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Determining Success in Community Managed Rural Water Supply Using Household Surveys

An analysis of data from the Community Water *Plus* project in India, and a best practice guide for using household surveys to determine water supply service levels

Australian AID

Community Water plus

May 2015

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Supervisors: Richard Franceys & Paul Hutchings

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Abstract

This report shows the results of a group project carried out by Community Water and Sanitation MSc students at Cranfield University: an analysis of household survey data collected through the Community Water *Plus* project in India. For the data analysis, surveys from 10 case studies (each comprising three 'best practice' villages and one 'control' village) were available. Following data validation and verification, surveys from seven case studies were deemed of suitable quality to conduct further analysis. To allow comparisons of service levels, a composite indicator was created to aggregate five individual parameters of water service. Using the geometric mean with thresholds was found to be the most suitable method of aggregation. 29 hypotheses of correlation were tested, and 17 found to be significant. Some of the main findings are that communal wealth is one of the most important factors affecting service levels in a village, and that household connections are the only technology which can provide a high level of service. This supports the current drive across the WaSH sector to move towards household connections – illustrated by the proposed inclusion of an indicator of providing 'a basic drinking water source which is located on premises' in Sustainable Development Goal 6.1.

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Community Water *plus*

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List of acronyms and abbreviations

BC	Backwards Caste
CM	Community Management
CW+	Community Water Plus
INR	Indian Rupees
JMP	Joint Monitoring Programme
lpcd	Litres per capita per day
MBC	Most Backwards Caste
MDGs	Milennium Development Goals
MICS	Multiple Indicator Cluster Survey
OBC	Other Backwards Caste
OC	Other Caste
OECD	Organisation for Economic Cooperation and Development
RWSN	Rural Water Supply Network
SC	Scheduled Caste
SDGs	Sustainable Development Goals
ST	Scheduled Tribe
UNICEF	United Nations Children's Fund
WaSH	Water, Sanitation and Hygiene
WEDC	Water Engineering and Development Centre
WHO	World Health Organisation

I Goal

The Community Water *Plus* (CW+) project is a three year research investigation initiated in April 2013 to gain more insights on the type, extent and style of supporting external entities (the 'plus') for sustainable Community Management (CM) programmes as well as the resources implications of this 'plus' (Smits et al., n.d.). Cranfield University is providing overall project coordination.

The project conducts an in-depth study of 20 widely claimed community-managed rural water supply success stories across India, looking at their degree of success (in respect to the water supply service levels, the level of community management, and the performance of the service provider) and identifying enabling environment factors for successful CM. The overall objective is to get better evidence of what a successful support programme looks like and what it costs.[1]

As part of the data collection process, household surveys have been conducted in four villages for each study. These surveys are primarily designed to validate whether or not the village in question is truly 'best practice' but also collect data on numerous socio-economic factors, potential explanatory variables.

The aim of this group project was to interrogate the data to understand what level of analysis could meaningfully be conducted, and establish some interim findings. Furthermore, the lessons learnt through carrying out this work have informed the compilation of a guide on 'Best Practice for Household Surveys'.

II Conceptual framework

II.1 Community Management for rural water supply

Community Management (CM) is the pre-eminent model for managing rural water supplies in many low-income countries, including across large parts of India (Harvey & Reed, 2006). Community participation in water supplies emerged in the late 1970s as a response to the failure of governments to provide clean water to their populace, and reflected a desire to ensure that communities were fully involved in all aspects of development (van Wijk-Sijbesma, 1981).

During the International Drinking Water and Sanitation Decade (the 1980s) CM began to be applied systematically, with the development of 'Village Level Operation and Maintenance' (Carter et al., 1999). This was seen as a way of dramatically increasing access to clean water, in what was thought to be a cost effective way (McCommon et al., 1990). Further refinements during the 1990s saw the influence of neo-liberalism with the adoption of the 'demand responsive approach'. Communities were expected to express demand before services were implemented, often though contributing a share of the capital costs (Rout, 2014).

However, despite the success of CM in supporting the rapid expansion of water services to rural communities, there is a growing consensus that the approach is reaching the limits of applicability (Moriarty et al., 2013). Particularly as communities demand better service levels (which, this report

[1] Further information on the CW+ project can be found at http://www.waterservicesthatlast.org/countries/india_community_water_plus_project/community_water_plus

will demonstrate, must mean piped water supplies) the capacity of communities to manage and finance their own services is uncertain.

There is a growing consensus that to ensure sustainability of community managed water supplies, communities need on-going support from governments and other external actors (Moriarty et al., 2013). The CW+ project aims to identify and quantify the nature and resource implications of this support for the first time.

II.2 The service level approach

II.2.1 The general approach

There is a desire across the WaSH sector to categorise the quality of water supplies people access, both to evaluate the effectiveness of programmes and to allow for monitoring against national and international targets. The most widespread categorisation is that used by the Joint Monitoring Programme (JMP) to monitor progress against the Millennium Development Goals (MDGs): that is to classify drinking water sources as improved (e.g. piped supplies, protected boreholes) or unimproved (e.g. surface water, unprotected dug well) (JMP, 2014).

This approach provides limited granularity, and doesn't allow policy makers to differentiate between potentially differing levels of service from the same type of source. Furthermore, the emphasis on technology can lead to a focus on building new infrastructure rather than ensuring people receive the planned level of service (Moriarty et al., 2011). An oft-quoted indicator of this is that across Sub-Saharan Africa 36% of handpumps are non-functional (RWSN, 2009) - delivering a low level of service which would nonetheless be classified as 'improved' by the JMP definition.

2015 marks the end of the MDGs and the start of the Sustainable Development Goals (SDGs). Although the MDG target to 'Halve, by 2015, the proportion of the population without sustainable access to safe drinking water' was met in 2010 (JMP, 2014), 748 million people globally still lack access to an improved water source. When coupled with the fact that access to an improved source may not result in an acceptable service level, it is clear that there is a need to move to both more challenging targets (which the SDGs are) and a more nuanced form of monitoring if the human right to water is to be realised.

The aim of the service level approach is to move away from assessing access to water and focus on the actual service people receive. One version of measuring service levels has water supply being scored on different criteria, such as quantity, quality, accessibility or reliability (Moriarty et al., 2011). Each criteria is scored on an ordinal scale ranging from 'no service' to 'high'. The original idea applies a nominal logic to determine the overall service level for a person or household. This overall service level is set by the lowest single indicator. This approach means that for example someone accessing a high quantity of water of good quality still only has sub-standard service if he has to spend more than 30 minutes a day to collect this water. Table 1 shows the proposed service levels and indicators from the WASHCost project (Moriarty et al., 2011). A service level of 'basic' or higher maps to the JMP definition of an 'improved' source, while a service level of 'no service' or 'sub-standard' maps to 'unimproved' and should be considered unacceptable.

Table 1 - Service Levels (Moriarty et al., 2011)

Service level	Quantity (litres per person per day)	Quality	Accessibility (minutes/capita/ day)	Reliability	Status (JMP)
High	>= 60	Good	Less than 10	Very reliable	Improved
Intermediate	Greater than 40	Acceptable	Less than 30	Reliable/Secure	
Basic (normative)	Greater than 20				
Sub-standard	Greater than 5	Problematic	Less than 60	Problematic	Unimproved
No service	Less than 5	Unacceptable	Greater than 60	Unreliable/ insecure	

Although some of the first references to a service level approach were advanced by Lloyd and Bartam in the early 1990s (Lloyd & Bartram, 1991), it has not been consistently adopted across the sector for large scale implementation. In part this is due to the inherent difficulties of collecting data required in rural areas of low income countries - issues which are explored throughout this report. Although the SDGs do not follow the service level approach, the definition (Table 2) is made up of several factors, which must be assessed individually to understand the service received.

Table 2 - Definition of SDG Target 6.1 (JMP, 2015)

Target 6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all

Language in proposed targets	Normative interpretation
By 2030, achieve	
universal	Implies all exposures and settings including households, schools, health facilities, workplaces, etc.
and ***equitable***	Implies progressive reduction and elimination of inequalities between population sub-groups
access	Implies sufficient water to meet domestic needs is reliably available close to home
to ***safe***	Safe drinking water is free from pathogens and elevated levels of toxic chemicals at all times
and ***affordable***	Payment for services does not present a barrier to access or prevent people meeting other basic human needs
drinking water	Water used for drinking, cooking, food preparation and personal hygiene
for all	Suitable for use by men, women, girls and boys of all ages including people living with disabilities

II.2.2 The selected service levels in the CW+ project

The service levels according to India's Norms for providing drinking water in rural areas are as follows (Ministry for Drinking Water & Sanitation, 2013):

- *Goal for 2017:* 55 litres per capita per day (lpcd) within household premises or within 100 metres radius from household (or 30 minutes of time taken for fetching water in a day)
- *Goal for 2022:* 70 lpcd within household premises or at a horizontal or vertical distance of not more than 50 metres from household

However, those standards are political targets, highly ambitious and largely focused on household connections. The selected basic service level for the CW+ project were based on the available standards provided by Indian policy at the beginning of the project in 2013, as follows:

- 40 lpcd of safe drinking water for human beings within household premises or within 1,600 metres in the plains and 100 metres elevation in hilly areas from household, to meet domestic requirements

Whilst the norm of 40 lpcd was appropriate for this research, it is vital that when designing service levels, reference is always made to the appropriate national or international norms. This can limit the comparability of data taken in different areas, or across longer time-spans.

II.3 The role of households surveys

Household surveys are a frequently used across the WaSH sector to assess access to water (JMP, 2006) and monitor programme success. They provide an invaluable source of information which can be used on a local level, or aggregated to provide national and international comparisons (Kleinau & Pyle, 2004). In the context of assessing water service levels, they stand out as the only tool which allows researchers to understand what service households receive, as opposed to what is planned by providers or local authorities. Despite this, household surveys do have limitations: households are unlikely to have an understanding or knowledge of the technical details of water supplies which are essential to understanding the service provided. Furthermore, the reliability of data from household surveys is often questionable. These limitations are explored in the guidance accompanying this report.

In relation to the CW+ project household surveys are used to assess overall service levels provided to individual households. Full details of the household survey process are provided later in this report. Alternative research tools are used to assess other aspects of service provision, such as the effectiveness of Community Service Providers. As this project was limited in scope to analysing only data from household surveys, any conclusion drawn are in themselves limited. Without the context provided by research on the service providers and the broader enabling environment, the finding in this report are only indicative.

III Methodology

III.1 Presentation of the dataset

In the framework of the CW+ project, the dataset was established involving a three-tiered selection process:

- *1st layer:* select programmes across India that deliver best practice CM across various social, technical and geographical spectrums, following a stratified purposive sampling approach. Successful CM programmes were identified from academic and grey literature as well as through the sector knowledge of the consortium partners, the national and state governments and through the CW+ project's civil society network.
- *2nd layer:* identify villages to study within these programmes based on locating critical cases that reflect CW+ project's understanding of CM within the given programmes, following a systematic purposive approach. This includes three 'average best practice' villages where programmes lead to success in villages that do not have exceptional circumstances and one control village per programme, usually close-by to the primary district of fieldwork, which is not part of that programme but shares a set of observed covariates (e.g., technology, social, demographic, geographic, and other community characteristics) with the other cases.
- *3nd layer:* select households within the villages using a systematic approach to sampling and covering the entire geographical and socio-economic spread of the village.

To ensure that the CW+ project's research questions would be answered while considering the resources available to each research partner, 20 case studies were selected with each of them containing four villages where 30 surveys were conducted in each village.

The 10 case studies completed to date, resulting in 1,200 household surveys to analyse in this study, are shown in Table 3.

Table 3 - Case studies in CW+

	Name of the case study	State	District	Best practices villages + Control village	Research team
1	Tamil Nadu - Dharmapuri	Tamil Nadu	Dharmapuri	Ramianahalli/Vagurappampatti/ Thoppampatt + Maruthipatt	CEC
2	Jaipur	Rajasthan	Jaipur	Vidhani/Bhater/Bayothawala + Shri Krishanpura	MNIT
3	Punjab	Punjab	Mohali	Singhpura/Shahpur/Daumajra + Ghataur	MNIT
4	Jharkhand	Jharkhand	Ranchi	Bero/Khijri/Rai Bazar + Brambe	XISS
5	Gujarat - Gandhinagar	Gujarat	Ghandinagar	Motipuraveda/Amarpura Kherna/Sardhav + Prantiya	ASCI
6	Gujarat - Kutch	Gujarat	Kutch	Bharasar/Shinay/Kanakpar + Jabravandh Badhuvand	ASCI
7	Odisha	Odisha	Ganjam/Bargarh/ Jharsuguda/Deoghar	Kanamona/Lambrupali/Lakhanpur + Tinkbir	XISS
8	Tamil Nadu - Erode	Tamil Nadu	Erode	Kathirampatti/Nanjanapuram/Manalmedu + Vannankattu Valasu	CEC
9	Karnataka	Karnataka	Belgaum	Hirenandi/Iddalhonda/Shiraguppi + Halaga	CEC
10	West Bengal	West Bengal	South 24 Parganas	Majher Para/Parbotipur/5 No. Gheri + Kanchantala	IRC

This study acknowledges that the 10 case studies completed to date represent a subset of the data. Thus, all conclusions drawn from the data available at the moment are assumptions that will need to be confirmed in further analysis, once the whole dataset is available. Much of the analysis has been conducted in a way which should make analysis of additional data trivial.

III.2 Parameters to assess service levels

III.2.1 Selection of individual parameters

In line with the service level approach, and with reference to Indian National Guidelines for drinking water referenced above, the CW+ project uses the six service level parameters shown in Table 4. Of these, one is not obtained from household surveys (water quality: testing).

Table 4 - Service levels for CW+ project (Smits et al., n.d.)

Service level	Quantity (lpcd)	Accessibility (cumulative time spent per day by the family on fetching water)	Water quality: perception	Water quality: testing	Continuity (hours/day)[5]	Reliability: piped supplies	Reliability: handpumps
High	> 80 lpcd	0-10 minutes per day	Good	All tested samples are within permissible levels	> 3	Supply above the agreed schedule and duration, and response time doesn't exceed 24 hours.	Response time is less than 24 hours and handpumps are down for not more than 12 days per year
Improved	60-80 lpcd	10-20 minutes per day			2-3	Supply above the agreed schedule and duration, and response time doesn't exceed 48 hours.	Response time is less than 48 hours and handpumps are down for not more than 12 days per year
Basic	40-60 lpcd	20-30 minutes per day	Acceptable		1-2	Supply according to an agreed schedule and duration and response time doesn't exceed 48 hours	Response time is less than 48 hours and handpumps are not broken down for more than 15 days per year
Sub-standard	20-40 lpcd	30-60 minutes per day	Bad	Tested samples are tested positive for one parameter	< 1	Supply has scheduled times, duration and delivery but this is not always met, or response time exceeds 48 hours	Response time is more than 48 hours or handpumps are broken down for more than 15 days per year
No service	< 20 lpcd	> 60 minutes per day		Samples are tested positive and the contamination levels are very high		Supply has scheduled times, duration and delivery but this is hardly ever met, or response time more than 2 weeks	Response time it more than 2 weeks or handpumps are broken down for more than 30 days per years

Other than 'water quality: perception' and 'continuity', each of the parameters is calculated from multiple questions in the household survey. For instance, asking how many litres per capita per day of water a household uses is both a complex question and unlikely to provide accurate data. The calculation of each parameter is as follows:

Quantity

Quantity of water is calculated in two different ways for individual household connections and communal supply. In the case of households connected to piped water supply, quantity is determined from the size of household storage, the time it takes to fill this storage, and the total time that water is available per day. In the case of households with continuous 24-hour supply, household storage was deemed irrelevant and a high service level for quantity was assigned.

For households with communal supply, e.g. standposts or communal wells, the total quantity is the number of pots fetched per day multiplied with the size of the pot. The overall quantity is then divided by the total size of the household to obtain the quantity in litres per capita per day (lpcd).

Accessibility

The indicator for accessibility is based on the cumulative time spent per day by the family on fetching water, in minutes. Household connections are classified as having a high service level, as the water is accessible at the house. For communal supplies, time spent per day is the product of the time taken per trip and the trips per day needed to fetch water.

Quality

In this study, the indicator for quality is based on the perceived water quality by the interviewee. The response 'good' corresponds to a high service level, 'acceptable' to a basic service level, while the response 'bad' gives a sub-standard service level.

Although perceived water quality is very important for the acceptance of water supply schemes (Rojas, 2013), no literature showing that it is a good proxy for chemical or microbiological water quality could be found. Water quality testing would be necessary to actually determine water quality and health risks arising from contamination.

Continuity

The indicator for continuity is only calculated for piped water supplies and is based on the amount of time in which water is available per day.

Reliability

For piped supplies, the indicator is based on the response time for repairs and the regularity of supply. For handpumps, the indicator relies on both repair response time for repairs and total downtime in the last year. Some respondents did not provide information on the response time for repairs, because the water source didn't have any breakdowns in the previous 12 months. In these cases, a high service level for reliability was assigned.

III.2.2 Creation of a composite indicator

In order to facilitate meaningful analysis of service levels, it is desirable to create a single 'overall service level' which captures the level of service received by a household. Aggregating multiple indicators is non-trivial and selection of the method used to combine indicators can have a significant impact on the service levels reported. When not designed and explained carefully, composite indicators can be unintelligible to policy makers and potentially provide a misleading picture of the data they are attempting to synthesise (Nardo et al., 2008).

In selecting a method there is a need to strike a balance between sophistication, ease of applicability by practitioners and ease of understanding by policy makers. Therefore heavily mathematical methods such as the various multivariate analyses were not considered. Several models were tested, the summary results of which can be seen in Figure 1.

The WaSHCost project used a form of nominal logic where 'the [overall] level of service accessed by a person is set by the level of the lowest individual indicator' (Moriarty et al., 2011). This method has the advantage of being intuitive and easy to understand. It also makes explicit the assumption that all parameters of service delivery are equally important to the overall service level. However, this aggregation does not give a composite picture of service level, as only a change in the lowest service level parameter is reflected in the overall score (Swamee & Tyagi, 2000). This method is shown in Figure 1 as 'Nominal'.

The first level of sophistication is to calculate overall service levels using the arithmetic mean of individual parameters. This was done by assigning a score (1-5) for each service level (no service to high) and averaging these scores. The average was rounded down to the nearest integer, and assigned to the relevant service level. Rounding down is preferred over conventional rounding as it gives an inherently conservative overall result. Using the arithmetic mean, a household achieving only a basic level of service in one parameter can still be classified as high overall in some scenarios, which is an undesirable result.

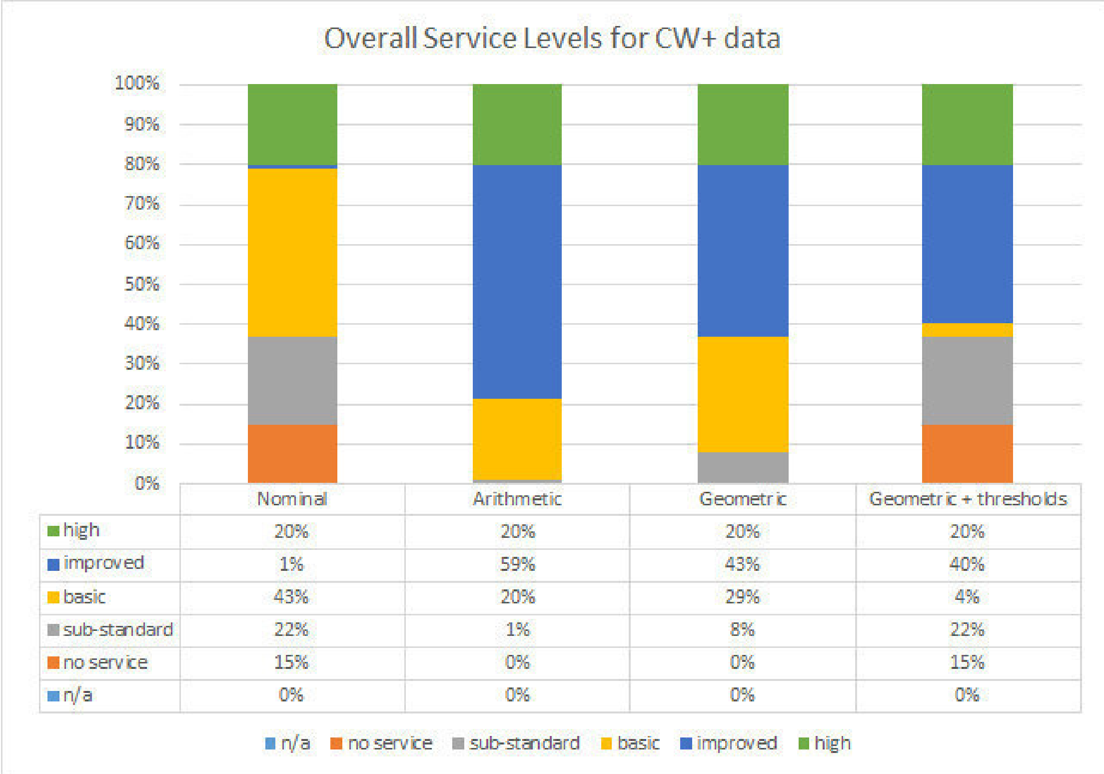


Figure 1 - Composite Indicators for CW+ Data

Consideration was given to weighting individual parameters to reflect their relative importance. Intuitively it appears obvious that parameters such as quantity and quality of water may have a bigger impact on end users in terms of health outcomes. A review of relevant literature failed to provide a robust basis for assigning weightings - the limited literature available is typically context specific, limiting general applicability. A conventional approach to assigning weightings in the absence of literature is to consult with 'experts' (Booysen, 2002). However, this is a relatively subjective method of assigning weights, and can lead to a distortion of the final composite indicator if one parameter is heavily weighted. Munda & Nardo (2005) showed that in a linear aggregation, weights have the mathematical meaning of trade-off ratios (that is, the extent to which a high score in one indicator can compensate for a low score in another); not the 'importance coefficients' (aiming to reflect the benefit of individual indicators to end users) they are often treated as in composite indicators.

Full compensability between parameters is a further drawback of the arithmetic mean, e.g. high reliability can compensate for a low quantity of water collected. This is undesirable if all individual parameters are equally legitimate (Garriga & Foguet, 2010). An approach using nominal logic would entail full non-compensability. Compensability has the effect of allowing utilities which perform poorly in a single parameter to nonetheless achieve a high overall service level. This is illustrated in Figure 1 ('Arithmetic') where nearly 80% of households are returned with a high or improved overall service level.

Where partial non-compensability is desired, the geometric mean (Equation 1) may be an appropriate aggregation method (Garriga & Foguet, 2010; Nardo et al., 2008; Swamee & Tyagi, 2000). It has been shown to be effective in aggregating measures of water quality (Landwehr and Deininger, 1976, cited in Swamee & Tyagi, 2000). It has the benefits of being relatively simple to understand and implement whilst generating results which are intuitive and predictable. In addition, with geometric aggregation an improvement in parameters with a low score will have a greater impact on the overall score than improvement in parameters with a high score. This provides an incentive to policy makers and service providers to address those parameters of service level which are weakest, before those which are comparatively strong (Munda & Nardo, 2005).

$$Geometric\ Mean = \sqrt[n]{a_1\ a_2\ \cdots a_n} \tag{1}$$

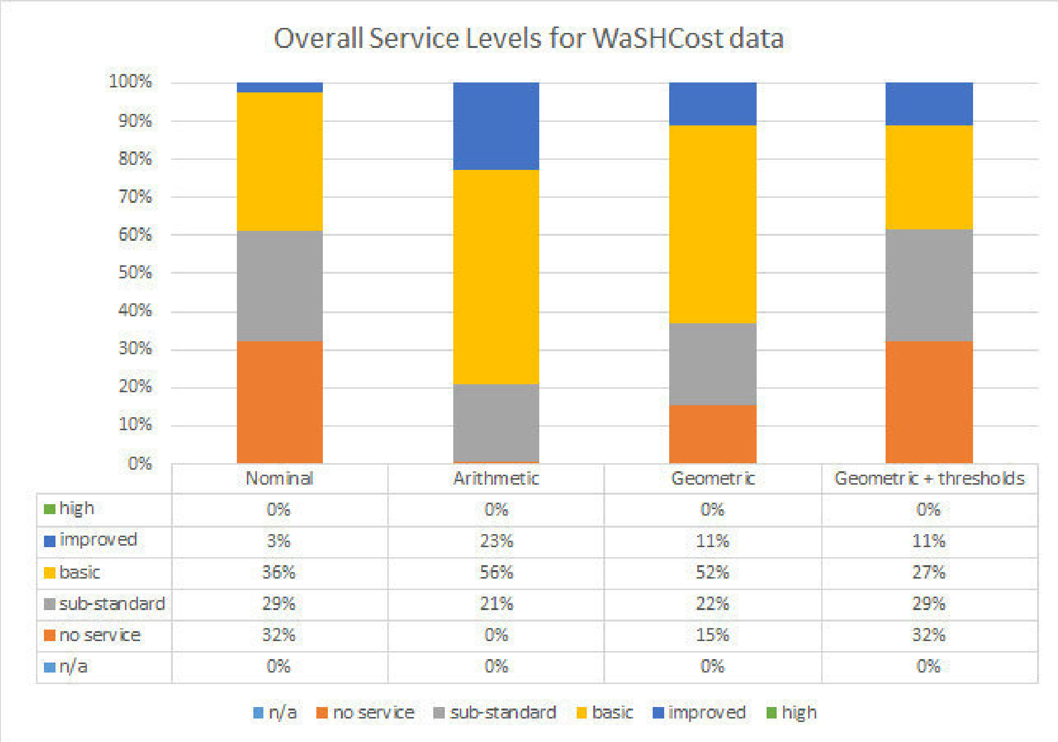
Overall service levels calculated by the geometric mean are shown in Figure 1 ('Geometric'). Whilst limiting the impact of compensability and eclipsing (where the composite indicator is insensitive to a single variable), it is apparent that the model overestimates overall service levels at the lower end of the scale. Despite 88 households scoring no service in at least one parameter and 129 scoring sub-standard, the overall indicator contains only 45 households scored as sub-standard.

To avoid this undesirable effect, the geometric mean was combined with various thresholds. In 'Geometric + thresholds' these are: if any single parameter is no service or sub-standard, the overall indicator cannot exceed this. This echoes the nominal logic employed by the WaSHCost project, and ensures that households where service is unacceptable for any single parameter cannot be given an overall service level which is acceptable. This means that a household with an overall service level of basic or above can be assumed to have access to water that meets or exceeds the JMP definition of improved, and relevant national standards.

Using this revised method has the effect of increasing the number of households receiving an improved service, and reducing the number receiving a basic service compared to using nominal logic. This results in a relatively small number of households (4%) with basic overall service. This appears small, but analysis of a larger dataset from the WaSHCost project[2] shows 27% of households returned a basic service - only a 9% reduction compared to nominal logic. All indicators described above are shown for this larger dataset in Figure 2. This suggests that there is no inherent bias in the aggregation method and the results are supported by the underlying data.

In all analyses carried out for this study, the method 'Geometric + thresholds' is used to create a composite indicator. In order to allow inter-village comparisons, the overall service levels were categorised as acceptable (basic, improved and high) or unacceptable (sub-standard and no service). This definition refers back to the normative standards set out in the national guidelines. This allows the results to be presented as a single figure for each village - i.e. X% of households access an acceptable water supply. This provides a reporting measure which is similar to that used by the JMP, but with higher standards, and a more sophisticated underlying understanding of the actual service provided.

[2] The WaSHCost data is a sample of 5232 households across Andhra Pradesh, with no distinction between 'control' or 'best practice' villages. More information on this project can be found at http://www.ircwash.org/washcost



	Nominal	Arithmetic	Geometric	Geometric + thresholds
high	0%	0%	0%	0%
improved	3%	23%	11%	11%
basic	36%	56%	52%	27%
sub-standard	29%	21%	22%	29%
no service	32%	0%	15%	32%
n/a	0%	0%	0%	0%

Figure 2 - Composite indicators for WaSHCost data

This method of aggregation is appropriate for this dataset and may be more widely applicable within the WaSH sector, but each implementation needs to be context-aware. For example, the Triple-S project in Ghana (Adank et al., 2013) used an overall indicator which counted the number of service level indicators which met the benchmark. Scoring basic or higher on each parameter corresponds to a basic service level, while failing one or more led to varying levels of sub-standard service. This is shown for CW+ in Figure 3.

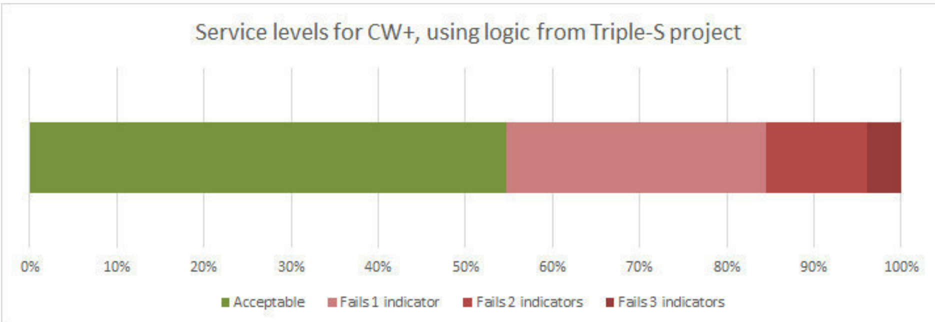


Figure 3 – Triple-S indicator for CW+ data

This provides greater granularity at the unacceptable service level, at the expense of insight into variations performance of acceptable services. In the context of CW+ - where there are many well-functioning systems delivering a good service - this compromise would not be appropriate. The authors independently came to a similar analysis of modes of failure when more than one parameter is unacceptable, which are discussed in chapter IV.1.1.

III.3 Data Quality

All data was systematically reviewed to ensure that it was of sufficient quality to be used for analysis. This quality check assessed the completeness, credibility and formatting of the submitted data.

Completeness

The following steps were taken:

- Largely incomplete data sets were excluded.
- Some data was returned to the field workers to complete some critical missing data needed for the analysis. Although this was not possible within the timescales of this project, it is important for the wider CW+ project.
- Superfluous data, not needed in calculation for certain water sources, was deleted.
- Where records were largely complete but lacked the data needed to calculate all service levels, the following logic was used: if no service level was returned for quantity (as this was deemed to be an essential parameter) or more than two other parameters, no overall service level was assigned.

Credibility

Data which was clearly incorrectly entered and where the correct answer was apparent, e.g. number of pots less than number of trips, was corrected. When assumptions were made, comments were added to specify how the data was interpreted. These corrections were sent back to the research teams as feedback.

Formatting

In several cases research teams had made alterations to the format of the survey worksheets. These were corrected to ensure all survey data was in the same format before analysis.

As a result of the work on data quality, the case studies were categorised as follows:

- Kutch-Gujarat (#6) and Tamil Nadu - Erode (#8): high quality data, needing only minimal cleaning, formatting and assumptions before analysis;
- Tamil Nadu - Dharmapuri (#1), Gandhinagar-Gujarat (#5), Odisha (#7) and West Bengal (#10): quite complete and usable data for analysis. Some data was entered incorrectly but right answers were quite apparent. Some assumptions were required, therefore the data had to return to the field researchers for clarification;
- Karnataka (#9): three habitations contain quite good and complete data whereas the remaining habitation was missing important data and could not be included for analysis.
- Jaipur (#2), Punjab (#3) and Jharkhand (#4): significant amounts of data were missing requiring further input from the field researchers before the data could be used for analysis. Currently too poor to use for analysis.

III.4 Identifying correlations between variables

A literature review was carried out to identify relationship hypotheses related to water services which could be tested using data from the survey. Both academic journal papers and 'grey literature' were reviewed to include as many experiences from the rural water sector as possible. Every relationship found in the literature was systematically inserted in a matrix (for a schematic of the matrix, see Figure 4). The matrix is a double entry table which links all variables from the survey.

The review focused on assessing the relationship between aspects of water service levels and influencing factors. Although the data potentially provides the opportunity to test links between socio-economic factors (such as education and income) this is not important in the context of the CW+ project. To complete the relationship matrix, a systematic review of every possible link was carried out by the group to assess whether it should be tested. This resulted in a total of 250 hypotheses being identified. The full matrix is available as Annex 1.

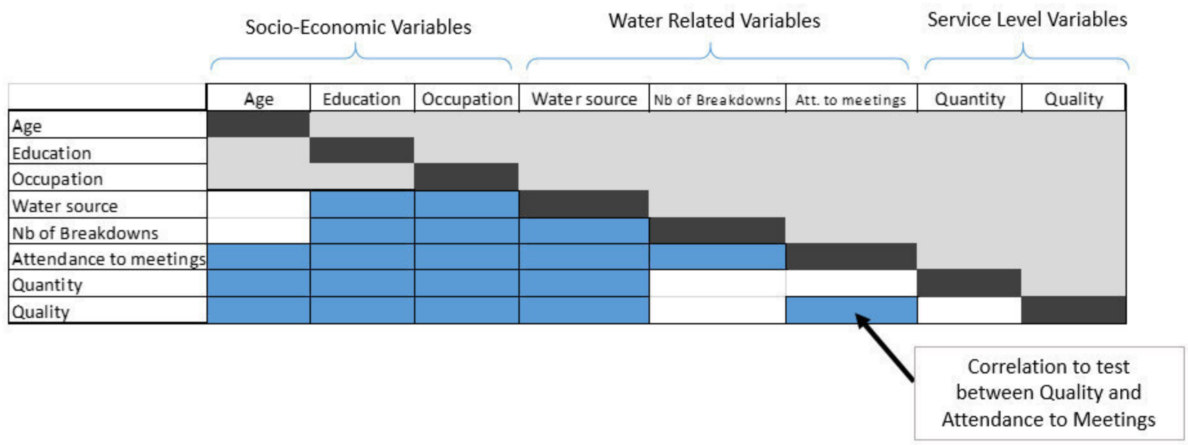


Figure 4 - Schematic of hypotheses matrix

III.5 Statistical tests used

Data from the survey comes in three different data types which need to be analysed differently:

- Nominal data, such as religion, forms distinct categories but cannot be ordered in a meaningful way.
- Ordinal data, such as service level, is also given in distinct categories, but has a clear order. 'High' corresponds to better service than 'improved', likewise 'no service' denotes worse service than 'sub-standard'. The differences between these categories however are not defined and cannot be treated as equal.
- Interval data, such as household income, is measured on a scale with equal intervals. The difference between INR 1000 and INR 1200 is the same as between INR 2500 and INR 2700 (Vaus, 2002).

Generally, statistical tests are used to assess:

1. whether there is a difference in the mean between two groups of one variable, such as comparing income between best practice and control villages
2. whether one variable is dependent on one or more other variables, for example the correlation of total household income and overall service level

For the first question, two tests are generally used. The independent sample *t*-test is used if the variable is measured on an interval scale and the data is normally distributed. If data is not normally distributed or measured on an ordinal scale, the Mann-Whitney *U*-test is used to determine differences of the median between groups (Sirkin, 2006).

To measure the association between two variables on a nominal scale, Cramer's *V* is used. It is based on the chi-square distribution and ranges from 0 to 1, where a value of 0 means there is no correlation and a value of 1 describes a perfect association (Field, 2013).

For ordinal variables, Kendall's *tau-b* (τ_b) is used for square, Kendall's *tau-c* (τ_c) for rectangular contingency tables. Kendall's *tau* is the preferred measure because it explicitly adjusts for ties (Field, 2013; Sirkin, 2006).

Association between two interval or one interval and one ordinal variable can be measured by correlation coefficients. The Spearman's correlation coefficient *r* describes the strength of a linear relationship between two variables. It is one of the most widely used measures of correlation, but highly sensitive to outliers and does not capture non-linear associations between variables (Vaus, 2002). If interval data contains outliers or the data is measured on an ordinal scale, Spearman's *rho* (ρ) is used. In addition *rho* has the benefit of showing the strength of any monotonic, but not necessarily linear, association. For the correlation of data containing a high number of tied ranks, i.e. a lot of identical values on at least one variable, Kendall's *tau* is used instead (Field, 2013).

To test if the calculated effects are due to chance or sampling errors, inferential statistics are used. A *p*-value is calculated which describes the probability of obtaining the result if the null hypothesis is true. The null hypothesis is that there is no relationship between the variables or no difference between the groups. A *p*-value of less than 0.05 is considered significant, whilst a value of less than 0.01 is considered highly significant (Coolican, 2009).

The analysis was conducted in IBM SPSS 22, after data had been imported from the MS Excel database. The raw data and SPSS syntax for the data import and analysis are available upon request.

The strength of correlations is classified according to Table 5 and is valid for positive or negative coefficients.

Table 5 - Strength of associations (Field, 2013)

Correlation Coefficient	Interpretation
<0.1	Negligible effect
0.1-0.3	Small effect
0.3-0.5	Medium effect
>0.5	Large effect

IV Results

IV.1 Descriptive Statistics

IV.1.1 Water service levels

A total of 807 households were included in the analysis of the data, out of circa 1200 households originally surveyed.

Table 6a to c show the service levels calculated for each of the five individual parameters and the overall service level, split for best practice and control villages. This only includes the primary water source in summer, for reasons discussed below. Although best practice villages are clearly differentiated from control in terms of household receiving an acceptable service (60% vs 34%), 40 % of best practice households receive an unacceptable service.

Table 6a - Service levels for entire dataset

Service Level	Quantity	Accessibility	Quality	Continuity	Reliability	Overall
high	43%	74%	91%	27%	75%	**15%**
improved	9%	4%	0%	0%	14%	**34%**
basic	13%	6%	8%	68%	0%	**4%**
sub-standard	14%	10%	2%	5%	9%	**21%**
no service	21%	7%	0%	0%	2%	**26%**

Table 6b - Service levels for best practice villages

Service Level	Quantity	Accessibility	Quality	Continuity	Reliability	Overall
high	48%	84%	94%	31%	79%	**20%**
improved	9%	3%	0%	0%	14%	**37%**
basic	11%	4%	4%	63%	0%	**2%**
sub-standard	14%	8%	1%	6%	7%	**21%**
no service	19%	2%	0%	0%	1%	**19%**

Table 6c - Service levels for control villages

Service Level	Quantity	Accessibility	Quality	Continuity	Reliability	Overall
high	28%	40%	80%	16%	66%	**1%**
improved	11%	6%	0%	1%	15%	**25%**
basic	20%	13%	19%	82%	0%	**7%**
sub-standard	15%	19%	2%	2%	15%	**22%**
no service	27%	22%	0%	0%	4%	**45%**

Best practice villages clearly outperform control villages in each parameter with the exception of continuity and quality. The lack of differentiation in quality service levels may be due to the fact that this measure is only perceived quality, and results may not reflect actual water quality measures. Continuity is only applied to piped supplies and the threshold for 'basic' is relatively low (only one hour of supply per day). It is likely that where the capital finance is in place to construct a piped water scheme, regardless of any other supporting factors the system is capable of supplying water for at least some time every day.

Overall, 47% of households receive an unacceptable service. This contrasts strongly with the results of applying the JMP definition of 'improved/unimproved' to the dataset: only 1.7% of households (14 records) access an unimproved source. The most common failure point is quantity - 74% of households with an unacceptable service access less than 40 lpcd. This suggests that even where households access an improved source, such as a handpump, they are unable to collect enough water to meet minimum standards.

In best practice villages, 57% of households receive at least 60 lpcd of water (an improved service level). This maps approximately to the Indian norm for drinking water from 2017 onwards which is 55 lpcd. This suggests that where successful piped water supplies are implemented, they exceed existing norms, and provide sufficiently high service to meet future targets.

A further disaggregation by case study, best practice/control and summer/non summer is shown in Figure 5 below, using the categorisation of acceptable or unacceptable services.

The chart clearly shows that in every case study except Karnataka and West Bengal, best practice villages receive significantly better services than control villages, largely vindicating the choice of villages for the study. It should be noted that the concept of best practice can be relative - the best practice villages in Tamil Nadu (Dharmapuri) receive worse service than the control village in Gujarat (Gandhinagar). The West Bengal case study is discussed in more detail below.

Figure 5 - Overall service levels by case study

Seasonality

In all cases bar two (Tamil Nadu, Erode and Odisha) there is no difference between the service levels in summer and non-summer. In Odisha this is a single household. In Tamil Nadu, Erode, the difference is due to continuity for piped supplies being worse in summer than non-summer. This does not affect all households and is largely in a single village (Manalmedu). In the analysis which follows, only data for summer has been used as for the majority of households there is no difference. Where there is a difference, by using summer data only the analysis is conservative (i.e. it always returns the lowest service level).

Main source only

Excluding West Bengal (again as discussed below) only 55 households (8%) use a secondary water source. All 55 use a piped supply as the primary source, and complement this with an alternative source. 27 of these households are in a single case study (Gujarat, Gandhinagar) and use bottled water in addition to household connections. Applying the service level framework to bottled water results in no service due to the very low quantities purchased. This is understandable – the thresholds used for service levels reflect all domestic water use, not just drinking water. This may underestimate the value of bottled water in some scenarios: both the MDGs and SDGs class bottled water as an improved source if households use a basic water source for other domestic purposes (JMP, 2015), as is the case here.

It should also be noted that there is no generally accepted method of aggregating service levels across multiple sources. Due to the limited number of households using multiple sources in this dataset, the focus of analysis is on the main water source only.

Failure on multiple parameters

Out of 366 households which receive an unacceptable service, just over one third fail on multiple parameters, e.g. quantity and accessibility. These multiple modes of failure are important for understanding the limiting factors when seeking to improve services for communities. Figure 6 shows failure modes for all households that receive insufficient quantities of water.

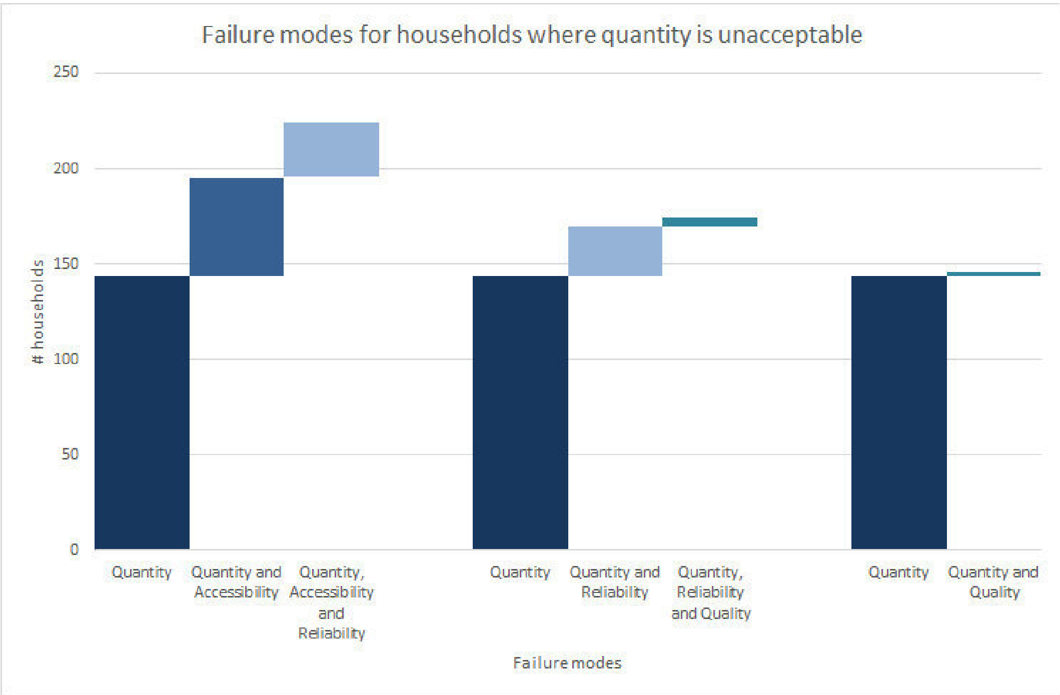


Figure 6 - Failure on multiple parameters

This illustrates that simply improving quantity will not help all households which receive insufficient quantity: 45% of these fail on at least one additional parameter. In these cases improvements would also have to be made to accessibility, reliability and quality. This is a relatively simplistic way of looking at improvements to services - moving from a handpump to a piped supply will improve both quantity and accessibility. But it may still be a useful tool for policy makers to understand why services are failing and the potential impact on service levels of different investment options.

West Bengal

The West Bengal case study shows 100% of households with an unacceptable water supply. This is because all households collect very small quantities of water from boreholes as drinking water, with an unknown quantity of water collected from open sources for bathing and domestic use. In each household, the quantity collected is below the threshold for no service. In 24 households, the service level for accessibility or reliability is also assessed as no service (46% of these households are in the control village).

The very low quantity collected can be linked to the technology used and local hydrogeological conditions - the boreholes are fed from a very deep aquifer, up to 300m below ground level in some areas (Mukherjee & Fryar, 2008), which is severely restricted in yield. This case study stands in marked contrast to all the others, as all households receive unacceptable service. Including this case study in the analysis of factors affecting overall service levels is likely to skew results - the factors affecting service level are dominated by hydrogeological factors which it is not possible to control for. For this reason, West Bengal has been excluded from much of the further analysis.

However, it is interesting to note that reported incomes in the West Bengal are significantly lower than in other case studies. This links with the idea that underlying wealth is a key 'building block' in community managed water supplies (Hutchings et al., 2015). In West Bengal the underlying wealth is insufficient to provide access to acceptable supplies given the local conditions.

IV.1.2 Socio-economic description of the data

A total of 807 households in five Indian states are included in the analysis. Table 7 below gives a socio-economic description of the sample.

Table 7 - Religion, caste and income of surveyed households

	Best Practice		Control	
Education				
	Male		**Female**	
Illiterate	24%	35%	23%	44%
1st to 5th class	20%	23%	18%	14%
6th to 10th class	35%	32%	42%	29%
Intermediate	12%	5%	6%	7%
Degree and higher	9%	4%	11%	6%
Religion				
Hindu	94.9%		85.4%	
Muslim	4.8%		14.6%	
Christian	0.3%		0.0%	
Caste				
BC	34.6%		32.4%	
MBC	12.9%		1.7%	
OBC	2.6%		0.6%	
OC	20.7%		18.2%	
OTHER	9.5%		14.8%	
SC	15.5%		31.8%	
ST	4.3%		0.6%	

	Best Practice	Control
Annual household income (INR)		
Mean	86,721	90,315
Median	60,000	50,000
Maximum	560,000	1,200,000
Minimum	1,500	10,000
Standard Deviation	89,632	123,551

IV.2 Statistical analysis

Using the hypotheses identified in the previously described relationship matrix, IBM SPSS 22 was used to test if significant correlations are present. Initially all analyses were conducted at an individual household level, for example testing whether or not there is an association between the type of water source used by a household and the caste it belongs to. The results yielded by this approach are shown in Annex 2, 9 out of 14 relationships showing some level of correlation.

In seeking to explore the underlying reasons for these relationships, it becomes apparent that in many cases, the correlation can be shown to be based on a false premise: due to the often homogeneous nature of villages, by proxy any relationship is not on an individual, but on a village level. This is illustrated by the relationship between caste and household connections. The analysis showed that there was a correlation between caste and the water source used (Table 8), suggesting that households belonging to marginalised castes (SC and ST) are discriminated against in access to household connections.

Table 8 - Caste by water source crosstabulation

Caste		**Water Source**		**Total**
		Household Connection	Other Water Sources	
OC	Count	69	20	89
	%	77.50%	22.50%	100.00%
BC and MBC	Count	293	43	336
	%	87.20%	12.80%	100.00%
SC and ST	Count	84	88	172
	%	48.80%	51.20%	100.00%
Other	Count	45	115	160
	%	28.10%	71.90%	100.00%
Total	Count	491	266	757
	%	64.90%	35.10%	100.00%

However, subsequent exploration of the underlying data revealed that almost all villages have either only household connections or only use other water sources. This means that in these villages there is no discrimination against specific castes, as everybody is using the same source type. Also, villages are mostly homogeneous in respect to caste. Therefore, the conclusion that marginalised castes in a village are less likely to have a household connection cannot be considered valid, as the table above basically compares entire villages with each other. Further inspection revealed that only one village, Hirenandi, actually shows heterogeneity in regards to source type and caste. This village was tested separately, and no connection between caste and source type could be found.

In light of these findings, the main focus was moved away from testing every relationship identified in the matrix towards analysing data on a village level. As described in chapter IV.1.1, a percentage of households receiving at least basic service on each parameter and overall was calculated for each village. This way, villages could be compared to each other, results of which are shown in Table 9.

With the caveats described above, some tests on a household level were still considered to yield meaningful results and are shown in Table 10. The most relevant results are discussed below.

Table 9 - Analysis results on village level

#	Relationship	Context	Interpretation	Statistical Test	Significance
1	Median Village Income vs. Overall	Best Practice	Significant, strongly positive	ρ=0.770	p<0.001**
		Control	Not significant	ρ=-0.631	p=0.129
2	Median Village Income vs. % HH connections	Best Practice	Highly significant, strongly positive	τ_b=0.508	p=0.004
		Control	Not significant	τ_b=-0.309	p=0.347
3	% Pucca Houses vs. Overall Service Level	Excl. WB	Highly significant, strongly positive	ρ=0.689	p<0.001**
4	% Medium and Distant Households vs. Accessibility		Not significant	τ_b=0.185	p=0.220
5	% Medium and Distant Households vs. Quantity		Not significant	ρ=-0.007	p=0.971
6	% Medium and Distant Households vs. Overall	Excl. WB	Not significant	ρ=0.087	p=0.667
7	% Religious Minorities vs. Overall	Excl. WB	Not significant	ρ=0.059	p=0.788
8	% Religious Minorities vs. % HH connections	Excl. WB	Not significant	τ_b=0.011	p=0.950
9	% SC/ST vs. Overall	Excl. WB	Not significant	ρ=0.084	p=0.702
10	% SC/ST vs. % Household connections	Excl. WB	Not significant	τ_b=-0.172	p=0.254
11	Mean Tariff vs. Overall		Not significant	ρ=0.089	p=0.667
12	Mean Tariff vs. Median Village Income		Not significant	ρ=0.310	p=0.123
13	Mean Tariff vs. Reliability	>80% HH connections	Not significant	τ_b=0.222	p=0.262
14	% Land ownership vs. Overall		Not significant	ρ=0.002	p=0.992

Table 10 - Analysis results at household level

#	Relationship	Context	Interpretation	Statistical Test	Significance
1	Houshold income between Water Source	Villages with more than 10% in both categories	Highly significant	Mann-Whitney U=2608.5, n=178	p<0.001**
2	Household income vs. Overall Service Level	Best Practice, excl. WB	Highly significant, weak	τ_b=0.143	p<0.001**
		Control, excl. WB	Highly significant, weak	τ_b =-0.205	p<0.001**
3	Water Source vs. Overall		Highly significant, strong	τ_b =-0.678	p<0.001**
4	Water Source vs. Quantity		Highly significant, strong	τ_c=-0.608	p<0.001**
5	Water Source vs. Quality		Highly significant, weak	τ_c=-0.146	p<0.001**
6	Water Source vs. Reliability		Highly significant, weak	τ_c=-0.192	p<0.001**
7	Satisfaction vs. Overall		Highly significant, weak to moderate	τ_c=0.264	p<0.001**
8	Satisfaction vs. Quality		Highly significant, moderate to strong	τ_b=0.492	p<0.001**
9	Education vs. Water Committee Membership	Villages with 2 or more Water Committee members	Significant, weak	τ_c=0.099	p=0.023

#	Relationship	Context	Interpretation	Statistical Test	Significance
10	Supply duration vs. Overall	Intermittent vs. Continuous for HH-conn.	Highly significant, strong	τ_c=0.682	p<0.001**
11	Storage vs. Overall	HH-connections w/ intermittent supply	Highly significant, moderate to strong	τ_b=0.445	p<0.001**
12	Storage vs. Household Income	HH-connections w/ intermittent supply	Significant, weak	ρ=0.125	p=0.011*
13	Storage vs. Supply Duration	HH-connections w/ intermittent supply	Highly significant, moderate	ρ=-0.331	p<0.001**
14	Supply Duration vs. Overall	HH-connections w/ intermittent supply	No correlation	τ_b =0.009	p=0.841
15	Household size vs. Quantity	Other water sources	Significant, weak	τ_b=-0.128	p=0.009**
		HH-connections	Significant, weak	τ_b=-0.117	p=0.001**

V Discussion

V.1.1 Income and service levels

Median village incomes and the overall service level in a village are not significantly correlated if all villages are analysed together. However, when best practice and control villages are analysed separately, a highly significant, strongly positive correlation can be found for best practice villages, as shown in Figure 7. This can be interpreted as showing that underlying wealth is necessary for improving service, but it is not enough alone. An enabling environment, as present in the best practice villages, is also necessary to achieve high service levels, which confirms earlier studies by Hutchings et al. (2015).

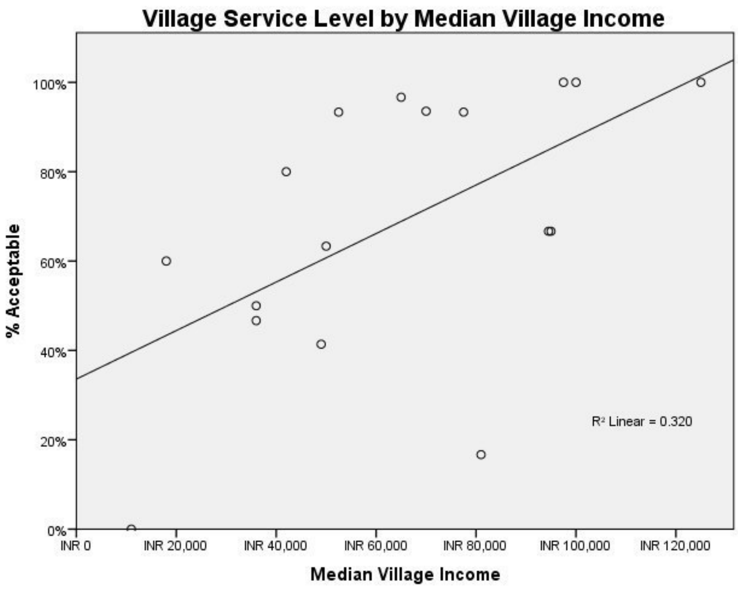


Figure 7 - Village service level by median village income for best practice villages

Individual household income is found to be significantly, but much more weakly, correlated to the service level a household receives. This can be interpreted as showing that communal wealth is more important for the overall service levels, which is understandable as community managed water supply schemes are run on a communal scale. Furthermore, for best practice villages, there is a significant, strongly positive correlation between median village income and the percentage of household connections in a village. This corroborates the hypothesis that communal wealth is a highly important factor for successful provision of water supply services on a village level.

V.1.2 Income and water source- household level

Income was compared between households with household connections and those using other water sources. For this comparison, only villages where multiple water sources are used, with at least 10% of households accessing each type of source, were included. There is a statistically significant difference in median annual household incomes between the users of household connections (INR 41,000) and other water sources (INR 30,000), shown in Figure 8. However, this difference is quite small, suggesting that, for the poorest, a small increase in income can have a big impact on the service received. This agrees with findings by Fonseca (2014), who found that in Mozambique, the poorest and poor use handpumps, while the least poor receive piped water. The least poor in the mentioned study are still around the national, and well below the international, poverty line.

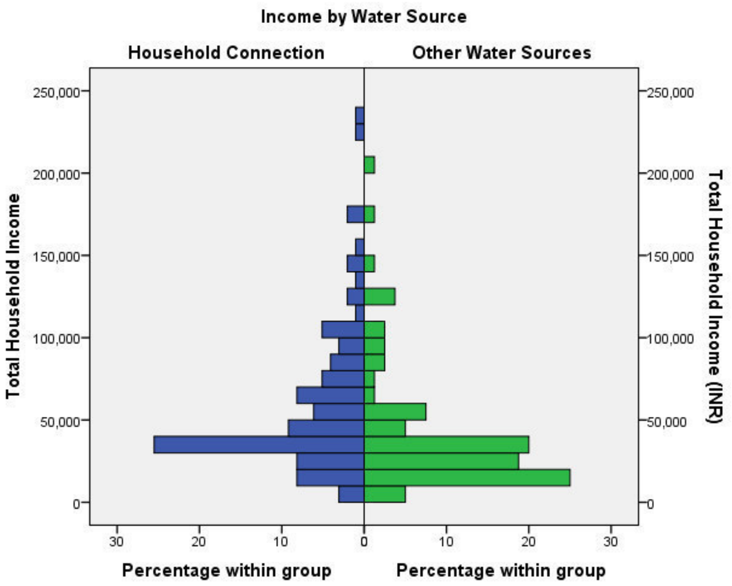


Figure 8 - Median income of users of household connections and other water sources

V.1.3 House type and water source

The percentage of pucca houses, which are higher-quality houses constructed from materials such as concrete, is strongly positively correlated to the percentage of household connections in a village, as shown in Figure 9. This result was expected and could be explained by villages with a high percentage of pucca houses being more formally planned and having better overall infrastructure. This corresponds to results by Jalan & Ravallion (2003), which identified that pucca households are more likely to have access to piped water.

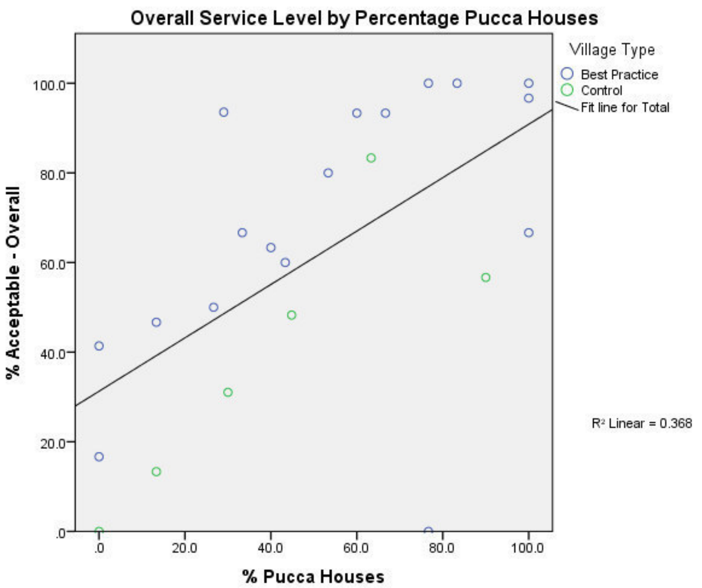


Figure 9 - Village service level by percentage pucca houses

V.1.4 Water source and overall service

Looking at overall service levels, household connections score significantly higher than other water sources. As shown in Table 11, point sources provide acceptable service to only 15% of their users, compared to 72% for household connections. More than two thirds of point source users receive the lowest level of no service, compared to 5% for household connections. This clearly shows the importance of household connections for the service users receive. This result is reflected in the proposed SDG 6.1, which aims at providing a drinking water source that is located on premises (JMP, 2015).

Table 11 - Overall service level by water source

	No service	Sub-standard	Basic	Improved	High
Household Connection	5%	23%	3%	47%	22%
Other Water Sources	68%	18%	5%	8%	2%

V.1.5 Water source and quantity

Comparing household connections and other water sources, there is a significant difference in the quantity parameter. As shown in Figure 10, 58.7% of users of household connections and only 10.9% of users of other sources receive high service in respect to quantity. 70.7% of users of other water sources receive unacceptable quantities of water. A study of service levels of point sources in Uganda came to similar conclusions, with only one third of users fetching the national standard of 20 lpcd (Bey et al., 2014; Magara, 2014).

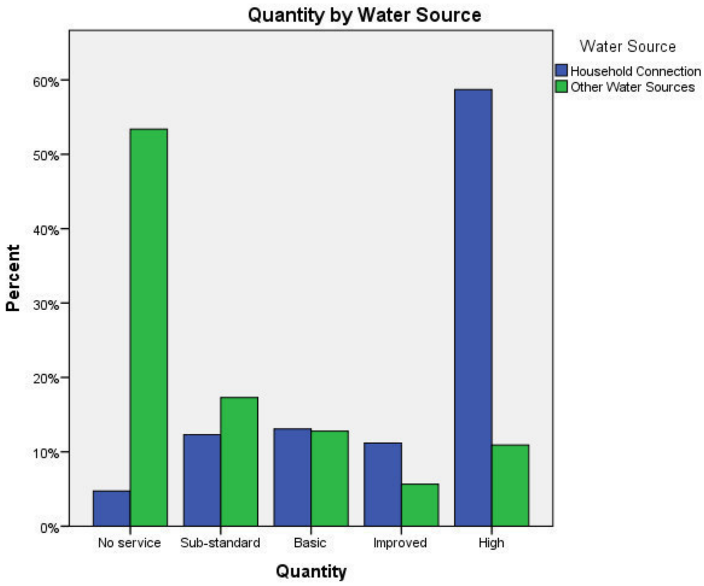


Figure 10 - Quantity by water source

V.1.6 Water source and quality

There is a significant difference in perceived water quality between users of household connections and other water sources. 96.1% of household connection users consider their water quality 'good', compared to 79.4% in the other source group. However, there is no significant difference in the percentages for 'bad' water quality (1.3% for household connections vs. 2.2% for other water sources). This difference is supported by a study by Brown et al. (2013), which shows a significant difference in the water quality of on-plot piped water compared to other sources, even if they are 'improved' according to JMP. The health benefits of piped water have been confirmed by several other studies (Gamper-Rabindran et al., 2010; Gélinas et al., 1996; Jalan & Ravallion, 2003). However, a severe limitation of this study is that only data on perceived water quality is available. Without water quality testing, no informed assessment of the seemingly low percentages of 'bad' water quality for all sources can be made.

V.1.7 Water source and reliability

Household connections score significantly higher on the reliability parameter than other water sources. 81.3% of household connections have high reliability scores, compared to 61.9% of other water sources. In the analysed sample, 23.7% of the other water sources fail to provide acceptable service in respect to reliability, a figure that is similar to reported percentages of handpump non-functionality (Kleemeier, 2010; RWSN, 2009). However, it needs to be added that the reliability parameter used in this study is a perceived measure, as it is only derived from asking respondents how many times their water supply had broken down in the last year and how long it took to repair breakdowns.

V.1.8 Supply duration for household connections

Comparing users of household connections that receive 24-hour supply to those receiving intermittent supply, there is a highly significant difference in overall service levels. 97.5% of the continuous supply group receives high overall service, while not a single household in the intermittent supply group reaches that level. The extremely high percentage for the continuous supply group is somewhat expected, as these users are assigned a high quantity automatically and by definition receive high scores for continuity.

The results for the intermittent supply group are more interesting however. As shown in Table 12 below, not a single household receives a high overall service level. While a large proportion reaches an improved overall service level, more than a third receive an unacceptable overall service. The table shows the generally low scores on continuity, resulting from many households with a supply duration of one to two hours. It also shows the impact intermittent supply has on the quantity users receive, even if they have household connections.

Table 12 - Service levels for household connections with intermittent supply

	No service	Sub-standard	Basic	Improved	High
Quantity	6%	16%	17%	14%	47%
Quality	0%	2%	3%	0%	95%
Accessibility	0%	0%	0%	0%	100%
Continuity	0%	8%	86%	0%	6%
Reliability	0%	6%	0%	17%	77%
Overall Service Level	**6%**	**29%**	**4%**	**61%**	**0%**

V.1.9 Household connections with intermittent supply

For households that have a household connection, but no continuous 24-hour supply, the overall service level is correlated moderately to strongly to the size of household storage. While this might seem obvious, it is still an important result, as it shows that even in schemes that provide household connections, individuals are forced to rely on coping strategies to reach high service levels, which agrees with findings by Zérah (2000) and Whittington et al. (2002). This is further supported by the moderately negative correlation of the supply duration per day and the size of household storage. The supply duration per day is not correlated with the overall service level, which again supports the assumption that households develop strategies to cope with intermittent supply. The size of household storage is only weakly correlated with household income, which means that poorer households still invest in water storage to some extent.

V.1.10 Household size and quantity

A study of point water sources in Malawi by Shaw (2014) found a correlation between the household size and quantity of water available per person. For households using point sources, the CW+ dataset also shows a weakly negative correlation, confirming the experience from Malawi. In the CW+ data, this correlation also exists for users with household connections. This suggests that as household size grows, the overall quantity available to the household does not increase proportionately.

V.1.11 Caste, religion

On a village level, there is no significant correlation between the percentage of scheduled castes and tribes or the percentage of religious minorities and the overall service level in a village. This shows that the case studies selected for the CW+ project provide an equitable service, even to villages with a high percentage of marginalised groups.

V.1.12 Tariff

No correlation could be found between the average tariff paid in a village and the overall village service level. In villages with a majority of household connections, the average tariff paid is not correlated to reliability either. Because tariffs are mostly set at levels well below cost recovery for operating expenditure, much less bigger capital maintenance costs (Cardone & Fonseca, 2003; Fonseca & Njiru, 2003), the tariff does not influence service levels, as funding and support needs to come from other sources. For example, in one case study the cost of producing bulk water is INR 93 per m^3, while the cost charged to the community is only INR 3 per m^3 (Hutchings, 2015). The average tariff paid is not correlated to the median village income either, which might show that tariffs are arbitrarily set by water committees and do not correspond to the ability or willingness to pay in a village. Information on ‘community service provider performance’ collected by the CW+ project would help to understand this issue further.

V.1.13 Education of water committee members

Analysing villages where more than one respondent is part of the water committee, education levels of water committee members and non-members are found to be significantly different. 19.6% of water committee members have a degree or postgraduate degree, compared to 7.6% of non-members. The illiteracy rate is 25.4% amongst non-members, compared to 15.2% amongst members. This might suggest that communities exercise discretion in electing committee members who possess the skills needed for the committee to function effectively. This is potentially interesting in the light of models of increasing professionalisation of community management (Hutchings et al., 2015), but the result needs greater contextual information to draw any meaningful conclusions.

V.2 Limitations of the study

V.2.1 Limited number of case studies

The results shown above were obtained with only a subset of the whole CW+ household survey data and should therefore be seen as indicative results that still needs to be confirmed with the complete data as it becomes available.

V.2.2 Survey design

The original aim of the household surveys was only to assess service levels, and not a full-scale analysis of factors affecting it. The aim of this project was to explore to what extent this limited survey design could be used for exploring factors behind success in delivering water services. While a lot of interesting results could be obtained, the authors believe that the level of analysis conducted is at the limit of what is possible using this data.

V.2.3 Assumptions made to assess service levels

In order to assign service levels to households in some cases assumptions were made as to the service received. These were:

- that a 24-hour household connection always provides high quantity;
- that a household connection always equates to high accessibility.

Whilst defendable, these assumptions do limit the scope of analysis that can be performed in relation to household connections. For example, assuming high accessibility does not recognise that there are differing levels of household connections: from a single tap in a yard used to fill several pots, to multiple taps within the dwelling. The data collected did not allow disaggregation on this level. Recording and understanding the difference in service received by these users may not be significant when comparing to users of communal sources, but will be increasingly important as users demand household connections and further differentiation is needed.

V.2.4 Limits of household surveys

Information on many factors affecting water supply services can simply not be obtained from household surveys. As this study was limited to household survey data, it would need to be complemented by additional research in order to include wider issues such as the support environment, government involvement or further information on the water committees. This additional information could come from interviews with key informants, administrative data or focus group discussions and would enable a triangulation of information.

VI Conclusion

This study provided an insight into the first tranche of household survey data collected in the CW+ project. Even though some issues with data quality, completeness and credibility were encountered, the majority of data could be used for further analysis.

The water service each household receives was assessed on five parameters: quantity, quality, accessibility, reliability and continuity. To combine these individual parameters into one overall service level, a composite indicator consisting of a geometric mean with thresholds was created. In the authors' opinion, this composite indicator gives a meaningful and nuanced picture of the overall service level a household receives. This approach is relatively simple and has the potential to be applied more widely in the WaSH sector. Using this overall indicator of service, 53% of households were shown to receive an 'acceptable service' - that is meeting Indian national standards for drinking water. In total, 15% of households received a 'high' level of service.

To find determinants of success, hypotheses showing possible associations between variables were identified through a literature review. Out of these, 29 were tested and 17 showed a statistically significant correlation. In the course of the analysis, the main focus was shifted from analysing data on a household level towards the village level, as seemingly relevant correlations on the household level were often found to be caused by a homogeneity of variables in single villages.

The most important results are that service levels are only weakly correlated to income on the household level, but strongly correlated to median income on the village level. This is interpreted as showing the importance of underlying communal wealth in providing water services. Household income levels do play a key role in the sense that users of household connections and point water sources show a statistically significant difference in income. However, this difference is quite small and at the lower end of the income spectrum, suggesting that, for the poorest, a small increase in income can have a big impact on the service received.

During the analysis, the immense difference in service levels between private household connections and other water sources became apparent. Household connections were found to be the only way of achieving high service levels, both overall and especially in respect to quantity. The superiority of household connections is confirmed by several studies and is reflected in the proposed indicator for SDG target 6.1 of providing 'a basic drinking water source which is located on premises'. The analysis also showed that just having a household connection is not enough, as users with a household connection with intermittent supply received significantly lower service levels. Therefore, the aim should be providing household connections with continuous 24-hour service.

The analysis also demonstrated that even sources that are classified as 'improved' according to the MDG definition often deliver unacceptable service. Looking at the main source used by households, only 1.7% (14 households) could be classified as 'unimproved' under the JMP definition. This contrasts with 47% of households receiving an 'unacceptable' level of service using the CW+ service ladder, mostly due to the insufficient quantities supplied by, and the poor accessibility of point sources. This strongly suggests that the JMP definition provides an unrealistically positive picture of access to drinking water.

In the analysed dataset, no correlations between the percentage of scheduled castes and tribes or religious minorities and the service level in a village could be found. This shows that in the selected case studies, the service providers succeed in delivering equitable water services to all villages surveyed.

The limitations of this study are mainly due to the fact that only part of the whole CW+ household survey dataset was available. Therefore findings from this study are not necessarily representative of other regions and should be confirmed with additional studies when all data is available. Furthermore, due to the limited scope of this study, only household survey data was used, while additional contextual data would be needed to assess many factors affecting water service delivery. In particular, where this study has identified significant correlations, contextual data is necessary to understand the underlying causes. Such data is being collected as part of the wider CW+ project.

Despite these limitations, this project has demonstrated that it was possible to conduct significant analysis using the available household survey data.

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Annex 1: Hypothesis matrix

	Habitation	Revenue Village	Gram Panchayat	District	Location house/source	Type of house	Religion	Caste	Land ownership	Ration card	Sex	Age	Education	Occupation	Income	HH size	No male	No female	No children	No elderly	No disabled	Water source	Water fetcher	Perception of quality	Satisfaction	No breakdowns	Time taken for repairs	Clear who to complain	Ever complained	Water tariff per month	Amount of tariff	Add payment for repairs	Family part of W com	Meeting exisiting	Attendance to meeting	Awareness campains	Attendance to trainings	Attendance to awareness c.	Quality	Continuity	Quantity	Accessibility	Reliability
Habitation																																											
Revenue Village																																											
Gram Panchayat																																											
District																																											
Location house/source																																											
Type of house																																											
Religion																																											
Caste																																											
Land ownership																																											
Ration card																																											
Sex																																											
Age																																											
Education																																											
Occupation																																											
Income																																											
HH size																																											
No male																																											
No female																																											
No children																																											
No elderly																																											
No disabled																																											
Water Source					30										25																												
Water Fetcher																																											
Perception of Quality													1																														
Satisfaction																						2																					
No Breakdown																																											
Time taken for repairs																																											
Clear who to complain																																											
Ever complained																																											
Water tariff per month					28								8		4	23						38		27		4 29	4																
Amount of tariff															4									27																			
Add payment for repairs													8		4							38				4 29	4																
Family part of water com								40					42																	5 21 26													
Meweting existing																																											
Attendance to meetings								40					20 42	35	20	10 33			10											5 21 26													
Awareness campaigns																																											
Attendance to trainings								40					20 42	35	20	10 33																											
Attendance to awareness c.								40					20 42	35	20	10 33																											
Quality													1																	27 32													
Continuity																																											
Quantity					7 22								6		6	13 18									1																		
Accessibility																						30																					
Reliability															4																												

References for hypotheses

1	Magara, 2014
2	Pedi & Touch, 2010
4, 5	Schweitzer, 2013
6, 15	Dave et al., 2011
7, 13	UNICEF, 2009
8, 9, 10, 11, 12	Sun et al., 2010
14	UNICEF, 2009
16	Viger, 2009
17, 19, 20	Engel et al., 2005
18	Shaw, 2014
22	Brouwer, 1988
24, 25	Wedgwood & Sansom, 2003
26	Mugumya, 2013
33, 34	Doe & Sohail Khan, 2004
36, 37	Maheshwari. et al., 2014
38	Deverill et al., 2002
39	Alvarez & Corrales, 2014
40	Kumasi, 2013
41, 42	Adhikari & Di Falco, 2009

Socio-economic variables | Water related variables | Service level variables

Legend
Identified Links
Reference for hypothesis

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Annex 2: Discarded tests

#	Relationship	Context	Interpretation	Statistical Test	Significance
1	Membership in Water Committee vs. Overall Service Level		Not significant	tau-c=0.052	p=0.054
2	Caste vs. Water Source	Best Practice	Highly significant	tau-c=0.492	p<0.001**
		Control	Highly significant	tau-c=0.323	p<0.001**
3	Location vs. Overall Service Level	excluding HH-conn.	Highly significant	tau-c=0.203	p<0.001**
4	Location vs. Tariff paid	All records	Highly significant	tau-b=-0.247	p<0.001**
		excluding HH-conn.	Not significant	tau-c=0.001	p=0.985
5	Location vs. Membership in Water Committee		Not significant	tau-c=-0.041	p=0.109
6	Location vs. Attendance at Meetings		Not significant	tau-c=0.036	p=0.336
7	Location vs. Attendance at Awareness Sessions		Highly significant	tau-c=0.167	p<0.001**
8	Location vs. Quantity	all (excl. WB)	Significant	tau-c=-0.071	p=0.041
		excl. HH-conn (excl. WB)	Not significant	tau-c=-0.133	p=0.149
9	Location vs. Accessibility	excl HH-conn	Not significant	tau-c=0.038	p=0.590
10	House type vs. Overall Service Level		Highly significant	tau-c=0.260	p<0.001**
11	House type vs. Water Source		Highly significant	tau-c=-0.256	p<0.001**
12	Religion vs. Tariff		Highly significant	tau-b=0.111	p=0.001**
13	Religion vs. Membership in Water Committees		Not significant	tau-b=-0.004	p=0.900
14	Religion vs. Attendance at Meetings		Not significant	tau-b=0.002	p=0.952