300 community-leaders were eventually interviewed. Out of the 300 community leaders interviewed at baseline, only 187 were CAPS representatives. During end-line, 299[99] communities distributed across 16 departments of Nicaragua were visited, obtaining a total of 4,527 effective surveys (Household Questionnaire), 880 chlorine and ph. tests, 372 e coli tests in homes; and 116 chlorine and ph tests, 134 e-coli tests in systems (Measurement Questionnaire). Moreover, 69 UMAS/UTASH and 226 CAPS were interviewed. The data collected followed a close coordination with the FISE and local authorities to be able to minimize the time between the intervention rollout and the collection of both baseline (2015) and endline (2019) survey data (**Table 7-4**). With regards to the

[98] Increasing the Sustainability of Rural Water Service: Findings from the Impact Evaluation Baseline Survey in Nicaragua. Christian Borja-Vega, Joshua Gruber, Alexander Spevack. December 2017.

[99] During the recovery phase, the town of Las Limas San Miguel (ID: 13479) was not included in the department of Matagalpa, in view of the access complications that occurred during the general uprising that indicated that it was not feasible to go to the locality in question

baseline data, the dates of data collection were all before the beginning of any intervention or training session provided by the program. For the endline data, the data collection was a bit more delayed after the last training sessions provided to allow more time of exposure to the intervention and maximized any observed changes in expected outcomes of the project.

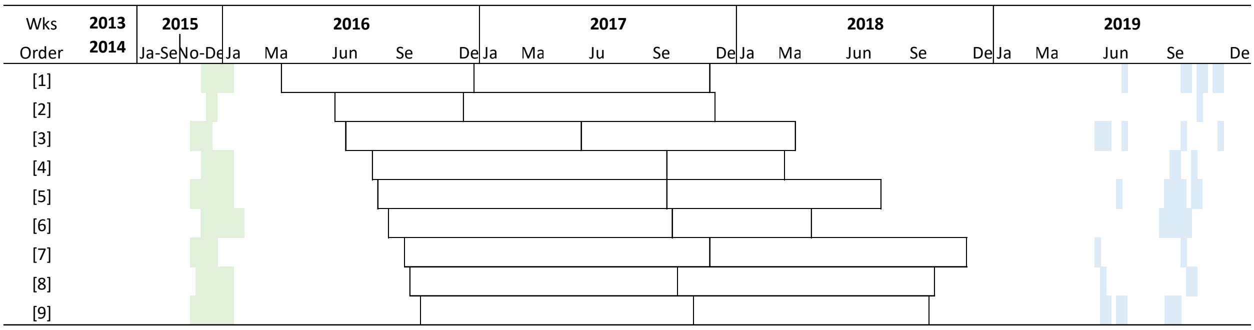


Table 7-4 Baseline and Endline Surveys in Relation to Workshop Rollout

Note: Green shades denote baseline surveys implementation and blue endline surveys. Horizontal bars denote workshop dates per departmental groups. The start of the bar marks the date of the first workshop; the line in the middle of the bar, and the end of the bar, the third.

Workshop order	Program Mun	Evaluation Sample Mun	Communities Treatment	Communities Control	Surveyed Treatment	Surveyed Control	Contaminated Controls n	Contaminated Controls %
[1]	12	6	11	11	11	11	2	18%
[2]	8	1	2	2	2	2	0	0%
[3]	21	11	22	22	22	22	8	36%
[4]	8	7	14	14	14	14	9	64%
[5]	19	15	30	30	30	29	4	14%
[6]	20	15	29	29	29	29	6	21%
[7]	18	4	8	8	8	8	1	13%
[8]	22	5	10	10	9	10	2	20%
[9]	23	12	24	24	24	24	6	25%
	151	76	150	150	148	148	38	26%

Table 7-5 Evaluation Sample

Note: Community Laguna #2, a treatment community, has no complete surveys on baseline and households in community Las Limas San Miguel, control community, could not interviewed on endline. Both communities are dropped from the analysis.

For the study, 298 communities were used, merging CAPS data with household survey datasets, both linked using SIASAR locations data. The administration of baseline and end-line surveys above show the relationship of data collection and the rollout of the workshops. The shades of green illustrate the dates for the implementation of baseline surveys and the shades of blue the implementation of end-line surveys. Horizontal bars denote workshop dates per departmental groups. The start of the bar marks the date of the first workshop, the line in the middle of the bar denotes the date of the second workshop, and the end of the bar illustrates the date of the third workshop.

It's worth highlighting that FISE was meticulous in ensuring that the project interventions were implemented after the baseline survey, and that the end-line survey was conducted after the conclusion of the program. The lag between the project implementation and end-line survey allowed for there to be additional time so that the knowledge acquired in the trainings was absorbed by the CAPS and filtered down to the household level. The end-line survey was administered in the second semester of 2019, to help ensure a time-of-exposure to the program of at least six-months. Municipal-level data draws from both surveys gathered from this impact evaluation, as well as data from SIASAR. For the information at the CAPS level, given that the endline questionnaire suffered from inconsistencies, this impact evaluated opted for use of SIASAR data from the first and second rollout instead. For the household-level indicators outlined in all subsequent sections, the data included is from baseline-endline data-collection administered as part of this evaluation.

7.4.1.Baseline Household Balance and Contamination

Tables 7-5 and 7-6 show the household baseline characteristics across socioeconomic indicators for treatment and control communities. Table 9 shows how, given that, at baseline, there are no statistically significant differences between groups, any change in indicators between groups can be causally associated with the intervention. This suggests that the randomisation of the program was correctly implemented. In other words, the households being compared in the intervention across treatment and control groups are "apples to apples."

	Treatment			Control			Difference	
Indicator	N	Mean	Std.Dev	N	Mean	Std.Dev	Dif.	p-value
Average HH size	2,383	4.67	2.13	2,454	4.72	2.20	-0.06	0.452
HH members, 5 and under	2,382	0.58	0.80	2,454	0.62	0.84	-0.04	0.169
HH members, 14-30	2,382	1.58	1.29	2,454	1.58	1.35	0.00	0.977
HH members 65+	2,382	0.25	0.56	2,449	0.25	0.59	0.00	0.842
Head knows how to read	2,383	0.70	0.46	2,454	0.70	0.46	0.00	0.922

Reports Active Employment	2,383	0.82	0.38	2,454	0.79	0.41	0.03	0.120
Wealth index	2,383	-0.05	1.95	2,454	0.06	2.00	-0.10	0.549
Poorest Quintile	2,383	0.22	0.42	2,454	0.22	0.41	0.00	0.918
Third Wealth Quintile	2,383	0.19	0.40	2,454	0.17	0.38	0.02	0.146
Richest Quintile	2,383	0.19	0.39	2,454	0.21	0.41	-0.03	0.329

Table 7-6 Demographic Household Characteristics among those in the Treatment vs. Control Groups

In order to test whether the level of contamination in treatment communities jeopardized the initial research design, mean tests of household differences, at baseline, were run between those 38 control communities that were contaminated vis a vis. those 112 control communities that were not.

Contamination of control communities can significantly jeopardize the validity of initial research design because: 1) it lowers the sample size, therefore potentially affecting the power of the experimental design 2) if may introduce differential bias into the groups, which may affecting the initial balance across baseline household characteristics presented in Table 9 (i.e., no longer “apples to apples” being analyzed)

Table 7-7 suggest that households in contaminated control communities did not have statistically significant differences from those in non-contaminated control communities. This, in turn, suggests that the contamination of the 38 control communities did not jeopardize the initial experimental design. Since the initial experimental design was not put at risk by the contamination of treatment communities, once we remove the 38 communities from the analysis, all changes in outcomes between treatment and control communities can be causally associated to the intervention.

	Contaminated Controls			Rest of Controls			Difference	
	N	Mean	Std.Dev	N	Mean	Std.Dev	Dif.	p-value
Average HH size	649	4.88	2.13	1,805	4.67	2.23	0.21	0.063
HH members, 5 and under	649	0.60	0.77	1,805	0.63	0.87	-0.03	0.495
HH members, 14-30	649	1.63	1.40	1,805	1.56	1.34	0.07	0.272
HH members 65+	646	0.26	0.58	1,803	0.24	0.59	0.02	0.606
Head knows how to read	649	0.68	0.47	1,805	0.71	0.46	-0.02	0.446
Reports Active Employment	649	0.80	0.40	1,805	0.79	0.41	0.02	0.599
Wealth index	649	0.15	1.99	1,805	0.02	2.00	0.13	0.614
Poorest Quintile	649	0.19	0.39	1,805	0.23	0.42	-0.04	0.297
Third Wealth Quintile	649	0.17	0.38	1,805	0.17	0.38	0.00	0.864
Richest Quintile	649	0.23	0.42	1,805	0.21	0.41	0.02	0.707

Table 7-7 Contaminated control relative to remaining controls

7.4.2.Empirical Specification

Since randomisation occurred at the community level, at the level of municipality, there is no “control group”, so only simple pre-post differences of means are reported at this level.

For the estimates at the community level, to tease out the causal effect of the intervention on the communities, an average treatment effect was used. With the statistical power of the evaluation design, and random assignment, the impacts may be identified by simply comparing the outcomes using a simple difference in outcomes between treatment and control communities, known as an average treatment effect (ATE).

The ATE measures the difference in mean (average) outcomes between units assigned to the treatment and units assigned to the control. To guarantee robustness, additional estimations were conducted using a difference-in-difference approach. The difference-in-difference strategy compares outcomes between treatment and control communities, and end-line and baseline. The ATE and the difference-in-difference estimates were similar, which support the notion that the experimental design used was rigorous. All results reported in this paper are from the ATE.

Two specifications are used, one at the level of the CAPS, and one at the household level. The first equation looks at indicators at the CAPS level. Impact at the CAPS level is estimated using only data from SIASAR, given that the end-line CAPS survey did not include estimates which could map onto all the indicators outlined in the tables above. The unit of observation is the CAPS. The sample here is restricted to 158 communities, since these are the only ones for which: a) we have SIASAR data, and b) for which there is a presence of CAPS at baseline. These 158 communities have 183 CAPS.

The equation for outcome y for CAPS a in community c has the following controls: a dummy variable for whether the community was assigned to treatment T_c, the mean of the outcome at SIASAR baseline at the community level, and municipality-level fixed effects.

The stratification was at the municipality level, with 76 strata. Simulations by Bruhn and McKenzie (2008) show that regressions which include variables used for stratification have more power to detect effects relative to those without them.

$$(1) \quad y_{ac} = \beta_0 + \beta_1 T_c + \beta_2 \bar{y}_c^{Baseline} + \mu_m + \varepsilon_{ac}$$

The differences observed in β_1 and β_2 summarize, on average, the effect of the program. The second equation is used to estimate impact at the household level. It considers all households *h* at end-line in community *c.* It has the same structure as equation (1). For example, it also uses the mean of the outcome at baseline survey at the community level.

$$(2) \quad y_{ic} = \beta_0 + \beta_1 T_c + \beta_2 \bar{y}_c^{Baseline} + \mu_m + \varepsilon_{ic}$$

The inclusion of outcome baseline means increases the power of our model to be able to tease out econometric effects. If the outcome systematically increases or decreases over time, the baseline outcome will have a higher predictive effect on the end-line values. Since treatment and control variables are statistically similar in all variables at baseline, the inclusion of the baseline mean does not influence the treatment effect.

7.5. Results

This section provides a summary of results at the UMAS/UTASH, CAPS, and household-level which are further fleshed-out in the subsequent sections below.

At the municipal level, the results suggest that, within the SIASAR scoring system, most municipalities involved in the study experienced improvements across several aspects of governance, monitoring and maintenance of rural water systems. Five out of the six indicators show a statistically significant improvement. The share of communities the UMAS/UTASH visited during the last twelve-months increased by 50 percent, the number of UMAS/UTASH with an assigned annual budget, funds for travel expenses and fuel, and internet services increased by 157 percent, and the share of communities supported for water quality monitoring increased by 63 percent, between baseline and end-line.

Despite the PROSASR capacitation, the number of technicians available by community to implement repair activities did not change (**Table 7-8**). This is an area that should be significantly improved: UMAS/UTASH should have greater access to human resources, to help better the maintenance and functionality of water systems.

In terms of CAPS, the sustainability index increased by 0.4, on a scale of 1 to 4, compared to the 2.5 average among controls. Put differently, the score along the general sustainability of water systems among CAPS in the treatment communities increased by 15.7 percent. The impacts presented here do not consider the legalization of the CAPS. This is because the PROSASR only provided technical assistance along the procedural steps for the legalizations of the CAPS but may have offer additional guidance in the final steps towards their legalization. The actual legalization process depends on the behavioral and organizational capacity of the CAPS to submit their legalization proposal to the relevant municipal authorities. More importantly, the legalization component was not phased out according to the research design, so it was administered to treatment and control communities alike.

CAPS experienced a statistically significant increase, in terms of standard deviation (proportion in relation to the mean of the control group) along the following indicators. There was an overall increase in score of 0.42 standard deviations, out of the five elements, four improved:

- CAPS management of service providers increased by .41 standard deviations
- CAPS financial solidity increased by .39 standard deviations.
- CAPS attention to operation and maintenance of the water basin increased by .33 standard deviations.
- CAPS adequate protection of the water source increased by .24 standard deviations.

The only CAPS-level indicator that did not improve with the PROSASR interventions was the establishment of adequate water tariffs. There can be two explanations for this: first, given that water tariffs are usually subject to political and technical incentives, no formal delineations for the establishment of rural water tariffs exist. Second, there exists no water valuation mechanisms in place to facilitate the exploitation of the water systems being administered by the CAPS. Hence, a possible step forward, in establishing parameters to better identify areas of hydraulic shortage, is to tabulate the value of water by cubic meter covered, and tailor it to the payment capacity of the communities. This would open possible avenues to increase financial support and help cover the gaps in the payment capacity collected via tariffs vis. a vis. the value and real cost of the hydraulic resources being distributed.

In terms of impacts in access to improved, or safely managed water, this increased with the program, but only during dry season. However, increases in access to improved water services in dry season are not statistically significant. There was no effect in access to improved water during rainy season. One possible area for improvement is to undergo a detailed, follow-up study to better identify policies which can be applied locally in response to incidents of high and low precipitation. Detail plans of action to preserve and increase the coverage of rural water services during these incidents and align them with the practices of water-system management.

The institutional water-strengthening programs had a small, but statistically significant, impact in access to improved sanitation. Access to improved sanitation increased by 3.7 % compared to a level of access of 46.5% in the control group (percentage increase of 8 %). Open defecation was reduced by 1.8 %, compared to a level of 4.8 % in the control group (a percent decrease of 37 %). Access to a non-shared sanitation service increases 3.2% relative to a level of access of 78.2% in the control group (percentual increase of 4.1%). The increases are even higher in all cases when excluding the contaminated control communities.

Diarrhoea (among any household members) was reduced by 2.2% in the treatment group, compared to the 14.2 % in the control group. This marks a 16 % difference between treatment and control groups. However, the estimate in the reduction of diarrhoea is not significant when we exclude the contaminated communities from the analysis. The estimate is, nevertheless, at the threshold of significance (p= 0.11).

On the other hand, the assistance of members of the community to meetings organized by CAPS increases by 1 % relative to a level of 29 % in the control group, but the increase is not significant. This is another area that merits improvement: strengthening of the CAPS was a central component of PROSASR, and citizen participation is key to ensure that the effects of these type of programs are preserved, and amplified, over time.

7.5.1.Simple Pre-Post Difference Results at the UMAS/UTASH level

The estimates here present a before and after analysis of the UMASH/UTASH for the 68 municipalities included in the impact evaluation surveys administered in both baseline and end-line. With some exceptions, the (non-casual) results presented here show positive outcomes: the indicators display increases in the number of activities by the UMAS/UTASH to support the CAPS, a decrease in the number of UMAS/UTASH who reported having a specific set of training needs, and an overall decrease in the number of UMAS/UTASH who reported having a series of short and long-term needs.

In terms of the activities the UMAS/UTASH conduct to support CAPS, as **Figure 7.5** shows, the two areas in which UMAS/UTASH support for CAPS increased the most are in the revision and updating of finance and of operational guidelines. The four aspects for which, on average, the UMAS/UTASH support to CAPS improved the least were in the collection of water quality measures, the creation of CAPS, and in conflict resolution regarding water. The average number of communities supported by the UMAS/UTASH increased from around 35 to 60 percent.

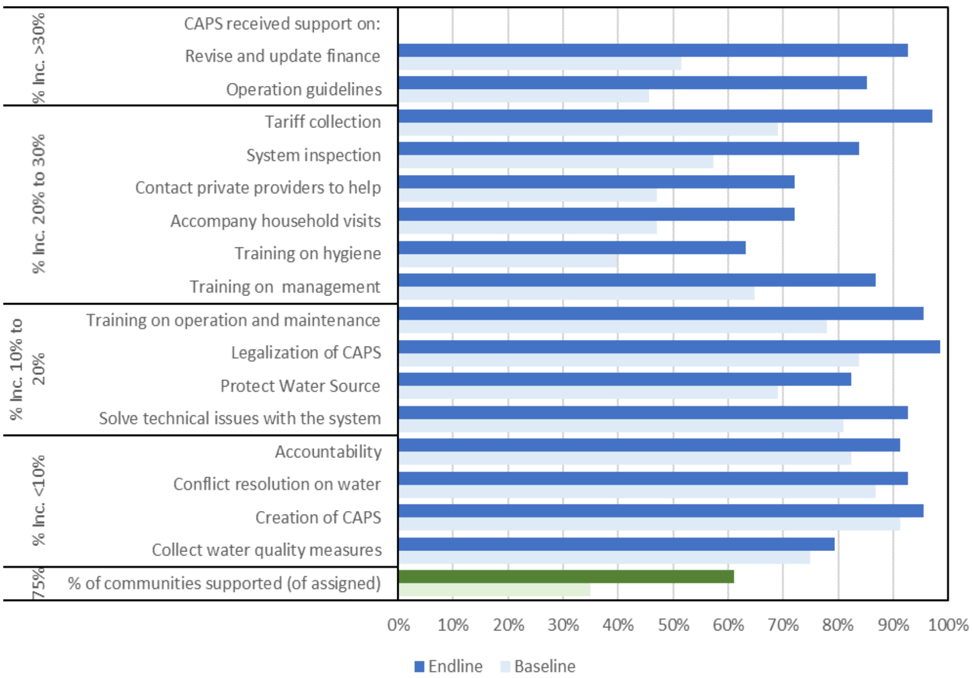


Figure 7-5 Average Change UMAS/UTASH – Before and After Results in Activities to Support CAPS

As **Figure 7-6** shows, there were significant decreases across all short and long-term needs reported by the UMAS/UTASH. In terms of short-term needs, the need for technical ability of human resources decreased from fifty-three percent to eight percent, and the need for technical equipment decreased from sixty-one percent to nineteen percent.

The UMAS/UTASH did express to be constrained in terms of the resources available to them. The number of UMASH/UTASH who stated that they had enough resources to support the CAPS decreased by almost fifty percent, from around twenty-two to twelve percent (**Figure 7-6**).

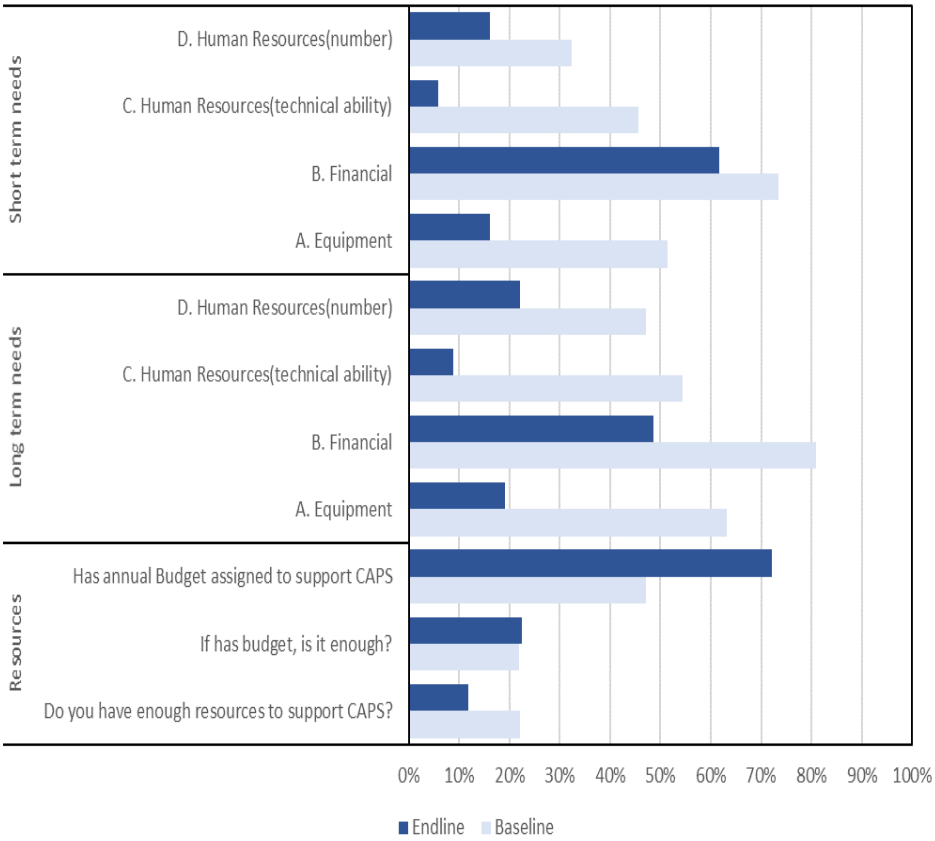


Figure 7-6 Average Change UMAS/UTASH – Before and After Results in short, long-term, and financial needs reported by the UMAS/UTASH

As illustrated in **Figure 7-7**, across all fronts, the training needs from UMAS/UTASH by FISE and training needs from UMAS/UTASH to the CAPS decreased between baseline and end-line. The training needs that decreased the most in relation to their support to CAPS are in terms of water quality analysis, from sixty-two percent to thirty-three percent. The UMAS/UTASH also stated that they had fewer training needs in terms of operational and maintenance infrastructure, water tariff collection, and water protection support. Regarding training needs for UMAS by FISE, all training needs decreased (**Figure 7-7**).

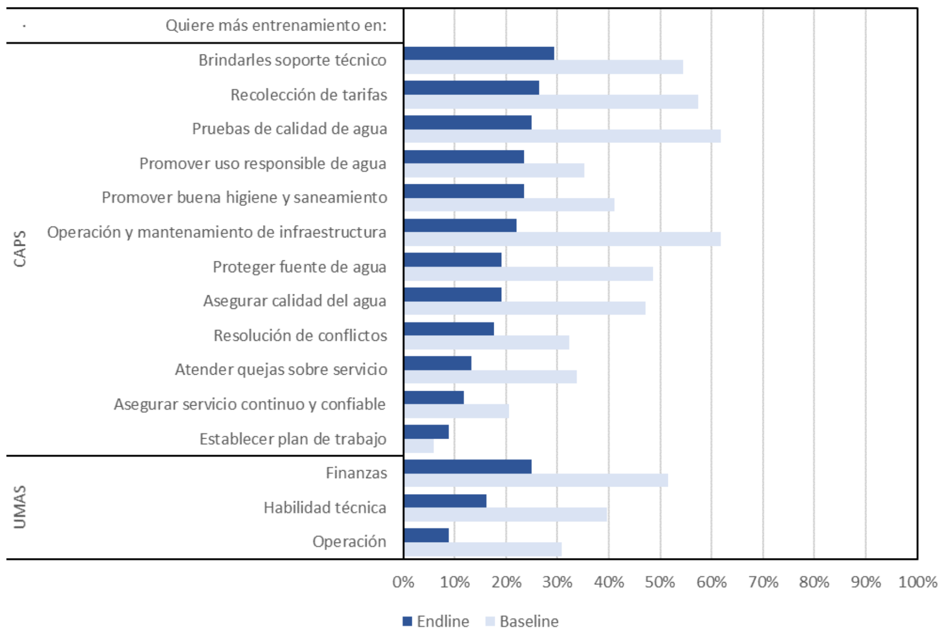


Figure 7-7 Average Change – Before and After Average Change in results in training needs reported by UMAS/UTASH

7.5.2.Estimates for UMAS Using SIASAR

The estimates at the UMAS/UTASH level presented here are conducted using SIASAR data. Of the 76 municipalities in the evaluation sample, only 57 of the municipalities with information for both round one and round on of SIASAR data also had an end-line interview conducted after the end of the third workshop. Thus, the analysis from SIASAR presented here includes indicators for only these 57 municipalities.

Table 11 presents the average changes in score of the UMAS/UTASH after the finalization of the AVAR workshop, according to the indicators outlined in Table 5. The overall average UMAS/UTASH score, used to measure whether an UMAS/UTASH is upgraded to a superior category, increased by 50 percent.

Five out of the six indicators show a statistically significant improvement. The share of communities the UMAS/UTASH visited during the last twelve-months increased by 50 percent, the number of UMAS/UTASH with an assigned annual budget, funds for travel expenses and fuel, and internet services increased by 157 percent, and the share of communities supported for water quality monitoring increased by 63 percent, between baseline and end-line.

The only indicator that showed no statistically significant increase is that of the ratio of communities to technicians.

	BASELINE 2013-2015	ENDLINE 2018-2019	Difference Points	%	Std.Dev.	p-value
UMAS SCORE	2.00	3.00	1.00	50%	1.32	0.000
1. Share of communities visited during the last 12 months	1.51	2.30	0.79	52%	0.66	0.000
2. Share of communities supported for water quality monitoring	1.18	1.91	0.74	63%	0.70	0.000
3. Human resources: Ratio of communities to technicians	3.23	3.25	0.02	1%	0.02	0.935
4. Transportation capacity: Ratio of vehicles to technicians	2.05	3.25	1.19	58%	0.87	0.000
5. Equipment: a. Water quality monitoring b. Information technology for supervision c. Informative printed material	1.75	3.28	1.53	87%	1.44	0.000
6. Has: a. Assigned annual budget b. Funds for travel expenses and fuel c. Internet service	1.44	3.68	2.25	156%	1.72	0.000

Note: Only 57 of the 76 municipalities in the evaluation sample have both data on SIASAR 2018-19 and also their information was added after the end of the third workshop. Std. Dev.= Standard Deviation.

Table 7-8 Differences of means for changes in UMAS score as used to determine whether UMAS/UTASH are upgraded to a superior category

7.5.3. Econometric Results at the CAPS level

The SIASAR estimates for the end-line data collection were not gathered after the end of the third workshop, so it’s difficult to gauge the full- effect of the program at the CAPS level. The results presented here are for 158 communities which, together, have 183 CAPS. As mentioned in the introduction, this points to the need for using updated SIASAR 2020 data to compute the estimates, once the program interventions have sunk in.

Having said that, the estimates presented here are promising. Results here suggest that, in comparison to the control group, CAPS experienced an increase across all indicators; when excluding the 38 contaminated communities, on average, in terms of the overall CAPS institutional index score, CAPS in treatment communities have a 15 % higher score than those in control communities.

As mentioned under the section “Compliance and Balance,” from the indicators included in Table 6, this section does not consider the legalization of the CAPS, because it was administered to all communities, treatment and control, alike.

Out of the four five indicators meant to measure improvements in CAPS, four of them improved, and the result is statistically significant. As shown in **Figure 7-8**, on average, CAPS management of service providers increased by 0.41 standard deviations in the treatment group compared to the control, CAPS financial solidity increased by 0.39 standard deviations in the treatment group compared to the control, CAPS attention to operation and maintenance of the water basin increased by 0.33 standard deviations compared to the control, and CAPS adequate protection of the water source increased by 0.24 standard deviations in comparison to the control group.

The bottom ladder of **Figure 7.8** presents the findings excluding the 38 contaminated control communities. Once these are excluded, across most indicators, improvements are even higher; CAPS management of the service provider increased by .54 standard deviations in the treatment group compared to the control, CAPS financial solidity increased by .55 standard deviations in the treatment group compared to the control, CAPS attention to operation and maintenance of the water basin increased by .53 standard deviations compared to the control.

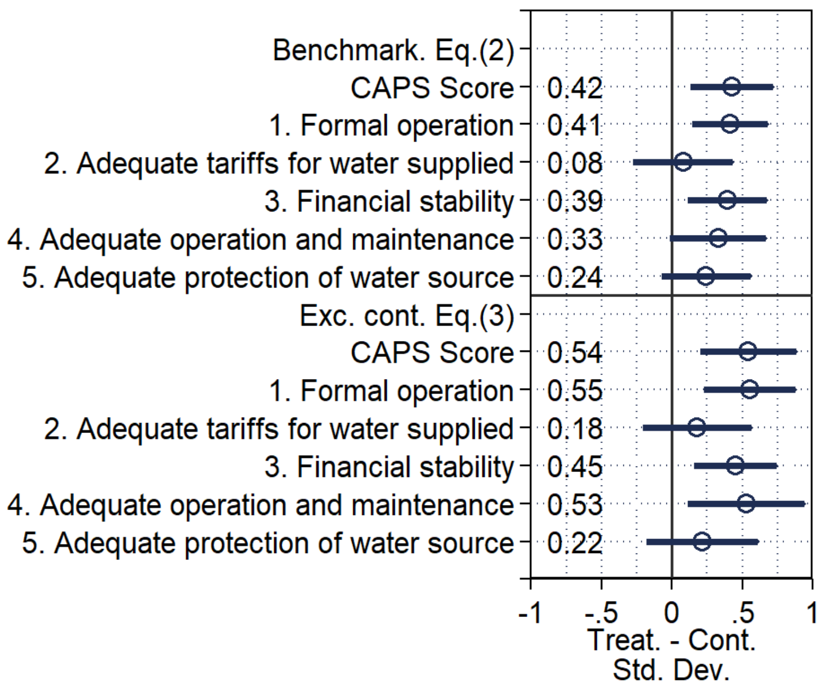


Figure 7-8 Change in Standard Deviations by CAPS component

In terms of the overall CAPS score, which is an aggregate of the indicators at end-line, when excluding the 38 contaminated communities, the average score of the CAPS increased 0.38 points vis. a vis. the 2.54 score in the control group. In other words, on average, in terms of the overall score, CAPS in treatment communities have a 15 % higher aggregate score than those in control communities. This is statistically significant at the one percent level. The effect is illustrated in **Table 7-9**, column three.

	a. CAPS Score			b. Share Legalized	
	(1)	(2)	(3)	(4)	(5)
Treatment=1	0.302***	0.297***	0.382***	0.096	0.100
	(0.103)	(0.104)	(0.120)	(0.071)	(0.085)
Baseline outcome		0.107	0.036	0.238**	0.133
		(0.098)	(0.106)	(0.107)	(0.133)
Constant	2.683***	2.423***	2.485***	0.568***	0.594***
	(0.074)	(0.243)	(0.274)	(0.063)	(0.069)
Obs. (CAPS)	183	183	159	183	159
Communities	158	158	138	158	138
Adj. R2	0.306	0.307	0.370	0.201	0.181
Municipality FE	Yes	Yes	Yes	Yes	Yes
Exclude contaminated	No	No	Yes	No	Yes
Control mean	2.692	2.692	2.541	0.647	0.623
% inc. over control	11.2%	11.0%	15.0%	14.8%	16.1%

Robust standard errors clustered at the municipality level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 7-9 Impact Evaluation Results on CAPS indicators

7.5.4.Econometric Results at the Household level

Given that the intervention finished recently, it is unlikely that the impact at the household level has fully sunk in. Household estimates suggest mostly non-significant estimates in access to water indicators, and in assistance of household members to meetings organized by CAPS. The findings also suggest slightly significant events in prevalence of diarrhoea among household members.

The household estimates suggest that the increase in improved water between treatment and control groups in not statistically significant, and this is true for both dry and wet season (**Table 7-10**). However, the evaluation does point to significant increases in sanitation indicators: access to improved sanitation increases by 6.8 % points over the 44.3 % reported in the control group. This marks a percentage difference of 15.4 %. Open defecation is reduced by 1.5 percentage points, compared to a mean of 4.7 % in the control group. This marks a percentage decrease of 32%. Access to a non-shared sanitation facility increases 3.5 % compared to the average access of 77.6 % in the control group. This marks a percentage difference of 4.5% compared to households in the control group.

	Water		Sanitation		
	SF (dry)	SF (wet)	SAN	OD	PSAN
Treatment=1	0.030	0.014	**0.068*** **	**-0.015***	**0.035** **
	(0.024)	(0.027)	(0.023)	(0.008)	(0.014)
Baseline outcome	**0.551*** **	**0.521*** **	**0.325*** **	**0.161*** **	**0.317*** **
	(0.058)	(0.057)	(0.050)	(0.054)	(0.056)
Constant	0.160***	0.246***	0.313***	0.031***	0.514***
	(0.019)	(0.023)	(0.023)	(0.006)	(0.049)
Obs. (HHs)	3,862	3,862	3,865	3,865	3,865
Communities	260	260	260	260	260
Adj. R2	0.18	0.2	0.11	0.04	0.05
Municipality FE	Yes	Yes	Yes	Yes	Yes
Exclude contaminated	Yes	Yes	Yes	Yes	Yes
Control mean	0.262	0.373	0.443	0.047	0.776
% inc. over control	11.5%	3.8%	15.4%	-32.0%	4.5%

Robust standard errors clustered at the municipality level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

SF (dry): Safely managed, dry season

SF (wet): Safely managed, wet season

SAN: Access to improved sanitation

OD: Use of open defecation

PSA: Has private sanitation facility

Table 7-10 Impact Evaluation Results on Water and Sanitation Excluding Contaminated Controls

Diarrhoea (among any household members) is reduced by 2.2% in the treatment group, compared to the 14.2 % in the control group. This marks a 16 % difference between treatment and control groups. However, although the estimate in the reduction of diarrhoea is not significant when we exclude the contaminated communities from the analysis (**Table 7-11**), the estimate is, however, at the threshold of significance (p = 0.10).

	DIA	MEET	TRA	DIA	MEET	TRA
Treatment=1	-0.022**	0.010	0.031	-0.016	-0.001	0.015
	(0.011)	(0.021)	(0.023)	(0.012)	(0.024)	(0.025)
Baseline outcome	0.030	0.097	0.017	0.022	0.076	0.010
	(0.081)	(0.073)	(0.104)	(0.090)	(0.079)	(0.105)
Constant	0.138***	0.251***	0.365***	0.133***	0.260***	0.372***
	(0.011)	(0.033)	(0.024)	(0.012)	(0.037)	(0.025)
Obs. (HHs)	4,513	3,014	2,794	3,865	2,485	2,316
Communities	298	254	254	260	217	217
Adj. R2	0.0212	0.0423	0.0584	0.0181	0.0487	0.0628
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Exclude contaminated	No	No	No	Yes	Yes	Yes
Control mean	0.142	0.292	0.375	0.137	0.279	0.369
% inc. over control	-15.5%	3.4%	8.3%	-11.6%	-0.4%	4.1%

Robust standard errors clustered at the municipality level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

DIA: Any member experienced diarrhoea (last 7 days)

MEET: Attended a meeting organized by CAPS (last 2 months, if com. has caps)

Table 7-11 Impact Evaluation Results on Diseases and on Relation with assistance to meetings by CAPS

Assistance to meetings organized by CAPS increases by 29 % compared to the control group, and assistance to trainings by CAPS increases by 3 % in the treatment against the control group, but the increases are not statistically significant (**Table 7-11**). Finally, some results point to the right progress in certain key indicators strictly related to rural water sustainability of systems. The double difference (before and after and treatment and control groups) show the following impacts (**Table 7-12**):

1. In dry season the impact of the training led to 11.3% more systems with safely managed attributes, even when reducing the sample and taking out the 38 contaminated communities the impacts on this indicator were still significant with an average 7.4% percent increase between 6 and 18 months of exposure.
2. Water sufficiency was statistically significant higher by 9.1% (dry season) and 2.6% (wet season), with an overall increase in the percentage of systems with uninterrupted service by 7.6%. The average hours increased of service were

2.4 per day for dry season and 3.3 per day for wet season, both statistically significant.

Exposure 6-18 months after treatment				
Double Difference BEFORE + AFTER/ENDLINE + BASLINE EFFECT				
	ALL SAMPLE		EXCLUDE CONTAMINATED CONTROLS (38)	
Outcome variables	COEFF	P-VAL	COEFF	P-VAL
Water System Safely Managed (dry season)	**11.3%**	**0.027**	**7.4%**	**0.097**
Water System Safely Managed (wet season)	7.8%	0.128	4.3%	0.361
Household Connected to System	9.5%	0.824	0.1%	0.762
Water is sufficient - Dry season	**9.1%**	**0.023**	**10.5%**	**0.016**
Water is sufficient - Wet season	**2.6%**	**0.066**	**2.6%**	**0.099**
Liters of water used per hous. member per day	-5.09	0.121	-4.00	0.312
Uninterrupted Service - Dry season /1	**7.6%**	**0.100**	1.8%	0.748
Uninterrupted Service - Wet season /1	7.9%	0.186	0.02	0.798
Hours of service per day - Dry season /1	**2.37**	**0.056**	2.77	0.535
Hours of service per day - Wet season/1	**3.35**	**0.031**	1.25	0.383
Improved sanitation coverage	3.3%	0.325	4.7%	0.247
Open defecation	-3.6%	**0.023**	-3.9%	**0.048**
Has private sanitation facility	4.1%	**0.073**	4.6%	**0.092**
Reports Handwashing Station	0.6%	0.745	-1.0%	0.611
Water and soap available (if has station)	0.0%	0.981	-0.3%	0.908
Trash in Yard	-3.4%	0.154	**-5.7%**	**0.041**
Feces in Yard	-0.2%	0.945	-1.5%	0.550
Any member experienced diarrea (last 7 days)	-1.7%	0.420	-3.1%	0.168
Any member experienced cuts or abrasions (last 7 days)	0.7%	0.629	1.4%	0.404
Opinion about water quality from the system: Bad	-2.7%	0.422	-0.7%	0.855
Community has CAPS	1.7%	0.666	3.0%	0.459
Attended a meeting organized by CAPS (last 2 months) /2	2.1%	0.519	3.3%	0.425
Received training from CAPS /2	11.0%	**0.002**	11.2%	**0.006**

Table 7-12 Main impacts on rural water sustainability outcomes for specific time of exposure

7.5.5.Tracking SDG 6 for safely managed coverage

There is only a decade left to fulfil goal 6.1 and 6.2 of the SDGs. In addition, the statistics of the survey are comparable to the JMP estimates and they help in updating the 2017 JMP figures. The results show the coverage of safely managed water according to the climatic season (**Table 7-13**).

	JMP, 2017	Dry season		Wet season		EL - BL	
	Rural areas	Baseline (BL)	Endline (EL)	Baseline	Endline	Dry	Wet
Safely managed	29%	17.1%	27.0%	24.2%	38.0%	9.9%	13.8%
Basic	30%	61.6%	57.5%	54.4%	46.5%	-4.1%	-7.9%
Limited	4%	2.7%	1.8%	2.7%	1.8%	-0.9%	-0.9%
Surface water or unimproved	37%	18.7%	13.8%	18.7%	13.8%	-5.0%	-5.0%

	Treat			Cont			Cont - (Exc cont)		
	BL	End	E-B	BL	End	E-B	BL	End	E-B
Dry Season									
Safely managed	15.8%	27.7%	12%	18.2%	26.4%	8%	18.9%	26.2%	7%
Basic	62.9%	55.8%	-7%	60.4%	59.1%	-1%	60.4%	59.0%	-1%
Limited	3.0%	1.6%	-1%	2.4%	1.9%	0%	1.9%	2.1%	0%
Surface water or unimproved	18.3%	15.0%	-3%	19.1%	12.6%	-6%	18.9%	12.8%	-6%
Wet season									
Safely managed	23.8%	38.4%	15%	24.7%	37.6%	13%	25.1%	37.3%	12%
Basic	54.9%	45.0%	-10%	53.9%	47.9%	-6%	54.1%	47.9%	-6%
Limited	3.0%	1.6%	-1%	2.4%	1.9%	0%	1.9%	2.1%	0%
Surface water or unimproved	18.3%	15.0%	-3%	19.1%	12.6%	-6%	18.9%	12.8%	-6%

Table 7-13 JMP and Survey Data Coverage Categories of SDGs

7.5.6. Advancing on Rural Water Quality Monitoring

The Rural Water and Sanitation Information System (SIASAR) is a cross-country initiative established in 2011. To date, eleven Latin-American countries and Kyrgyzstan participate[100]. SIASAR strives to monitor all rural communities within a country. It collects information using a set of four common questionnaires, which can be adapted to the local context. Questionnaires are applied to relevant actors (for example, community leaders) and cover aspects from the community, the water supply systems serving it, the firm or individuals who operate these systems, and the institutions that provide technical assistance to system providers. The information gets uploaded to an information system that provides basic consistency checks and calculates indicators. SIASAR key feature is systematic collection of rural water sector information and its analysis to support decision making. It uses across countries the same set of tools to collect, entry, host, and organize data. After basic consistency checks, the system generates a standardized set of indicators, classified into 24 components, which in turn are grouped into 6 dimensions: i) Water Service Level, ii) Sanitation and Hygiene Service Level, iii) Schools and Health Centers, iv) Water System Infrastructure, v) Service Provision, and vi) Technical Assistance Provision.

[100] See http://www.siasar.org/en

For each dimension, the system estimates a score, on a scale from A (best) to D (worst), in terms of the sustainability and quality of rural water systems. Based on these scores, it is expected that the relevant authorities--typically municipalities--can then define which post-construction activities need to be carried out to improve the score, or where to prioritize future investments[101].

SIASAR captures information not only on water service users but also on water service providers. Chief among the latter is water quality information. Information on service providers is collected through different mechanisms: a closed-question survey, direct observation, and water quality testing on-site. The methodology for collecting data consists of visiting all communities in a given area. In each community, all existing water systems are inspected, service providers are interviewed, and physical and technical factors that could explain poor performance of a rural water system are identified.

Using SIASAR data to estimate water access indicators provides advantages to the use of data gathered by traditional methods that focus only on water service users, such as household surveys and census. Nationally representative household surveys are typically used to estimate water access. First, for most countries, the information these surveys capture allows to estimate all rungs in the SDGs indicator ladder except the top one, safely managed access, because very few nationally representative surveys implement water tests. Surveys that do typically focus on certain geographic areas. Second, survey data limits the estimation of indicators to national, urban, or rural areas aggregates. Few surveys have samples large enough to estimate indicators at local levels and aggregated estimates might mask large local water access inequities. Unlike surveys, census data allows the estimation of local water access at any level, but census data gets updated infrequently and its limited in scope. Few census questionnaires capture distance to all water sources (either in time or meters), or capture availability of service, and none captures water quality (**Table 7-14**).

[101] See for instance: World Bank, 2017. Consolidation and Expansion Consolidation, Improvement and Expansion of the Rural Water and Sanitation Information System (SIASAR). Washington D.C

Safely managed	Water from and improved source located within the premises, available when need it, ***and free from fecal or physic-chemical contamination***
Basic	Water from and improved source located within a 30min round trip (including waiting time)
Limited	Water from and improved source located more than a 30min round trip (including waiting time)
Unimproved	Water from unprotected wells
Surface water	Water from rivers, springs, irrigation channels, etc.

Table 7-14 Sustainable Development Goal Ladder for Water Access

From system information, water quality test whether the providers treat the water with chlorine, estimated average distance to households served, and the number of hours per day the system supplies water for a total of 4,769 systems. Water quality information in SIASAR Nicaragua consists of when water was tested and whether results were satisfactory. Nicaragua's National Health Ministry routinely executes water quality tests and provides a results report to system providers. SIASAR interviewers ask for the report and sum up its information into three indicators. The first is date of interview, a field left missing in the information system when on report for the system is found. The second is whether no faecal contamination was found. The third is whether all chemical tests were deemed satisfactory according to national standards[102]. No other information is provided; for example, about measured chemical contamination levels.

Systems must have water quality test results carried-out in the year of interview or, at most, the year before. Systems with older tests are deemed as having no water quality information. Figure S1 in the supplementary material shows for all systems whether, a) have no recent test, b) have a recent test and the result was satisfactory and have test and an unsatisfactory result. The map shows a large overlap of these status for chemical and faecal contamination tests. This seems suspect. It might suggest that if results for only one test were available, interviewers reported that test result for both tests. Poverty rates indicators complement the analysis. Extreme municipality poverty rates are from Nicaragua's National Statistical Institute (INIDE)[103]. INIDE uses the 2005 Census, the most recent one available for the country, to estimate poverty

[102] The standards in Spanish are available at:
http://biblioteca.enacal.com.ni/bibliotec/Libros/pdf/CAPRE_Normas_Regional.pdf
[103] See for instance: https://www.inide.gob.ni/censos2005/CifrasMun/tablas_cifras.htm

according an unsatisfied basic needs index. Safely managed water and other access indicators are constructed at the community level using summarized system information. Most communities have a single system provider (78% have one and 11% have two) but a system may serve more than one community and a community might receive services from more than one system. For all systems, first we estimate whether the system has one of five negative attributes: 1) no recent water quality test, 2) faecal matter is detected, 3) chemical test result is unsatisfactory, 4) households are more than 100 meters away, on average, from the water collection point, and 5) whether water service is not provided 24 hours every day. Then we match systems to communities and summarize each of these negative attributes at the community level as to whether at least one system exhibits them. For example, the community is not free from chemical and faecal contamination if for at least one system servicing it faecal matter is detected or a chemical test result is unsatisfactory.

Table 7-15 shows how we adjust SIASAR community data to the SDG Water ladder, and what aspects of water quality should be collected. The first, and worst, rung in the later is access to surface or unimproved water. It is represented by the proportion of households in the community with no access to water service. Then we divide the proportion of households with access to improved water into limited and basic water as follows. If at least one system is deemed to be more than 100 meters away, on average, from the water collection point, households with access to improved water in the community are deemed to have limited access. Otherwise, these households are deemed to have basic access. We calculate safely managed indicators only for communities in which all related systems report recent water quality tests. All other communities are discarded.

		Surface Water or unimproved	Limited	Basic	Safely managed (1)	Safely managed (2)
A. Access	*(a) Drinking water source*					
	(a1) No access to water distribution system	Yes				
	(a2) Access to water distribution system		Yes	Yes	Yes	Yes
	(b) Time to source: Distance more than 100m		Yes	No	No	No
B. Quality	***Free from chemical and fecal contamination***				**Yes**	**Yes**
C. Availability	*Available 24hrs every day of the week*					Yes

Table 7-15 SDG Water Ladder Adjusted to SIASAR Data. Water distribution systems consist of aqueducts, wells, or rainwater

For Nicaragua, we use the Rural Water and Sanitation Information System (SIASAR). SIASAR is a census of rural communities with detailed information from water distribution systems, their operators, and the communities they serve. Although systems systematically report information—for example, all systems report whether and how they treat the water—a large proportion, 53 percent, report no recent water quality test results. Systems in both poor and non-poor municipalities are less likely to have information. According to municipality poverty rates, 59 percent of systems in municipalities with low extreme poverty levels and 58 percent in those with high have no water quality information.

Detailed SIASAR information allows to analyse attributes of safely managed access and explore the relation of water quality and characteristics of water distribution systems but large water quality information gaps and non-systematic collection hinder analysis and interpretation of results. We document, for example, that water treatment works. Eighty percent of systems that treat water with chlorine report to be free of faecal contamination compared with fifty percent that do not. Systems based on wells are less likely to treat the water compared with systems based on aqueducts. This reflects on water quality, only 54 percent of wells with water quality information report satisfactory results compared with 66 percent of those based in aqueducts. On the other hand, they are more likely to be closer to households and to experience fewer service interruptions. Households might prefer service from wells for their convenience and in consequence expose themselves to a higher disease risk. That desirable aspects of adequate water access are not necessarily complementary increases the challenge to ensure universal and adequate water access. Systems based on wells, however, are also less likely to report tests (45 vs 49) so it is unclear how systematically collected data would impact assessment of whether, and to what extent, these aspects are complementary.

In rural Nicaragua, even under the Millennium Development Goal (MDG) standard, access to water is low at 41 percent. Once we account for distance to water services, adequate access drops to 27 percent. Once we account for water quality, it drops to 7 percent. Finally, once we account for continuity of service and fulfil expectations of safely managed water, it drops to 3 percent. Estimation of the safely water managed indicator, however, necessarily drops from the analysis communities devoid of water quality information. Basic water access drops from 27 to 20 percent when we restrict the sample. Thus, a larger proportion of relatively better-off communities drop from the sample. We document discrepancies across regions in the proportion of sample who drop-out. It is unclear how systematically collected data would impact the assessment of safely managed access water and the differences observed across regions.

Nicaragua's water quality information gap is large as information gets collected for less than half of all rural water systems. What gets collected does so in a non-systematic way: collection is less likely in both poor and non-poor areas. **Figure 7-9** shows the location of rural water distribution systems in the country. The figure points-out which systems lack recent water quality test information. A large proportion of systems, 53 percent, report no recent water quality test results. The figure also depicts municipality poverty rates. The Caribbean region has the highest poverty rates in the country. It also has fewer water distribution systems compared to other regions. Lack of recent test results arises not only in systems located in poor municipalities but also in systems located in non-poor municipalities. High non-reporting rates can be observed south-east in the map, in municipalities of the South-Atlantic Autonomous region, but they can also be observed north-west, in relatively non-poor municipalities in the Matagalpa, Estelí, and Leon Central region departments. When all municipalities are considered, the proportion of systems with recent tests in non-poor municipalities and in poor municipalities is lower than the mean. The mean for all systems is 47 percent compared with 41 percent of systems located in non-poor municipalities (poverty rate below 25%) and 42 percent of those in poor municipalities (poverty rate 75% or more).

Figure 7-10 presents statistical evidence of the non-linear relation between water quality collection and geographic area poverty rate. Panel A shows the unconditional relation, which resembles an inverted-U shape: the probability that a system reports water quality information is at its lowest at the extremes and its highest at middle-low poverty levels (poverty rates between 25% to 50%). Panel B presents regression estimates. Column (1) shows that the correlation could be linear, as showed in through the systematic decrease on reporting in the poverty range 25 to 100 percent (Panel A). Column (2) fits a quadratic functional form. Estimates are imprecise but do suggest an inverted-U shape. Column (3) adds the number of systems in the municipality. Results suggest that reporting is higher the fewer systems are in the municipality. Results in column 3 buttress evidence of an inverted-U shape relation between poverty and water quality collection.

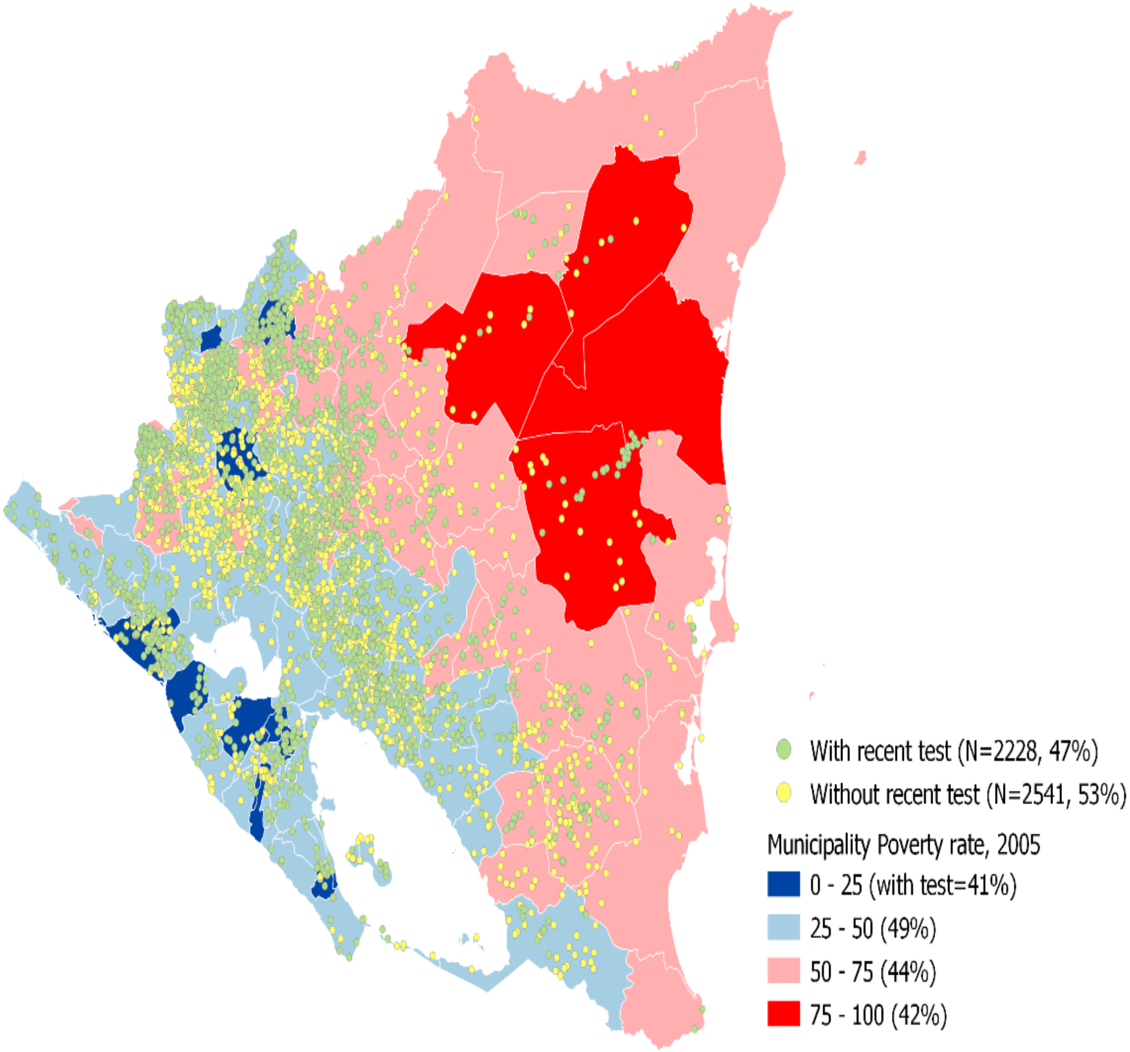
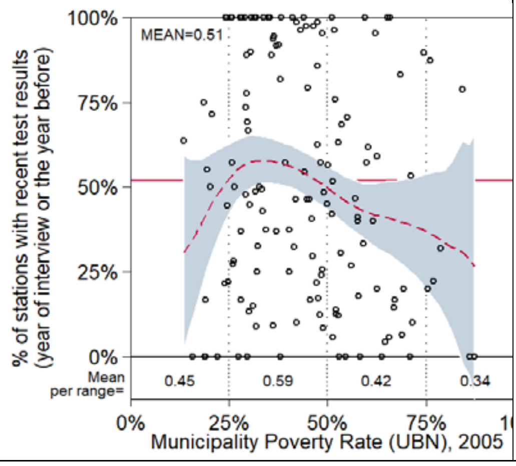


Figure 7-9 Water Distribution Systems According to Water Quality Test Availability and Municipality Poverty Rate

Note: Water distribution system data are from SIASAR 2013. Shaded regions depict municipality poverty rates according to an unsatisfied basic needs index constructed with data from the 2005 census. Green dots represent rural water distribution systems that report water quality test results and these results refer to the interview year or at most the year before. Yellow dots represent the remaining systems.

a. Unconditional Relation



b. Conditional Relation

	(1)	(2)	(3)
Poverty rate	-0.0039**	0.0110	0.0160*
	(0.0018)	(0.0088)	(0.0092)
Poverty rate squared		-0.0002*	-0.0002**
		(0.0001)	(0.0001)
# of systems			-0.0019***
			(0.0007)
Constant	0.6847***	0.3717*	0.3275
	(0.0867)	(0.2016)	(0.2052)
Municipalities	148	148	148
Adj. R2	0.026	0.040	0.061

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 7-10 Relation of Municipality Poverty Rate and Water Quality Test Reporting

Note: Information for whether rural water distribution systems report water quality data is from SIASAR 2013. Municipality poverty rates information is from an unsatisfied basic needs index constructed with data from the 2005 census. Panel A presents the unconditional relation of poverty with the proportion of systems in the municipality that report a recent test. Local linear regressions present the 95% confidence interval, use the Epanechnikov kernel, and use a poverty rate bandwidth of 10 percent. Panel B presents conditional relations using OLS regressions.

Presence of this non-linear relation can hinder analysis and interpretation of water quality indicators. Consider the following example. A relevant policy question is how effective chlorine treatment is to remove bacteriological contamination. SIASAR systematically collects whether systems treat water with chlorine thus policymakers can analyse these data to answer the question.

Table 7.16 presents statistics that use this information. It shows that only 30 percent of systems apply chlorine treatment and that systems based on wells are less likely (23%) to treat water in this way compared to those based on aqueducts (38%). It also provides evidence of non-systematic water quality collection by system type.

Only 45 percent of systems based on wells report recent faecal coliforms test results compared with 49 percent of those based on aqueducts. The large proportion of systems without information, compounded by its non-linear relation with poverty, impinges interpretation of why systems based on wells are less likely to apply chlorine treatment. It is unclear whether systems based on wells are less likely to treat water owing to systems' intrinsic characteristics that make treatment difficult or because they are more likely to locate in poor municipalities and thus have operators bereft of technical skills or resources to apply treatment.

Also, it could be that systems based on wells that locate in non-poor municipalities are less likely to treat water because they perceive the water source to be contamination free. Their perception, correct or not, could be the cause of non-collection of water quality tests. Why system based on wells are less likely to apply chlorine treatment is unclear.

What is clear is that treatment is effective. Information on the table relates chlorine treatment with faecal matter presence. Only 51 percent of systems that do not treat water are faecal matter presence free compared with 80 percent of systems that do.

Safely managed water access goes beyond access. It considers other desirable aspects such as quality, distance to service, and continuity of service. Analysis from SIASAR Nicaragua shows that these attributes need not to be complementary. Water from system based on wells shows lower quality than water from aqueducts. It also shows, however, to be closer to households and to have better continuity of service.

System type	# of Stations	Share that apply chlorine treatment	Share with recent fecal coliforms test	% with satisfactory results (Restricted to systems with recent tests)				
				All	Chlorine Treatment			
					Yes	No	Diff.	p-val
[31%] Aqueduct - Pump	1,482	34%	46%	64%	81%	56%	25%	0.00
[15%] Aqueduct - Gravity	715	46%	54%	71%	82%	61%	21%	0.00
[53%] Well - Pump	2,528	23%	45%	54%	78%	47%	32%	0.00
[1%] Rainwater	44	34%	57%	20%	33%	16%	18%	0.37
[100%] Total	4,769	30%	47%	60%	80%	51%	29%	0.00

Table 7-16 Relation of Chlorine Treatment and Faecal Coliforms Presence According to System Type

Note: Rows denote water distribution systems according to type and columns their characteristics. Right-most columns show the proportion of systems that report satisfactory faecal test results and contrast proportions according to whether systems treat water with chlorine. The table reports p-values for a two-sided difference in means test.

Table 7-17 present statistics of distance to service and continuity by system type. Only 37 percent of system based on wells are more than 100mts away from collection points compared to 68 percent of system based on aqueducts. They also experience fewer service disruptions (31 vs 46 percent). Households might prefer service from wells because they are closer and show fewer interruption. They might not be aware that such a choice increases exposure to diseases[104].

System type	# of Systems	More than 100mts away (on average)	Less than 24hrs per day
[31%] Aqueduct - Pump	1482	70%	38%
[15%] Aqueduct – Gravity	715	65%	63%
[53%] Well – Pump	2528	37%	31%
[1%] Rainwater	44	61%	27%
[100%] Total	4769	52%	38%

Table 7-17 Measures of Water Continuity of Service and Distance to Water Source According to System Type

Table 7-18 summarizes a detailed profile of water access for each of all rural communities in the country to a national level and to Nicaragua's three regions. Even under the Millennium Development Goal (MDG) standard, access to water in rural areas is low. Access is only 41 percent and as low as 11 percent in the Caribbean coast region. Once we account for distance to water services, adequate access drops to 27 percent. The basic water metric portrays a different regional rank vis-à-vis the MDG metric. The Pacific region, the region that encompasses Managua and the better-off municipalities in the country, has a higher access than the central region under the MDG metric but a lower one under the basic water.

Data on water quality allows to make a safely managed water profile. Once we account for water quality, basic access drops from 20 to 7 percent. Decreases are lower for the Central and Caribbean coast regions compared with the Pacific region. Finally, once we account to continuity of service, only 3 percent of rural areas have adequate water access.

[104] See for instance: Loebach, P., & Korinek, K. (2019). Disaster vulnerability, displacement, and infectious disease: Nicaragua and Hurricane Mitch. Population and Environment, 40(4), 434–455. https://doi.org/10.1007/s11111-019-00319-4; and Wolf, J., Johnston, R., Hunter, P. R., Gordon, B., Medlicott, K., & Prüss-Ustün, A. (2019). A Faecal Contamination Index for interpreting heterogeneous diarrhea impacts of water, sanitation and hygiene interventions and overall, regional and country estimates of community sanitation coverage with a focus on low- and middle-income countries. International Journal of Hygiene and Environmental Health. https://doi.org/10.1016/j.ijheh.2018.11.005; and Cronk, R., & Bartram, J. (2018). Identifying opportunities to improve piped water continuity and water system monitoring in Honduras, Nicaragua, and Panama: Evidence from Bayesian networks and regression analysis. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2018.06.017

These results also signal differences in quality of water distribution systems across regions. The main problem in the Caribbean coast region is lack of water distribution systems but the few they have shown relatively low contamination and are relatively close to households. In contrast, the Pacific region has more systems than the Central region, but its systems locate farther away, interrupt more often, and show lower water quality.

This profile, however, is partial and likely biased. To construct safely managed water, communities with systems without water quality necessarily drop-out from the sample. Basic water access drops from 27 to 20 percent when we remove communities without water quality information. These drops are higher in the Pacific and Caribbean coast regions. This suggest that better-off communities in terms of basic water drop-out. Estimates likely have a downward bias.

Figure 7-11 expands to the community level the summary in table 3. It shows that basic water access is high on the north-west areas of the country, in the Central region departments of Madriz, Estelí, Nueva Segovia, Matagalpa, and Jinotega. It is also high in the Pacific region departments of Carazo, Granada, Leon, and Managua. Once we account for water quality and continuity of service, very few pockets of communities with safely managed water remain. Most of the few that do remain locate in the central region departments of Matagalpa and Nueva Segovia.

			Rural areas of main regions					
	Rural		Pacific		Central		Caribbean Coast	
	Mean	std.dev.	Mean	std.dev.	Mean	std.dev.	Mean	std.dev.
MDG: Access to improved water	41%	(42%)	51%	(43%)	47%	(40%)	11%	(27%)
SDG Ladder								
0. Unimproved	59%	(42%)	49%	(43%)	53%	(40%)	89%	(27%)
1. Limited	14%	(32%)	24%	(39%)	12%	(28%)	2%	(12%)
2. Basic	27%	(39%)	27%	(40%)	35%	(40%)	9%	(25%)
Only if has systems with water quality tests								
2a Basic	20%	(35%)	21%	(36%)	30%	(39%)	3%	(15%)
3a Safely managed (1)	7%	(23%)	6%	(23%)	11%	(28%)	2%	(12%)
4a Safely managed (2)	3%	(15%)	2%	(13%)	5%	(19%)	0%	(6%)

Table 7-18 Percentage of Rural Households with Access to Improved or Safely Managed Water
Note: Unimproved water: No access to water from aqueduct, well, or rainwater systems. Limited: Access to water from systems and at least one system in the community is, on average, more than 100mts away from households serviced. Basic: No system that services the community is far away. Safely managed (1): Access to basic water and no system in the community reports faecal or chemical contamination. Safely managed (2): Access to safely managed (1) water and no system provides water less than 24 hours a day every day. Community level statistics are weighted by the number of households in the community.

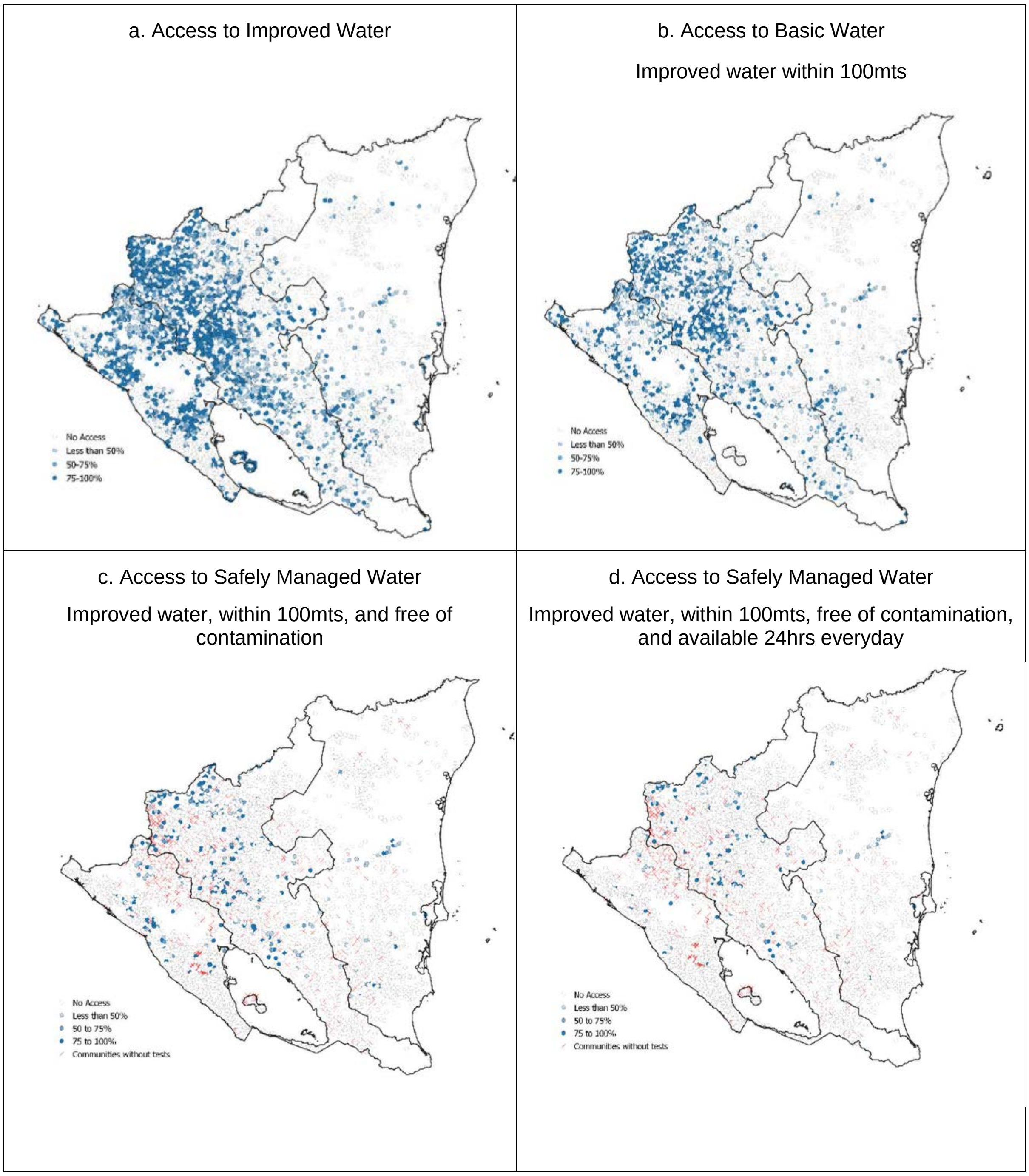


Figure 7-11 Access to Water in Rural Communities

Note: Dark blue dots denote high access to water, light blue medium-high access, and light-red dots low access. Demarcations for Nicaragua's three regions are provided. Left to right, these regions are Pacific, Central, and Caribbean Coast. Safely managed maps, panels c and d, exclude communities without water quality information.

7.6. Conclusions, Limitations and Recommendations

The research presented in this Thesis started in the end of 2015 and concluded in the last quarter of 2019, and the main intellectual curiosity behind it was to explore in depth the factors that drive rural water systems to prevail or fail over time. The rural water systems in developing countries are subject to many governance, technical, economic, social and environmental conditions and binding constraints that impede their proper functioning and service delivery over time. Typically, in developing countries, these systems tend to fail at higher rates than in developed economies, and they are mostly serving poor families and communities. In addition, the provision of water is the first step of a complex value chain of also delivering sanitation and hygiene in rural areas. The high failure rate coupled with the importance of access to reliable water supplies render this research topic extremely important; yet there is a dearth of empirical data and evidence on which to base an understanding of what makes communities to invest more time, effort and resources in keeping these rural water systems operating. Such an understanding is key for crafting local policies to improve their overall conditions and efficiency.

The results of the impact evaluation presented here suggest that Component I of PROSASR was successful in increasing the institutional capacity of CAPS. In comparison to those in the control group, CAPS in treatment groups experienced an increase across all project indicators; on average, compared to controls, CAPS in treatment communities experienced a 15 % increase in their institutional sustainability score, as measured by the project indicators gathered through SIASAR.

On average, in line with the project indicators, CAPS in treatment communities experienced a statistically significant increase in their institutional management, financial solidity, in their attention to operation and maintenance of water basin, and in their attention to water source. At the household level, the indicators on improved access to water did not show a statistically significant effect. Decreases in diarrhoea showed an effect, which were only statistically significant at 10%.

The largest household-level effect is for sanitation indicators, where treatment households experienced increases in access to improved sanitation, increases in access to improved, unshared sanitation, and decreases in levels of open-defecation. This is interesting, given that this was only a secondary component of the institutional strengthening aspect of PROSASR. This is an indirect effect of the information transmitted by the CAPS and the PROSASR to the households and communities in the treatment group. Moreover, UMAS/UTASH pre-post improvements across a range of institutional strengthening components, although not causal, were also positive and statistically significant.

The results are encouraging and should be considered into the design of future programs which seek to tackle the challenges facing the rural water and sanitation sector in the country. But the results should be read with caution. Not all the end- line surveys for CAPS were administered with homogenous time of exposure after the delivery of AVAR trainings, preventing the study from calculating the full magnitude of the effect of the program. Moreover, given that the AVAR trainings concluded in 2018, the effects at the household level require additional time to materialize. A follow-up household survey, in one or two years, would more fully grasp the long-term effects of the intervention. Moreover, updated CAPS questionnaires, from the SIASAR 2019-2020, will also offer additional evidence on the longer-term effects of the intervention.

This study also contributed to advance the research agenda and capabilities of local entities in the country, namely the FISE. The organization, design, implementation and completion of this research endeavour was closely managed and supervised by the FISE. FISE benefited in all process by learning the steps to conduct this type of rigorous research and identify potential caveats in the design and limitations of these types of RCT studies, and the means to replicate findings in the future. This study also generated the evidence to assess the effectiveness of a large-scale program and it is the first of its kind in the country, focusing on the governance and "soft" measures to improve the sustainability and functionality of rural water systems in Nicaragua.

The largest limitation of the study, and perhaps biggest deviation from a traditional, "gold-standard" RCT, is that the households interviewed were a semi- panel, so, although the intervention, and randomisation intro treatment and control, occurred at the community-level, the fact that not the same households were followed between baseline and end-line likely introduced some bias into the estimations. Moreover, this also prevents us from being able to measure levels of household attrition in the intervention. This is not minor, as differential household attrition between households in treatment and control communities could jeopardize the validity and reliability of the initial experimental design.

Second, given that the intervention was a capacity-building program at the level of the UMAS/UTASH, but the design of the experiment was randomised at the CAPS level, it is particularly difficult to ensure that additional contamination did not occur beyond the thirty-eight communities reported to us by FISE. As mentioned under the section on identification strategy, this identification strategy was followed because it was what was deemed the most feasible, and what provided the greatest statistical power. However, additional contamination of control communities, which introduced bias into our estimates, may have occurred beyond what is reported here.

One of the central recommendations to emerge from this paper is to expand funding to implement an additional post-end line household survey in one or two-year's time. Since the AVAR training finished recently, the effects of the intervention, especially at the level of the household, may have not yet fully materialized. A follow-up questionnaire, administered in one- or two-years' time, would allow us to detect longer-term impacts across the full water-sustainability ladder (for CAPS, UMAS), but particularly at the community/household level, where the impacts of the intervention take longer to filter-down. The SIASAR 2019-2020 will also provide additional evidence, at the CAPS level, to tease-out

This impact evaluation was conducted in a context of close collaboration between the government of Nicaragua, represented by FISE, UMAS, ARAS and CAPS, and the World Bank. The central lesson of this evaluation is that, in great measure, institutional strengthening programs of the rural water and sanitation sector show promise in improving the management of local water groups. The effects may be identifiable, if the evaluation design is rigorous and monitored; i.e. count with a random assignment of the program into treatment and control groups.

The positive results in sanitation are encouraging, but somewhat unexpected; the implementation of innovative subprojects of PROSASR, such as improved sanitation solutions, sludge management, chain of administration of chlorine in rural areas and vulnerability to climate change, not covered here, as well as the sanitation-support work conducted by the ARAS, may have contributed to changes experienced in sanitation indicators. Additional work is required to further flesh-out the factors driving the increases in sanitation, and how they may be connected to PROSASR.

The monitoring and rollout of the project was effective and helped accelerate the execution of the project. It's crucial that FISE continues its efforts at implementing new projects and programs aimed at improving rural WASH access. That FISE takes the findings from this impact evaluation into account, and improves project components, to accelerate the coverage of quality water and sanitation indicators in rural areas.

7.7. Training sessions the study

7.8. References

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7.9. Annex: Dates of the AVAR included in the Impact Evaluation and feedback from FISE and ARAS on the intervention

District/ Municipality	Avar Date 1	Avar Date 2	Avar Date 3
ACHUAPA	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
ACOYAPA	22,24 June 2016	22,24 May 2017	21,23 March 2018
BLUEFIELDS	20,22 March 2016	14,15 December 2016	15,17 November 2017
CAMOAPA	22,24 June 2016	22,24 May 2017	21,23 March 2018
CARDENAS	28,29 ,30 September 2016	4, 5, 6 October 2017	3, 4,5 October 2018
CHINANDEGA	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
CINCO PINOS	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
CIUDAD ANTIGUA	24,26 August 2016	27,29 September 2017	11,13 April 2018
CIUDAD DARIO	10,12 August 2016	20,22 September 2017	26,27 July 2018
COMALAPA	22,24 June 2016	22,24 May 2017	21,23 March 2018
CONDEGA	10,12 August 2016	20,22 September 2017	26,27 July 2018
DIPILTO	24,26 August 2016	27,29 September 2017	11,13 April 2018
EL ALMENDRO	22,24 June 2016	22,24 May 2017	21,23 March 2018
EL AYOTE	20,22 March 2016	14,15 December 2016	15,17 November 2017
EL CORAL	22,24 June 2016	22,24 May 2017	21,23 March 2018
EL CUA	3,5 August 2016	20,22 September 2017	7,9 March 2018
EL JICARAL	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
EL JICARO	24,26 August 2016	27,29 September 2017	11,13 April 2018
EL RAMA	20,22 March 2016	14,15 December 2016	15,17 November 2017

EL SAUCE	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
EL TUMA - LA DALIA	10,12 August 2016	20,22 September 2017	26,27 July 2018
EL VIEJO	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
ESQUIPULAS	10,12 August 2016	20,22 September 2017	26,27 July 2018
ESTELI	10,12 August 2016	20,22 September 2017	26,27 July 2018
GRANADA	28,29 ,30 September 2016	4, 5, 6 October 2017	3, 4,5 October 2018
JALAPA	24,26 August 2016	27,29 September 2017	11,13 April 2018
JINOTEGA	3,5 August 2016	20,22 September 2017	7,9 March 2018
JUIGALPA	22,24 June 2016	22,24 May 2017	21,23 March 2018
LA CRUZ DE RIO GRANDE	20,22 March 2016	14,15 December 2016	15,17 November 2017
LA PAZ CENTRO	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
LA TRINIDAD	10,12 August 2016	20,22 September 2017	26,27 July 2018
LARREYNAGA	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
LEON	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
MACUELIZO	24,26 August 2016	27,29 September 2017	11,13 April 2018
MATIGUAS	10,12 August 2016	20,22 September 2017	26,27 July 2018
MUELLE DE LOS BUEYES	20,22 March 2016	14,15 December 2016	15,17 November 2017
MURRA	24,26 August 2016	27,29 September 2017	11,13 April 2018
NUEVA GUINEA	20,22 March 2016	14,15 December 2016	15,17 November 2017

POSOLTEGA	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
PUEBLO NUEVO	10,12 August 2016	20,22 September 2017	26,27 July 2018
QUILALI	24,26 August 2016	27,29 September 2017	11,13 April 2018
RANCHO GRANDE	10,12 August 2016	20,22 September 2017	26,27 July 2018
RIO BLANCO	10,12 August 2016	20,22 September 2017	26,27 July 2018
RIVAS	28,29 ,30 September 2016	4, 5, 6 October 2017	3, 4,5 October 2018
SAN DIONISIO	10,12 August 2016	20,22 September 2017	26,27 July 2018
SAN FERNANDO	24,26 August 2016	27,29 September 2017	11,13 April 2018
SAN FRANCISCO DEL NORTE	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
SAN FRANCISCO LIBRE	21, 22, 23 September 2016	22,23, 24 November 2017	20, 21,22 November 2018
SAN ISIDRO	10,12 August 2016	20,22 September 2017	26,27 July 2018
SAN JOSE DE BOCAY	3,5 August 2016	20,22 September 2017	7,9 March 2018
SAN JOSE DE CUSMAPA	24,26 August 2016	27,29 September 2017	11,13 April 2018
SAN JUAN DE LIMAY	10,12 August 2016	20,22 September 2017	26,27 July 2018
SAN JUAN DEL RIO COCO	24,26 August 2016	27,29 September 2017	11,13 April 2018
SAN JUAN DEL SUR	28,29 ,30 September 2016	4, 5, 6 October 2017	3, 4,5 October 2018
SAN LORENZO	22,24 June 2016	22,24 May 2017	21,23 March 2018
SAN LUCAS	24,26 August 2016	27,29 September 2017	11,13 April 2018
SAN PEDRO DE LOVAGO	22,24 June 2016	22,24 May 2017	21,23 March 2018

SAN RAFAEL DEL NORTE	3,5 August 2016	20,22 September 2017	7,9 March 2018
SAN RAFAEL DEL SUR	21, 22, 23 September 2016	22,23, 24 November 2017	20, 21,22 November 2018
SAN SEBASTIAN DE YALI	3,5 August 2016	20,22 September 2017	7,9 March 2018
SANTA LUCIA	22,24 June 2016	22,24 May 2017	21,23 March 2018
SANTA MARIA DE PANTASMA	3,5 August 2016	20,22 September 2017	7,9 March 2018
SANTA TERESA	28,29 ,30 September 2016	4, 5, 6 October 2017	3, 4,5 October 2018
SANTO TOMAS	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
SEBACO	10,12 August 2016	20,22 September 2017	26,27 July 2018
SOMOTO	24,26 August 2016	27,29 September 2017	11,13 April 2018
TELPANECA	24,26 August 2016	27,29 September 2017	11,13 April 2018
TERRABONA	10,12 August 2016	20,22 September 2017	26,27 July 2018
TEUSTEPE	22,24 June 2016	22,24 May 2017	21,23 March 2018
TIPITAPA	21, 22, 23 September 2016	22,23, 24 November 2017	20, 21,22 November 2018
VILLA CARLOS FONSECA	22,24 June 2016	22,24 May 2017	21,23 March 2018
VILLANUEVA	12,13,14 October 2016	22, 23, 24 February 2017	26, 27, 28 September 2018
WASLALA			
WIWILI DE JINOTEGA	3,5 August 2016	20,22 September 2017	7,9 March 2018
WIWILI DE NUEVA SEGOVIA	24,26 August 2016	27,29 September 2017	11,13 April 2018
YALAGUINA	24,26 August 2016	27,29 September 2017	11,13 April 2018

Table 7-19 List of AVAR's rollout implementation by location and date

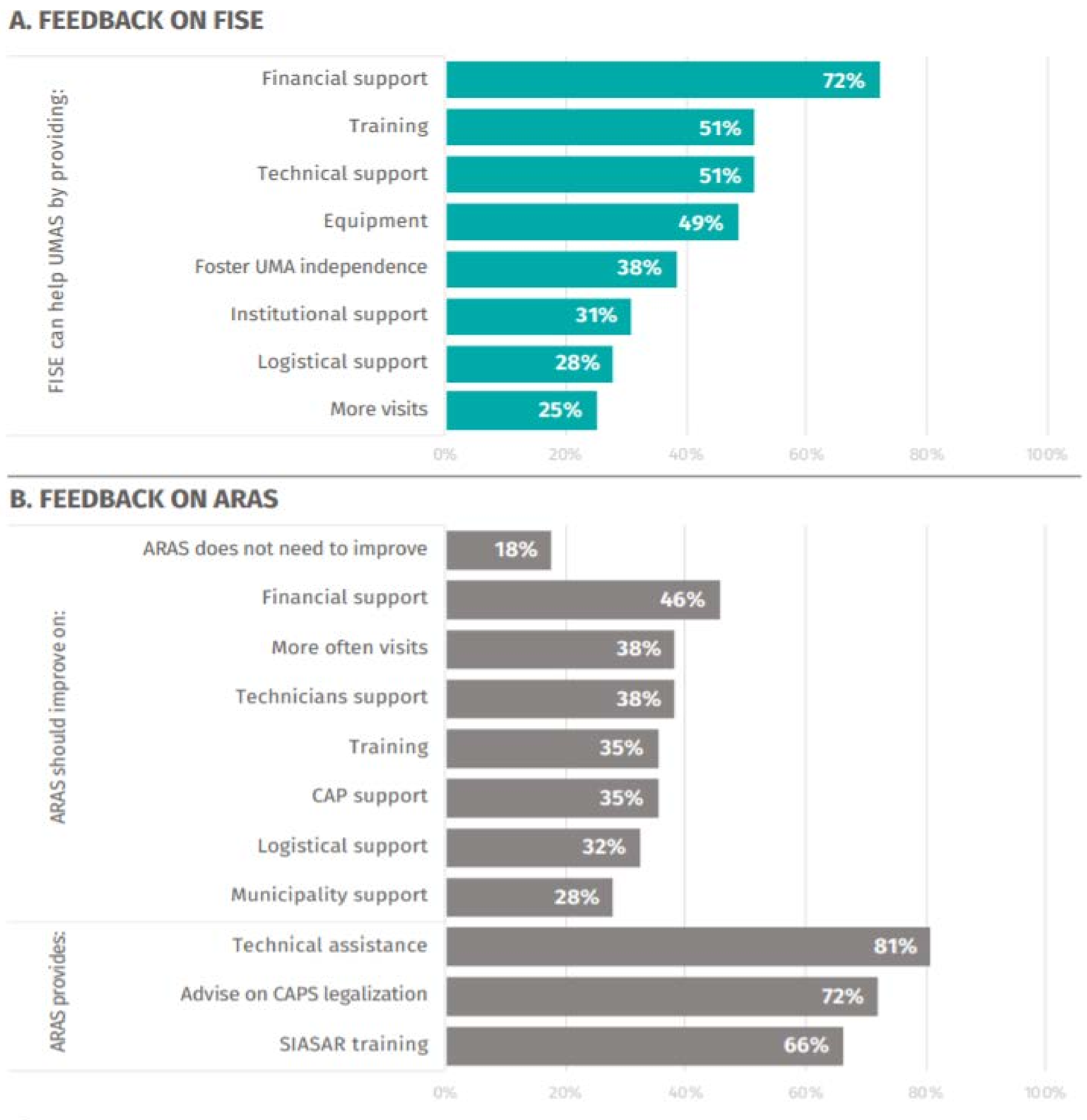

Figure 7-12 Perception feedback from ARAS and FISE

Chapter 8. Overall Conclusions and Recommendations

8.1. Overall Conclusions

The first three chapters of the Thesis explored knowledge gaps that exist in the literature related to the impacts produced by specific WASH interventions and outcomes. Chapters 4 through 7 showed quantitative evidence to fill in the gap on supply-side institutional and capacity building interventions to improve the sustainability of rural WASH systems in a low-income country setting. Specifically, chapters 5, 6 and 7 showed results from the impact evaluation study conducted in Nicaragua, which is one of the few WASH impact evaluations in the literature that targeted the performance of water providers through a capacity-building training program. The evaluation, thus, adds a unique contribution to the WASH literature by exploring the causal effects of improving the performance of operators and community water boards across a wide range of institutional improvements, community and household-level indicators.

The PROSASR objectives was to increase sustainable access to water and sanitation services in rural areas, through enhanced institutional capabilities of water and sanitation providers. The attainment of the project's objective was corroborated by the evidence produced by the impact evaluation, which empirically tested the theory of change (section 5.2), and described how the intervention worked and what type of impacts resulted from strengthening the institutional and management capabilities of UMAS so that they could, in turn, train CAPS on how to properly operate, and maintain the often-defective water and sanitation systems that serve the country's rural population.

8.2. Answering Research Questions

In section 1.5 of this Thesis, the three key research questions were answered to varying degrees. The first research question stated if capacity building and training to rural WASH systems operators helped them improve their performance, and hence resulted in increased sustainability of these systems. These training sessions indeed showed causal effects in the way in which the knowledge acquired by rural WASH systems' operators improved the frequency of formal arrangements for managing the systems, conducted more operations and maintenance activities, and promoted financial stability of the systems in terms of recording savings and accounting of revenues and costs. Specifically, the operations and maintenance activities targeted preventive measures for avoiding rural WASH systems disfunction and helped in the elaboration and application of technical guidelines to avoid systems failures. Indeed, one aspect to consider on the medium-term effects is how much these behaviours and knowledge will endure on key service providers to keep these activities continuing in the future. A final point to consider on the fulfilment of this research question is that the timeline between the exposure to the intervention (knowledge, information and practices) and the data collection of the endline survey reflects only short-run impacts and not necessarily the full extent of impacts related to this research question.

The second research question stated in section 1.5 explores the effects that the capacity building of local municipal governments (UMAS) have on their performance and assistance to the community water boards (CAPS). There are multiple criteria (section 7.5.2) to evaluate how effective were training sessions to UMAS to answer this research question. Based on the individual indices of the criteria and the composite index of UMAS performance (data available from surveys and SIASAR, prior and post intervention). These criteria included human and financial resources, and knowledge from UMAS to be able to deliver support to CAPS in a more efficient manner. In Chapters 5, 6 and 7 of this Thesis, it is stated how the training and capacity enhancement of UMAS targeted the improvement of those criteria, with the objective for UMAS to better support CAPS increase their overall performance scores. Development. That support translated in the development of Municipal Action Plans to equip the UMAS and CAPS with clear activities and resources to make WASH systems operationally and financially sustainable. The proportion of UMAS and CAPS having these plans in place increase due to the intervention in a statistically significant way. Further, these plans laid out a series of steps for the municipality to take in order to increase the sustainability score of the CAPS, which gave more clarity and guidance for CAPS to response to the different types of challenges faced by the WASH systems. Finally, among the performance criteria of UMAS and CAPS there was a statistically significant increase in the proportion of CAPS reporting adequate technical support to develop operation, corrective, and maintenance plans for water distribution systems. One caveat of these impacts is that these are related to intermediate outcomes, but the long-term outcomes of sustaining service coverage, given better reliability of

WASH systems, requires more prolonged time of exposure of UMAS and CAPS after the treatment.

The third question to be answered by the research is the degree in which these impacts vary according to the perceptions of communities in terms of water systems management and socio-economic outcomes. With the information presented in Chapter 7 there are two broad categories of evidence that showed how this question was answered. First, section 7.5.1 show changes perceptions from UMAS in terms of needs for training and long-term engagements to further advance the sustainability of rural WASH systems. These perceptions point at how communities highlighted the importance of water quality monitoring to improve WASH systems in the future. Secondly, with regards to socio-economic outcomes there were changes observed at the CAPS and household levels in terms of self-reported diarrhoea, open defecation, and solid waste management. These indicators showed statistically significant changes between baseline and endline data, due to the improvements in the management of rural WASH systems: open defecation decreased 37 percent, diarrhoea declined by 16 percent, and changes in behaviours towards sanitation and solid waste management also changed significantly, albeit modestly. One of the issues that was not addressed in this research question is related to the long-term socio-economic impacts that increased sustainability of WASH systems provides to households and communities. Additional data collection in the future is needed to observe changes in socio-economic outcomes such as health, human development and other important water resource and environmental management outcomes. Something to highlight in the findings of this research is the importance of the roles of community-based organizations on improving the performance of water and sanitation operators. Those operators are fundamental to keep safe water and sanitation services running in rural areas, and, thus, minimize risks to human development. The health risks associated with poor access to WASH are specially amplified in poor locations where the means and resources needed to develop resilience mechanisms are limited. Hence, the investments made by through the PROSASR are effective from the point of view of bringing tangible results without necessarily expensive infrastructure interventions.

8.3. Specific conclusions by Chapter

The research presented is this Thesis aimed to contribute to this knowledge gap through both rigorous analysis of evidence in the literature and a well-structured study based on a large-scale rural water supply implementation programme. It started with a meta-analysis of impact evaluation studies focused on the WASH sector. This background paper contributed to understand and confirm how WASH impact evaluations tend to focus on testing small-scale water quality improvement technologies, typically linked to health outcomes: more than half of all evaluations included in the meta-analysis focused on diarrhoea as a main outcome of interest. Furthermore, the meta-analysis confirmed that few programs have been evaluated using rigorous impact evaluation techniques, limiting researchers' ability to draw evidence-based conclusions, particularly focusing on the factors ("software" and "hardware") that drive rural water sustainability.

In chapter three, together with some co-authors, I presented innovative technologies to track and collect WASH indicators in the field. This research was important to identify information technology applications and options to reduce costs of collecting data in the field, particularly for the impact evaluation study in Nicaragua. The research also helped to identify means of making the transfer of data into cloud systems that allowed easy manipulation and transparency in updates of the information as it was collected in the field in real time. This helped in improving substantially the quality of information collected in the empirical case study in Nicaragua, at endline (2019) compared to the baseline (2015) survey; the former was collected using paper-based surveys.

In chapter 4, the analysis presented served as the basis to understanding the factors that drive rural water sustainability and functionality over time in Nicaragua. The study explored only correlations and not any causal attribution between the factors presented and the "survival" of rural water systems. However, the statistical method used was innovative and this is its first application to the WASH sector. The analysis utilized the large-scale rural water monitoring data (SIASAR) in Nicaragua and applied survival functions[105] to the rural water systems operating and not functioning, to explore the factors that contribute to the largest changes in the probability of a

[105] For further technical specification of survival functions see: https://data.princeton.edu/wws509/notes/c7s1

"functionality" status of these systems. The approach of utilizing survival functions also contributed to the literature of the topic since it was then replicated and published in 2018, by exploring the long-term factors driving rural water systems' sustainability in Kenya[106].

Chapters 5, 6 and 7 of this Thesis present the overall impact evaluation study in Nicaragua. The process of implementing a randomised controlled trial in 300 communities and reaching close to 4,500 households, aimed at exploring the impacts of large-scale training programs—to ultimately improve the management and operation of rural water systems—was complex. However, with close coordination with the Government of Nicaragua, the randomisation in the assignment of the treatment (training programs) was conducted relatively successfully, with 38 out of 150 treatment communities contaminated in the process. The baseline characteristics of treatment and control communities were not statistically significant, as presented in chapter 6. This created conditions to identify the causal attribution between the intervention and outcomes of interest. In chapter 7, it is presented the overall impacts of this large-scale program. The training program did improve governance, management and maintenance conditions of the community water boards and local providers responsible for the proper service delivery of these rural water systems, which are critical to guarantee the functioning of rural water systems over time.

8.4. Further research and policy considerations

The findings of the impact evaluation have some limitations, that are presented in section 7.5 of this Thesis. However, the results not only confirmed what was presented in chapters 2,3 and 4 but also pointed that the program is relatively effective in achieving its results over the short run. One key aspect to develop further research is to explore the long-term impacts of these types of training programs. This is because the overall intention of these programs are to enhance the functionality and sustainability of rural water systems over time, and, although the impacts were identified in chapter 7, a longer-term study, that collects data on key performance characteristics of these systems over time would reveal whether these training programs did result in embedded behaviour change and new practices over time. The dearth of long-term studies means that there is virtually no direct evidence linking

[106] See: https://www.ncbi.nlm.nih.gov/pubmed/29335170

programme design to long term functionality and service delivery outcomes in rural water supply anywhere in the world.

Nevertheless, this short-term empirical data suggests that well-structured training does influence the behaviour and institutional approaches used by community-level water service providers. On the policy side, these types of training programs may be important to maximize the effectiveness of government interventions for the rural water and sanitation sectors; they empower communities and water boards to assume their roles with the proper technical and managerial knowledge to keep rural water systems running. The findings also suggest that these types of training and institutionally capacity are useful when combined with robust long-term financial support mechanisms (like matching grants, or subsidised maintenance costs of these rural water systems) to improve the overall economic and cost-recovery conditions. This is particularly important in rural Nicaragua given the limited payment capacity of the communities living in these areas. Furthermore, in order to reinforce the sustainability of rural water services and improve equity in access to safely managed water services, post-construction and maintenance support programs are almost certainly needed.

In striving towards attaining universal access to safely managed services by 2030, significant work is needed to improve the functioning of rural water supply and sanitation systems. Thus, it is necessary to develop a comprehensive research portfolio on the efficacy of supply-side WASH interventions. Impact evaluations are of central importance in helping build a reliable, and rigorous, evidence-base of what works, since they provide quantifiable evidence on the efficacy of government programs and offer pinpointed estimates of the causal effect of an intervention. These estimates can then be integrated into the cost-benefit analyses of projects. Based on the experience in RWSS with WB support over the past decade, this IE is helping identify which approaches and methodologies work.