

Why Are So Many Water Points in Nigeria Non-Functional?

An Empirical Analysis of Contributing Factors

*Luis Andres
Gnanaraj Chellaraj
Basab Das Gupta
Jonathan Grabinsky
George Joseph*



WORLD BANK GROUP

Water Global Practice

March 2018

Abstract

This paper utilizes information from the 2015 Nigeria National Water and Sanitation Survey to identify the extent, timing, as well as reasons for the failure of water points. The paper finds that more than 38 percent of all improved water points are nonfunctional. The results indicate that nearly 27 percent of the water points are likely to fail in the first year of construction, while nearly 40 percent are likely to fail in the long run (after 8–10 years). The paper considers the reasons behind these failures, looking at whether they can or cannot be controlled. During the first year, a water point's

location—the political region and underlying hydrogeology—has the greatest impact on functionality. Other factors—specifically, those that can be controlled in the design, implementation, and operational stages—also contribute significantly. As water points age, their likelihood of failure is best predicted by factors that cannot be modified, as well as by the technology used. The paper concludes that, to improve the sustainability of water points, much can be done at the design, implementation, and operational stages. Over time, technology upgrades are important.

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**Luis Andres, Gnanaraj Chellaraj, Basab Das Gupta,
Jonathan Grabinsky, and George Joseph**

JEL Classification: D02, O18, Q25

Key words: Water schemes, Nigeria, Functionality

¹ Luis A. Andres: World Bank Water Global Practice, landres@worldbank.org [Corresponding author]. Gnanaraj Chellaraj: World Bank Water Global Practice, gchellaraj@worldbank.org . Basab Dasgupta: Social Impact, Impact Evaluation Division, bdasgupta@socialimpact.com . Jonathan Grabinsky Zabudovsky: World Bank Water Global Practice, jonathan.grabinsky@gmail.com . George Joseph: World Bank Water Global Practice, gjoseph@worldbank.org. Senior authorship is not assigned.

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1. Background

Evidence indicates that freshwater ecosystems are undergoing rapid change around the world. Due in part to urbanization and an overall increase in pollution, clean water will be increasingly unavailable, particularly in developing economies (Steele, forthcoming; Hoekstra et al., 2012). A lack of functional infrastructure, including for drinking water and sanitation, could constrain economic growth (Agenor, 2010; Barbier, 2004). Evidence also indicates that infrastructure—including water and sanitation—is likely to offset moderate macroeconomic shortcomings at the initial stages of economic development (Moller and Wacker, 2017; Gibson and Rioja, 2017).

In many developing countries, the non-functionality of water points is a major problem, and this trend is particularly pronounced in Sub-Saharan Africa. Evidence of water points' failure has been documented by a number of studies. In countries such as Tanzania (Gill and Flachenburg, 2015; Gill, 2014) and Ghana (Fisher et al., 2015), several water points, including hand pumps, fail frequently. The situation is similar in Mozambique (Jansz, 2011) and Uganda (Nekesa and Kulanyi, 2012).

In this paper, we use locally weighted scatterplot smoothing (LWSS, “Lowess smoothing” of running-line least squares), logit regression analysis, and Shapley decomposition to analyze the extent, the timing, and the reasons for the failure of water points in Nigeria. Our analysis indicates that, in the first year, a water point's location—both the political region and the underlying hydrogeology—has the greatest impact on functionality. Other factors that can be controlled in the design, implementation, and operational stages (maintenance, for example) also contribute significantly to failure rates. Furthermore, as water points age, the likelihood of their failure is best predicted by factors that cannot be modified, as well as the technology used, while repair and maintenance decline in importance.

The paper proceeds as follows. First, we discuss the particular context of Nigeria, before offering an overview of the literature behind this study. In Section 4, we discuss the methodology and data used to analyze and predict the failure of water schemes. In Section 5, we present our results. In Section 6, we conclude.

2. Nigeria's Context

Access to water supply, sanitation, and hygiene (WASH) services in Sub-Saharan Africa is limited: 319 million people in the region did not have access to improved water, and 694 million lacked access to improved sanitation facilities in 2015. Evidence suggests that limited or no access to WASH services adversely impacts development outcomes such as health, limits access to educational and economic opportunities, and hampers work efficiency and labor productivity (World Bank, 2016).

Nigeria, with a population of 182 million, is the largest country in Sub-Saharan Africa (World Bank, 2017). It has also been one of the fastest-growing economies in the region in recent years: the gross domestic product (GDP) quadrupled between 2005 and 2015. However, the country has had limited success in reducing poverty, most likely because of three factors: (1) economic growth has been negated by high rates of population growth, (2) there has been no large-scale creation of jobs and other opportunities for citizens, and (3) the inequality gap is widening rapidly. A number of other key indicators, such as measures of the accumulation of physical and human capital and households' access to basic services, suggest that Nigeria is lagging behind other countries in the region, despite its impressive GDP growth (World Bank, 2017).

In 2000, Nigeria had an estimated 224 trillion liters of surface water and 50 million trillion liters of groundwater for an estimated population of about 128 million. About 6 billion liters were consumed in 2001, which suggests an abundant water resource potential (Akujieze et al., 2003). But the country faces significant obstacles to utilizing its water potential: (1) available hydrogeological base maps are of poor quality, and hence not of much use in helping the government develop a water exploration and extraction plan, (2) knowledge of the Nigerian geological terrain is poor, (3) there is a lack of infrastructure facilities, and (4) there is no working legislature (Serrao-Neumann et al., 2017; Adekalu et al., 2002; Sene and Farquharson, 1998; Owolabi and Omotola, 1994). These problems significantly hinder the exploration,

exploitation, operation, control, and management of Nigeria's abundant groundwater resources. As a result, there is increasing dependence on harvesting rainwater (Nnaji and Mama, 2014; Ishaku et al., 2012).

Nigeria's rates of access to WASH services are below those seen in many other Sub-Saharan African countries. Fifty-seven million people in Nigeria live without access to improved water. As many as 130 million do not meet the Millennium Development Goal (MDG) standards for sanitation. Poor sanitation costs the country 455 billion naira (\$2 billion) per year. These problems persist although the country has achieved the MDGs for water (WHO/UNICEF, 2015).

Nigeria's urban areas have considerably better access to water and sanitation than its rural areas (World Bank, 2017). However, rapid rural-urban migration is placing significant strain on urban water infrastructure (Barbier and Chaudhry, 2014). For instance, the capital city of Abuja is a key destination for rural migrants seeking better employment and safety. The city is trying to provide water and sanitation services to a rapidly growing number of people, across disparate neighborhoods (Abubakar, 2014). A 2012 study indicated that the city's water scheme would no longer be adequate to meet the total water requirements of the entire city in 2015, even operating at full capacity (Idowu et al., 2012). Hence, the scheme must be expanded to meet residents' demand for potable water. Lagos, too, suffers a lack of potable water. (For a dynamic approach to modeling the future urban land-use scenario in Lagos, see Barredo and Demicheli, 2003.) Oyo State has suffered water contamination due to equipment failure (Sangodoyin, 1993). In the face of such problems, the impacts of community water and sanitation programs in Nigeria are limited. Many are abandoned prematurely because of numerous institutional and economic factors. In short, the delivery and maintenance of WASH services continues to be a major problem in the country (Ademiluyi and Odugbesan, 2008).

As the global community moves toward achieving the Sustainable Development Goals (SDGs), it is vital to evaluate Nigeria's current state of water and sanitation access to facilitate the development of effective policies and interventions to address present shortcomings. These efforts need to be targeted at the most vulnerable segments of the population, specifically those who live in poverty. The analysis and results presented here will therefore be of interest to policy makers and other key stakeholders in Nigeria.

3. Literature Review

A review of relevant surveys (Wilson et al., forthcoming) indicates that: (1) there is no widely agreed upon definition for water point functionality, and hence it is difficult to compare the results of various surveys, and (2) most surveys use the binary definition of “working” or “not working”, although some do refer to “partial functionality.”² A World Bank study (forthcoming) analyzes a range of indicator sets from countries and development partners, including 20 national monitoring systems and 20 monitoring frameworks from donors, and propose a shortlist of indicators and associated metrics as a global framework. This framework uses three broad sets of sustainability indicators relevant to (1) service levels (the characteristics of water that users receive); (2) functionality (the physical condition and functioning of a supply system); and (3) upkeep (those factors, including external backup support, that affect the performance of the service provider in its roles of operation, maintenance, and administration).

Literature on water point functionality in Nigeria is virtually nonexistent. A recent study of the causes of water schemes’ non-functionality (Andres et al., 2018) shows that 30% of schemes failed within their first year of operation, and more than 55% were not operational after 10 or more years. To identify the relative importance of each driver of failure in the different phases of a scheme’s life span, the analysis considers three phases—short term (the first year after installation), medium term (between three to six years after installation), and long term (more than eight years after installation). This is to better understand how different factors—such as hydrogeology, technology, location, size, management, and maintenance—affect a scheme’s performance across its life span. During the first year of operation, factors that can be controlled in the design, implementation, and operation stages predict the failure of 61% of water schemes. As water schemes age, their likelihood of failure is best predicted by those factors that cannot be modified, as well as by those that can be controlled during the operational stage. Meanwhile, the share of failures linked to factors such as repairs and maintenance decreases slightly. Thus, if water schemes are more

² <http://nora.nerc.ac.uk/514658/1/Handpump.pdf>.

carefully attended to during the design, implementation, and operational stages, it is possible to drastically reduce their failure rates.

While studies that analyze the causes of water scheme failure in Nigeria are virtually nonexistent, there are a few studies on sustainability. One study of community water and sanitation programs suggests involving all stakeholders in a collaborative process, with a view toward ensuring long-term sustainability (Ademiluyi and Odugbesan, 2008). For example, in the state of Akwa Ibom, a lack of maintenance, poor community participation, little or no coordination and cooperation among stakeholders, political factors, inefficient monitoring, and a lack of maintenance and oversight of public property were all responsible for the unsustainability of the rural water supply (Ibok and Daniel, 2014). A study of the Niger Delta (Ihuah and Kakulu, 2014) proposed a post-project management approach. This approach can effectively monitor, assess, link, and integrate the implementation and post-operational management of hand pumps along with community management.

Outside Nigeria, a few studies of water point functionality have been undertaken over the past four decades. A summary of the literature, including the countries studied, year of study, and the rates of non-functionality, is presented in Table 1 (Annex). In the developing countries surveyed around the world in the 1970s and 1980s, over 50% of water points were non-functional. More recent studies and surveys indicate that the percentage of failing water points has declined. Between the 1980s and 2010s, failure rates were generally under 40%. The two exceptions are Tanzania (WaterAid, 2009), where this rate was 54%, and Ethiopia, where it was 43% (Table 1). But these results should be interpreted with caution since the number of studies involved is small and some cover only a small portion of each country.

A few studies specifically focus on the causes of hand-pump failures in Sub-Saharan Africa. Hand pumps are generally of five types: suction, direct action, deep-well reciprocating, progressive cavity rotary, and displacement (Harvey and Reed, 2004). The critical issues that can undermine their sustainability are institutional, social, technical, environmental, and financial/economic in nature (Parry-Jones et al., 2001). One study finds that leaving rural water points to be managed by local communities is correlated with low functionality levels. Post-construction support—with complementary roles for communities, the private

sector, and all levels of government—is needed to improve the functionality of the rural water supply (SNV, 2013). In Ghana, only 21% of hand pumps were found to meet national norms and standards for the reliability, quality, and quantity of the water service provided (Adank et al., 2014). Service providers who operate and maintain these hand pumps also scored low on compliance with norms and guidelines related to governance, operations, and financial management. Ethiopia’s higher functionality rates are associated with good record-keeping, regular community meetings, financial audits, higher monthly fees, a paid caretaker, and water committees with the capacity to perform minor repairs (Alexander et al., 2015). The primary threats to the achievement of Tanzania’s water delivery targets include the inaccuracy of the baseline used for program design, difficulties faced by underserved districts trying to keep water points functional, and differences between the expected and real long-term functionality of water points, especially hand pumps (Jimenez and Perez-Foguet, 2011). In Chad (Thibert, 2016), an analysis of water and sanitation conducted in 28 villages in Bokoro District during October 2015 estimated that 61% of villages had access to a functional or semi-functional hand pump or borehole, and 39% of villages collected water from open wells or swamps at risk of contamination. Many of the remaining villages had reverted to contaminated surface water after their hand pumps had fallen into disrepair due to poor management of the water point. In the Democratic Republic of Congo, a lack of spare parts continues to be a major problem that adversely affects hand pump functionality (Koestler et al., 2014). Finally, a study of Rumphi District, Malawi, suggests that sustainability may be improved by giving communities a say in the type of hand pumps or water points to be installed (Holm et al., 2017).

Foster (2013) employed logistic regression analysis to identify operational, technical, institutional, financial, and environmental predictors of functionality for over 25,000 community-managed hand pumps in Liberia, Sierra Leone, and Uganda. Risk factors significantly associated with non-functionality across all three countries were (1) system age, (2) distance from the district/county capital, and (3) absence of user fee collection. Other variables included in the model were well type, hand pump type, funding organization, implementing organization, proximity of spare parts, availability of a hand pump mechanic, regular

servicing, regular water committee meetings, women in key positions in the water committee, rainfall season, and perceived water quality.

Carter and Ross (2016) demonstrate empirically that reducing the high rates of early post-construction abandonment as well as of total downtime would greatly improve the service performance of hand pumps. Around 85% of wells or boreholes equipped with hand pumps are expected to function. To generate a more nuanced understanding of service performance, going beyond functionality, it is recommended that monitoring include the collection of quantitative data on rates of abandonment and the frequency and duration of breakdowns, combined with descriptive narratives of actions taken to manage and repair water points. Cronk and Bartram (2017) show that fee collection in Nigeria and Tanzania is positively related to functionality; the authors recommend that for Tanzania fees should be collected monthly rather than when pumps break down. Furthermore, in Nigeria, systems managed by the private sector are likely to be more functional than those managed by communities. In Malawi, factors adversely affecting the functionality of hand pumps include the inefficiency of user committees, corruption, a lack of spare parts, a lack of community ownership, and the inadequate involvement of non-governmental organizations (NGOs) (Rural Water Supply Network, 2014). Ways to improve functionality include community involvement, skills training, private sector involvement, and technology upgrades (Walters and Javernick-Will, 2015).

Baumann (2009) provides a comprehensive list of conditions needed for pumps to function. “Soft” conditions include community ownership; a perceived need for the water point; and user skills, behaviors, norms, and practices. “Hard” conditions include human resources and suitable technologies. Finally, there are financial conditions, such as the availability of finance for capital expenditure and the ability of users to pay for services. Without all these conditions being met simultaneously, pumps are bound to fail.

The water point is the only visible and aging part of an expensive system. Finding water and drilling a borehole constitute the main part of the investment (Carter et al., 1996). Thus, although hand pumps are not expensive, when they fail, the entire system fails. Over the years, and particularly in remote areas,

governments have proven to be incapable and unwilling to provide the operation and maintenance services needed for water points to remain functional.

The role of maintenance is important (Koestler et al., 2010; Morgan, 1993). This has been shown in the case of Zimbabwe (Mudege, 1993). In Mexico, studies reveal a bias favoring the development of new public infrastructure while neglecting the maintenance of existing infrastructure (Gibson and Rioja, 2017; McNeill, 1985). Lack of maintenance led to hand pump failures in Morocco in the early 1980s (Lynch, 1984). Maintenance is a problem in industrialized countries as well. In some parts of the United States, particularly in rural areas, water points are virtually nonexistent and many houses lack indoor plumbing (RCAP, 2010; Vance, 2016; Fetterman, 1967).³

The choice of technology is also important (Janke et al., 2017). The fixed costs associated with installing wells and pumps significantly impact their number and location (Hsiao and Chang, 2002). Furthermore, hand pump failures often result in extended service disruption leading to high but avoidable financial, health, and development costs. There are several innovative ways of addressing these problems. For example, one manually operated hand pump employs a gear drive in the power train to ease operations and at the same time increase efficiency (Nasir et al., 2004; McNeill, 1985). These studies suggest that even small increases in efficiency can have sweeping results, considering the critical nature of hand pumps. Finally, using data on hand pump usage in rural Kenya, Koehler et al. (2015) evaluated the impact of dramatic improvements in maintenance services on payment preferences. They suggest that it might be possible to improve the sustainability of rural water supply by pooling maintenance and financial risks and taking advantage of advances in monitoring and payment technologies.

Evidence shows that aid disbursements make a strong, positive, and significant contribution to improving access to WASH services (Gopalan and Rajan, 2016) in lower-middle-income countries but not

³ In rural areas where the population is dispersed, such as parts of Texas along the Mexico border, the chances of not having either indoor plumbing or any form of water scheme increases sharply. In six states—Alabama, New Mexico, Arizona, West Virginia, Kentucky, and Mississippi—half of the households without these services live below the poverty level. The dire situation in the U.S. Appalachia has not changed much in the past 50 years.

in low- or upper-middle-income countries. This contribution was found to be greater in rural than in urban areas. Another recent study suggests that donors need to increase aid allocation to WASH in Sub-Saharan Africa (Ndikumana and Pickbourn, 2017). Structural constraints that could limit access to WASH (and their alleviation through foreign assistance) need to be identified and addressed.

4. Methodology and Data

(a) Methodology

A locally weighted scatterplot smoothing (LWSS, “Lowess Smoothing” of running-line least squares) is used to undertake a locally weighted non-parametric regression of “non-functionality” (0,1) for 43,443 water points that are between 1 and 15 years old.⁴ To analyze the relative importance of a series of factors in explaining the probability of a water point failure, a logistic regression econometric model is estimated and the Shapley decomposition is used to analyze the relative shares of the factors in explaining the failure probabilities. Quantitative indices are used to measure poverty and inequality through the Shapley decomposition. For instance, in poverty reduction policies the decomposition of the observed variation must be measured to evaluate the contribution of each explanatory factor. The same is true when attempting to explain the failure of water points. Shorrocks (1984, 1982, 1980) reviews the Shapley (1953) decomposition, which is applicable to functionality. Let S be the aggregate indicator that measures water scheme outcomes, X_k , where $k = 1, 2, \dots, m$ is a set of factors contributing to the value of S . The following equation can thus be written:

$$S = f(X_1, X_2, \dots, X_m)$$

Where $f(.)$ is an appropriate aggregation function. The goal of all decomposition techniques is to attribute contributions, C_k , to each of the factors, X_k , so that the value of S becomes equal to the sum of m

⁴ We define age as 2015, which is when the survey was conducted, minus the year when the water point was commissioned. So the formula is: age = 2015 – year of commission.

contributions to water point functionality outcomes. These X include the explanatory variables of functionality outcomes used in the linear probability regression.

Water points that are only a year old, those between three and six years, and those older than eight years were grouped together and the reasons for early, mid-term, and long-term failures were analyzed. To explain the likelihood of failure in each of these three age groups, the relative shares of technology, location, promoters, management, maintenance, and operation are decomposed.⁵ Next, the factors affecting water point functionality are grouped together into three broader categories and analyzed. These are factors such as (1) *political region* and *hydrogeology*, which cannot be changed; (2) *technology* and *how promoters operate and implement interventions*, which are influential at the design and implementation stage (and can be taken into account when developing new points); and (3) *management* and *maintenance* (the availability of parts and repairing agents), which are influential at the operational stage (and can be addressed for existing points).

(b) Data Sources and Descriptive Statistics

In 2015, a National Water and Sanitation Survey (NWSS) of all water points and water schemes was conducted throughout Nigeria. This survey was commissioned by the Federal Ministry of Water Resources (FMWR), and data were collected across the country at the ward level. The survey consisted of four questionnaires—of households, water points, water schemes, and public sanitation practices (conducted in schools and health centers). The household survey was of more than 202,000 households, while the water points and schemes surveys provided information on 89,721 “improved”⁶ water points across states and local government areas (LGAs).

In this study, we focus on water points. Figure 1 maps the distribution of water points across Nigeria. While it is evident that functional water points are distributed across the country, they are highly concentrated in the northern and western regions. The NWSS 2015 reveals that of 89,721 improved water

⁵ A breakdown of the dependent variables by region is provided in Table 4.

⁶ For the purposes of this study, sources of improved water include tube wells and boreholes, infiltration galleries, protected springs and dug wells, rainwater harvesting sites, gravity flow systems, and pumped-piped systems (using either ground or surface water).

points, 89.5% are tube wells or boreholes. The rest are protected dug wells, springs, sites where rainwater is harvested, or infiltration galleries (Table 2).⁷ Around 79% of these water points have been constructed by government agencies over the years. Among those, the majority are built by state governments (29.8%), followed by federal governments (25.4%) and local governments (23.6%). The rest were built by donors (7.6%), NGOs (5.1%), and philanthropists and others (8.4%). In terms of functionality (Table 3), the NWSS 2015 shows that 48,628 (54.1%) water points are fully functional and 6,920 (7.7%) are in bad condition, while the remaining 34,325 (38.2%) are not functional. Altogether, the total share of “working” water points is 61.8%. Nationally, around 75% of these points are functional for most of the year; only one-third of states perform below the national average.

The most striking finding is that more than one-third (38.2%) of all water points in Nigeria are not functioning at all. The main question is whether these water points fail because of age or other factors. In the results section, we plot the likelihood (probability) of failure against the respective age of these water points and categorize them by their location, technology, and promoter. A corresponding year of construction was reported for only 49,600 out of the 89,871 water points. Among water points with such data, we consider only those that are between 1 to 15 years old,⁸ of which there are 42,443 individual points.

To understand whether differences in operation and management play a role in deciding the longevity of water points, we also categorize them by their maintenance and management arrangements. While the presence of a “management committee” is indicated by that of a WASHCOM⁹ in a given community, maintenance is indicated by the local availability of spare parts and of agents who conduct routine repairs. Table 4 provides a breakdown of the various factors that affect the performance of water

³ In the functionality analysis we exclude rainwater harvesting and infiltration galleries because of their low incidence; these two sources, when combined, compose a share of less than 1%. This reduces the number of observations used in the rest of the analysis to 89,871.

⁸ The authors have used locally weighted scatterplot smoothing (“Lowess” of running-line least squares) to estimate a locally weighted regression of “non-functionality” (0,1) on age in years ($1 < \text{age} < 15$) for water points and schemes. These are presented in Figures 2–7.

⁹ A WASHCOM is a community-based water, sanitation, and hygiene committee. WASHCOMs in Nigeria help raise awareness of hygiene practices and the importance of defecating in latrines. The United Nations Children’s Fund (UNICEF) and the Rural Water and Sanitation Agency (RUWASA) have also trained members in borehole maintenance, basic bookkeeping, and general roles and responsibilities. The committees regularly share messages with their communities at social gatherings, such as naming ceremonies and weddings.

points aged between 1 and 15 years. Well over half of all water points are in rural areas, and the hand pump is the most common extraction device. However, while hand pumps dominated the northern regions, motorized pumps dominated the south.

As presented in Table 4, water points are promoted at the federal, state, and local levels of government, and the dominance of one level over another varies by region. The federal government is the primary promoter in the north-central, northeast, and southeast regions. Meanwhile, local authorities dominate the northwest, and state authorities dominate the south-south and southwest regions (Table 4). A WASHCOM is present in only one-third of communities. A low level of groundwater productivity was observed across all regions except the southeast, where productivity is at a mid-level, and the south-south, where productivity is for the most part high. The type of groundwater storage, measured by its depth in millimeters (mm), also varied by region, although nationally, low-depth storage is most common. Two exceptions are the northwest and south-south, where high-depth storage dominates. Groundwater depth, measured in meters below ground, is most commonly very shallow across the nation. However, at the regional level, this was the case for only the northeast, northwest, and southwest.

There is significant regional variation in who conducts repairs and maintenance. A large share of repairs are done by agents—local mechanics/artisans—at the community level (Table 4). Spare parts are available in slightly over 50% of all cases in Nigeria. This pattern is true for all regions except the north-central, where spare parts were not readily available for nearly two-thirds of cases.

5. Results

The results of a locally weighted scatterplot smoothing (LWSS, “Lowess Smoothing” of running-line least squares) regression of “non-functionality” (0,1) on age in years ($1 < \text{age} < 15$) for water points are presented in Figures 2–11.

(a) Functionality Analysis

Around 25–30% of water points are likely to fail within the very first year after installation, irrespective of whether they are located in rural or urban areas. The likelihood of failure increases with age, but does not vary much by location when water points are under 8–10 years (Figure 2). Beyond that age, however, older water points in rural areas perform better than their urban counterparts. After 8 years, the likelihood of failure in urban areas is about 40% and this increases to 45% by the age of 15, compared with rural areas where 8 years after installation, the failure rate is around 35% and this declines to 30% by the age of 15.

Regionally, the likelihood of failure is higher in the south than in the north, irrespective of age. To identify spatial differences, we separate all water points into six political zones and plot their likelihood of failure against their respective age. Figure 3 shows that the likelihood of failure is lowest in the northwest, followed by the northeast and north-central regions. The likelihood of failure in the northwest region is around 15% during year one, while it is around 25% in the northeast¹⁰ and slightly above 30% in the north-central region. The likelihood of failure increases steadily with age in the northeast and north-central regions—to 35% and 45%, respectively, by year 15—while it is largely stable in the northwest at around 18–20%.

The likelihood that failure corresponds with age in the southeast and southwest regions is similar to that of the north-central region—the poorest performer in the north (Figure 3). Notably, in comparison with other regions, the south-south region has the largest failure rates at all ages: the likelihood of failure in the initial years is close to 40% and later exceeds 60% at the age of 15 years.

Comparing technologies suggests that the likelihood of failure among motorized pumps is almost 20% higher than for hand pumps after 8–10 years. Figure 4 shows that in the initial years, both manual pumps and motorized pumps have a 25–30% chance of failure. In later years, hand pumps maintain

¹⁰ It must be noted that due to ongoing conflict in northeastern Nigeria, the availability of data for this area is limited. As such, the analysis presented in this report provides a useful overview though not a full representation of the functionality of water points and schemes in the region.

a similar likelihood of failure, while for motorized pumps the rate increases to almost 50% after 8–10 years. We observe a similar pattern when disaggregating by location (these results can be provided upon request).

A water point sponsored by donors, NGOs, or a community-based organization (CBO) is almost 5–10% less likely to fail in its first year than a point promoted by the federal or state government (Figure 5). Among government-sponsored water points, those backed at the local level are the best performers: they have a steady likelihood of failure of about 20–30% over their lifetime. By contrast, federally sponsored water points are about 30% likely to fail in the initial years, and this increases to more than 50% after 10 years. Donor- and NGO/CBO-sponsored water points maintain close to a 10% advantage over federally and state-sponsored water points across their life span.

Evidence suggests that the likelihood of failure is 15–20% less when water points are repaired and maintained by a WASHCOM than by local artisans. In the initial years, the likelihood of WASHCOM-maintained water points failing was around 10% as compared with 30% for those maintained by local mechanics or artisans (Figure 6). The likelihood of failure among government- and donor/NGO-maintained water points is similar—at around 30%—and remains steady over their life span. Interestingly, in the initial years, while the likelihood of failure is similar to that of water points maintained by local mechanics, it starts converging with the failure rate of WASHCOM-maintained water points after 8–10 years of age.

Similarly, evidence suggests that the likelihood of failure is 5–10% less when spare parts are locally available. Approximately 80% of non-performing water points are subject to mechanical failure and in about 45% of cases, spare parts are not locally available. When spare parts are available, the likelihood of failure is 5% less in the initial years, and almost 10% less after 8–10 years (Figure 7). The above analysis suggests that proper know-how and the availability of required spare parts can immediately improve the functionality of water points by a significant margin.

WASHCOM-managed water points are the least likely to fail. More than 35% of water points have a WASHCOM present. Figure 8 suggests that WASHCOM-managed water points are about 10% less likely to fail during their entire life span than those not managed by a WASHCOM.

Those water points with deep groundwater storage are less likely to fail than are those with low to medium groundwater storage capacity. The failure rates of water points with a groundwater storage higher than 25,000 mm is 20% in year 1, increasing to about 25% by year 8, before declining to less than 20% by year 15 (Figure 9). Meanwhile, for those water points with shallower groundwater storage capacity—those with a storage depth less than 25,000 mm—the initial failure rate starts at about 30%, before steadily increasing to a high of about 45% by year 15. The deeper the storage level, the less likely it is that the water point will fail.

Water points with high groundwater productivity (liters per second) have a lower failure rate than those with lower groundwater productivity. The failure rates of those water points with high groundwater productivity—those that pump water at a rate faster than five liters per second—start at 20%, increasing to about 25% by year 8 before declining to about 20% by year 15 (Figure 10). Meanwhile, for those water points with lower productivity levels—those that pump water at a rate slower than 5 liters per second—the initial failure rate starts at about 30%, before steadily increasing and reaching a high of about 45% by year 15. In other words, the higher the groundwater productivity, the less likely it is that the water point will fail.

The failure rate of water points with (very) shallow groundwater depth is higher than it is for those with shallow to medium-level depth. For those points with shallow to medium groundwater depth—that is, 25 to 100 meters below ground level—the probability of failure starts at 20% in the first year, and declines to about 18% by year 8 and 15% by year 15 (Figure 11). For those points whose groundwater depth is very shallow or shallow—that is, 0 to 25 meters below ground level—the failure rate starts at about 30% and increases to about 43% at the 8-year mark, then remains steady thereafter. Shallow groundwater depth results in higher levels of non-functionality.

(b) Empirical Results

Table 5 presents the logit regression estimates of the determinants of the non-functionality of water points for the full sample of water points that are one year old, three to six years old, and more than eight years old. The regression results are only for the sample of water points between 1 and 15 years of age

where the scheme size is not equal to “none.” As in the case of the LWSS curves, the outcome variable is binary and equals 0 if the water point is functional and 1 if it is non-functional.

The results indicate that the presence of a WASHCOM has a negative and significant impact on non-functionality for the full sample at the 1% level, for three-to-six-year-old schemes at the 5% level, and for eight-year-old schemes at the 10% level. The availability of spare parts is negative and significant for non-functionality at the 1% level for all samples as well as subsamples. Together, these results suggest that the presence of a WASHCOM and availability of spare parts play a major role in helping prevent the breakdown of water points. In addition, a WASHCOM plays a significant and negative role at the 1% level for the full sample and subsamples. A water point that involves motorized extraction is more likely to be non-functional across the full sample and among water points that are three to six years old and over eight years old, while it is more likely to be functional in the first year. Those points that involve other types of extraction are more likely to be non-functional across the full sample and in the initial three years. Donors and philanthropists have a significant and negative impact on non-functionality in all cases. Local governments and NGOs/CBOs have a significant and negative impact on the full sample and those water points that are over eight years old. Meanwhile, the state had a positive impact on non-functionality across the full sample (at the 1% level) and on those points that are over eight years old (at the 10% level).

The impact of groundwater productivity varies by age. Relative to high productivity, low to medium productivity has a significant and negative impact at the 1% level across the full sample, and specifically the three-to-six-year subsamples. Medium productivity, relative to high productivity, has a significant impact at the 10% level for only two cases: those water points over one year old and those between three and six years. For null relative to high, the impact is positive and significant at the 10% level across the full sample and at the 5% level for those points over eight years old. In general, shallow groundwater storage seems to significantly and adversely affect functionality. The deeper the storage, the better the functionality. Relative to the northeast, only the northwest has a lower probability of failure, and this is significant at the 1% level in all cases. Relative to the northeast, all other regions have higher failure rates, and in several cases, these rates are significant at the 5% or 1% levels.

(c) Shapley Decomposition of Water Points' Failure

In this section, we use logit analysis to calculate the impact of various factors on water points' failure (Table 5). We group together water points that are one year old, three to six years old, and over eight years old to determine failure by age. We then predict the impact of hydrogeology, technology, location, promoters, management, and maintenance and operation in explaining the likelihood of water scheme failure in each of these three age groups, along with the Shapley values (Table 6) for each component's contribution to failure (Figure 10). We also group these factors into three categories. First, we assess factors that cannot be changed, such as *political region* and *rural-urban location*. Second, we consider factors that are influential at the design and implementation stage (and can be taken into account when developing new points)—namely *technology* and *how promoters operate and implement interventions*. Third, we consider factors that are influential at the operational stage (and can be addressed for existing points): *management* and *maintenance* (the availability of parts and repairing agents).

The Shapley values are presented in Table 6, columns 1, 3, and 5. The marginal contribution of most of the components to the failure of the water points shows a general upward trend as the points age, with the exception of repairs and maintenance and settlement types,¹¹ which are important during the first year after installation. The most notable finding is that hydrogeology (i.e., groundwater productivity, depth, and storage) increases in importance as the water point ages. Initially, WASHCOM increases in importance, but by the eighth year its importance declines.

In the very first year (Figure 12), while locational variations—such as settlement type and regional distribution—explain over 28% of the failure rate, 42% is largely explained by two sets of indicators: repair and maintenance (31%) and the role of a WASHCOM in management (10%). Other factors explain the remaining 30%. Here, water points' hydrogeology (18%) as well as promoters (11%) play a key role, while technology (1%) carries little weight in explaining failure within the very first year.

¹¹ Settlement type refers to urban, rural, and small town location. For more information, see a breakdown of categories in Figure 2 and Table 4.

In the medium term, when water points are three to six years old, the relative importance of hydrogeology increases (21.1%) as does the political region (31.9%), while the relative importance of maintenance and repair declines by more than 12%. The contribution of a WASHCOM remains relatively flat at 11.6%. Overall, more than 23% of the likelihood of failure in the medium term can still be explained by variations in management and maintenance. Further, the relative importance of extraction technology increases by more than 5% in explaining failure among this group. The relative importance of promoters declines slightly.

When we examine the relative contribution of the same drivers to the likelihood of failure among water points older than eight years, we find that the relative importance of technology increases slightly—to about 11%—while the relative shares of maintenance and management decline to about 12%. We find an almost 12% increase in the relative importance of political regions, whereas the importance of hydrogeology remains flat.

In conclusion, among all indicators that are identified as drivers of functionality and that can be controlled by policy makers, better technology matters in the short, medium, and longer terms (9–11%). Maintenance and management are important drivers in the initial stages, after which they decline in importance. Factors that cannot be controlled in the short or medium term, such as location, also contribute significantly to the failure of water points in Nigeria.

6. Conclusions and Policy Implications

The NWSS 2015 survey data enable us to identify the failure rates of water points and schemes across their lifetimes as well as the factors contributing to these failures.¹² More than 38% of all improved water points are non-functional, and many failed within the first year. The results indicate that nearly 27%

¹² Note that this model does not intend to make causal inferences. Absent a control group, as exists in experimental or quasi-experimental research designs, it is not possible to make any strict causal inferences about the role that each of these factors plays in explaining the probability of water point failure. Further experimental research is needed to further clarify the causal factors driving water point failure.

of water points are likely to fail in the first year of construction, while nearly 40% are likely to fail in the long run (after 8–10 years).

Our analysis of the data reveals several factors that impact water points' functionality. First, location matters. Water points and schemes in the country's north generally outperform their counterparts in the south. Water points in urban areas perform worse than those in rural areas. This is likely due to urban overcrowding amid rapid increases in urban populations driven by rural-urban migration. The availability of pumps is likely to be much higher per capita in rural than in urban areas.

Hydrogeology plays a major role in the functionality of water points, and this role increases in importance over time. Where groundwater depth and storage are deeper, water points are more likely to be functional. Technology also plays a role. In the long run (after 8–10 years), motorized pumps are almost 20% more likely to fail than are manual hand pumps, despite the fact that both exhibit similar rates of failure during their initial years. Finally, factors that cannot be changed (such as location) explain 30–63% of water points' failure. Factors that are influential at the design and implementation stage (e.g., promoters, the type of technology used) explain about 20% of the failure rate, and factors that are influential at the operational stage (e.g., maintenance and management) are responsible for 12–31% of this rate. Finally, maintenance by a WASHCOM yields improved water point functionality.

There are striking similarities between the patterns of failed water schemes (Andres et al., 2018) and failed water points in Nigeria. In both cases, water infrastructure performs better in the north than in the south, performs better with the presence of a WASHCOM, when spare parts are available, and when the promoters are NGOs rather than government authorities. For both water schemes and points, repair and maintenance decline in importance as the infrastructure ages. However, there are some significant differences. Technology and location—both in terms of political region and underlying hydrogeology—grow in importance as water points age, but decline in importance for schemes. On the other hand, the presence of a WASHCOM grows in importance as a scheme's infrastructure ages, a pattern that does not hold for water points. Finally, the importance of the initial promoter does not change much as water points age, while it declines in importance for schemes.

To improve the performance of water points, it is key that the predictors of functionality covered in this paper be seriously considered. There is a tendency for projects to fall apart when donors leave. This may be because local skills are inadequate, or the technology is too costly to maintain. Furthermore, a water point designed for use by, for example, 200 people a day might instead be used by 300 people, resulting in more wear and tear and greater need for costly maintenance and repair—which likely explains some of the urban-rural disparities. Urban areas are concentrated in the south and large-scale migration is likely to put pressure on existing water points' infrastructure. The other central issue is hydrogeology: the choice of extraction technology could play a central role in preventing failure over the medium and long term. Finally, although the role of a WASHCOM in explaining water points' failure declines in importance over time, our results indicate that the management functions of a WASHCOM may play a key role in helping prevent water point failure during the initial stages.

References

- Abubakar, I. R. 2014. "Abuja: City Profile." *Cities*, 41: 81–91.
- Adank, M., Kumasi, T. C., Chimbar, T. L., Atengdem, J., Agbemor, B. D., Dickinson, N. and Abbey, E. 2014. "The State of Handpump Water Services in Ghana: Findings from Three Districts." Paper Presented at the 37th WEDC International Conference, Hanoi, Vietnam.
- Adekalu, K.O., Osunbitan, J. A. and Ojo, O. E. 2002. "Water Sources and Demand in Southwestern Nigeria: Implication for Development Planners and Scientists." *Technovation*, 22: 799–805.
- Ademiluyi, I. A. and Odugbesan, J. A. 2008. "Sustainability and Impact of Community Water Supply and Sanitation Programmes in Nigeria: An Overview." *African Journal of Agricultural Research*, 3: 811–817.
- Agenor, P-R. 2010. "A Theory of Infrastructure-Led Development." *Journal of Economic Dynamics and Control*, 34: 932–950.
- Akujieze, C. N., Coker, S.L.J. and Oteze, G. E. 2003. "Groundwater in Nigeria—A Millennium Experience—Distribution, Practice, Problems and Solutions." *Hydrogeology*, 11: 259–274.
- Alexander, K. T., Tesfaye, Y., Dreibelbis, R., Abaire, B. and Freeman, M. C. 2015. "Governance and Functionality of Community Water Schemes in Rural Ethiopia." *International Journal of Public Health*, 60: 977–986.

- Andres, L., Grabinsky, J., Das Gupta, B., Chellaraj, G. and Joseph, G. 2018. “An Evaluation of the Causes of Water Scheme Failures in Nigeria.” Global Water Programs GP, World Bank, Washington, DC.
- Barbier, E. B. 2004. “Water and Economic Growth.” *Economic Record*, 80:1–16.
- Barbier, E. B. and Chaudhry, A. M. 2014. “Urban Growth and Water.” *Water Resources and Economics*, 6: 1–17.
- Barredo, J. I. and Demicheli, L. 2003. “Urban Sustainability in Developing Countries’ Megacities: Modeling and Predicting Future Urban Growth in Lagos.” *Cities*, 20: 297–310.
- Baumann, E. 2009. “May-day! May-day! Our Hand Pumps Are Not Working.” *Rural Water Supply Network: Perspectives*, 1.
- Cairncross, S., Curtis, D., Carruthers, I., Feachem, R., Bradley, D. and Baldwin, G. 1980. “Evaluation for Village Water Supply Planning.” Technical Paper 15, International Reference Center for Community Water Supply and Sanitation, the Hague.
- Carter, R. C. and Ross, I. 2016. “Beyond ‘Functionality’ of Handpump-Supplied Rural Water Services in Developing Countries.” *Waterlines*, 35: 94–110.
- Carter, R. C., Tyrell, S. F. and Howsam, P. 1996. “Strategies for Handpump Water Supply Programs in Less Developed Countries.” *Journal of the Chartered Institution of Water and Environmental Management*, 10: 130–136.
- Cleaver, F. 1991. “Maintenance of Rural Water Supplies in Zimbabwe.” *Waterlines*, 9: 23–26.
- Cronk, R. and Bartram, J. 2017. Factors Influencing Water System Functionality in Nigeria and Tanzania: A Regression and Bayesian Network Analysis.” *Environmental Science and Technology*, 51: 11336–11345.
- Duti, V. A. 2012. “Tracking Functionality for Sustainability.” Theme paper, 2011 Annual Review Conference of the Community Water and Sanitation Agency, Kumasi.
- Fetterman, J. 1967. “Stinking Creek: The Portrait of a Small Mountain Community.” Dutton.
- Fisher, M. B., Shields, K. F., Chan, T. U., Christenson, E., Cronk, R. D., Leker, H., Samani, D., Apoya, P., Lutz, A. and Bartram, J. 2015. “Understanding Handpump Sustainability: Determinants of Rural Water Source Functionality in the Greater Afram Plains Region of Ghana.” *Water Resources Research*, 51: 8431–8449.
- Foster, T. 2013. “Predictors of Sustainability for Community-Managed Handpumps in Sub-Saharan Africa: Evidence from Liberia, Sierra Leone, and Uganda.” *Environmental Science and Technology*, 47: 12037–12046.
- Gibson, J. and Rioja, F. 2017. “Public Infrastructure Maintenance and the Distribution of Wealth.” *Economic Inquiry*, 55: 175–186.
- Gill, L. 2014. “Evaluation of the Short, Medium and Long Term Sustainability of Concern’s WASH Programme in the Kagera Region of North-West Tanzania.” Department of Civil, Structural and Environmental Engineering, Trinity College, Dublin.

- Gill, L. and Flachenburg, F. 2015. “Sustainability of Hand-Dug Wells in Tanzania: Results from a Post-Evaluation.” Briefing Paper, 38th WEDC International Conference, Loughborough University, UK.
- Gopalan, S. and Rajan, R. S. 2016. “Has Foreign Aid Been Effective in the Water Supply and Sanitation Sector? Evidence from Panel Data.” *World Development*, 85: 84–104.
- Harvey, P. and Reed, B. 2004. “Rural Water Supply in Africa: Building Blocks for Handpump Sustainability.” Loughborough University, Loughborough, UK.
- Hazelton, D. G. 2000. *The Development of Effective Community Water Supply Systems Using Deep and Shallow Well Handpumps*. Report to the Water Research Commission by the Water Resources Management Programme, Division of Water, Environment and Forestry Technology, CSIR.
- Hoekstra, A. Y., Mekonnen, A. M., Chapagain, A. K., Mathews, R. E. and Richter, B.D. 2012. “Global Monthly Water Scarcity: Blue Water Footprints Versus Blue Water Availability.” https://www.2000litergesellschaft.ch/fileadmin/user_upload/Referenzen_und_Literatur/HOEKST_RA_ET_AL_2012_Blue_Water_Footprints_Versus_Blue_Water_Availability.pdf.
- Holm, R., Singini, W. and Gwayi, S. 2016. “Comparative Evaluation of the Cost of Water in Northern Malawi: From Rural Water Wells to Science Education.” *Applied Economics*, 48: 4573–4583.
- Holm, R., Stroud, R., Msilimba, G. and Gwaji, S. 2015. “Functionality and Water Quality of Elephant Pumps: Implications for Sustainable Drinking Water Supplies in Rural Malawi.” *Groundwater for Sustainable Development*, 1: 129–134.
- Holm, R., Kamangira, A., Kasulo, V., Kaponda, P., Hara, E., Carney-Filmore, C. and Nhlema, M. 2017. “The Handpump Choice is Yours: A Pilot Study in Rumphu District, Malawi.” *Waterlines*, 36: 358–366.
- Hsiao, C. and Chang, L. 2002. “Dynamic Optimal Groundwater Management with Inclusion of Fixed Costs.” *Journal of Water Resources Planning and Management*, 128: 57–65.
- Ibok, E. E. and Daniel, E. E. 2014. “Rural Water Supply and Sustainable Development in Nigeria: A Case Analysis of Akwa Ibom State.” *American Journal of Rural Development*, 2: 68–73.
- Idowu, O. A., Awomeso, J. A. and Martins, O. 2012. “An Evaluation of Demand for and Supply of Potable Water in an Urban Center of Abeokuta and Environs, Southwestern Nigeria.” *Water Resources Management*, 26: 2109–2121.
- Ihuah, P. W. and Kakulu, I. I. 2014. “Rural Water Supply Projects and Sustainable Development in Nigeria.” *Journal of Sustainable Development in Africa*, 16: 56–68.
- Ishaku, H. T., Majid, M. R. and Johar, F. 2012. “Rainwater Harvesting: An Alternative to Safe Water Supply in Nigerian Rural Communities.” *Water Resources Management*, 26: 295–305.
- Janke, J.R., Ng., S. and Bellisario, A. 2017. “An Inventory and Estimated Water Stored in Firn Fields, Glaciers, Debris Covered Glaciers, and Rock Glaciers in the Aconcagua River Basin, Chile.” *Geomorphology*, 296: 142-152.

- Jansz, S. 2011. *A Study into Rural Water Supply Sustainability in Niassa Province, Mozambique*. WaterAid Report, pp 60.
- Jimenez, A. and Perez-Foguet, A. 2011. "Water Point Mapping for the Analysis of Rural Water Supply Plans: Case Study from Tanzania." *Journal of Water Resources Planning and Management*, 137: 439–447.
- Koehler, J., Thomson, P. and Hope, R. 2015. "Pump-Priming Payments for Sustainable Water Services in Rural Africa." *World Development*, 74: 397–411.
- Koestler, A., Kahorha, J. and Biteete, L. 2014. "Supply Chain Analysis of Handpumps and Spare Parts in Eastern Democratic Republic of Congo." UNICEF, Norway.
- Koestler, L., Koestler, A., Koestler, M. A. and Koestler, V.J. 2010. "Improving Sustainability Using Incentives for Operation and Maintenance: The Concept of Water-Person Years." *Waterlines*, 29: 147–162.
- Lynch, W. 1984. "Handpumps in Rural Morocco." *Waterlines*, 3: 15–18.
- McNeill, D. 1985. "The Appraisal of Rural Water Supplies." *World Development*, 13: 1175–1178.
- McPherson, H. J. and McGarry, M. G. 1987. "User Participation and Implementation Strategies in Water and Sanitation Projects." *International Journal of Water Resources Development*, 3: 23–30.
- Moller, L. C. and Wacker, K. M. 2017. "Explaining Ethiopia's Growth Acceleration—The Role of Infrastructure and Macroeconomic Policy." *World Development*, 96: 198–215.
- Morgan, P. 1993. "Maintenance the Key to Handpump Survival." *Waterlines*, 11: 2–4.
- Mudege, N. 1993. "Handpump Maintenance in Zimbabwe." *Waterlines*, 11: 9–12.
- Mudgal, A. K. 1997. "India Hand Pump Revolution: Challenge and Change." Hand pump Technology Network Working Paper WP 01/97, UNICEF, New Delhi.
- Nasir, A., Ubokwe, S. O. and Isah, A. 2004. "Development of a Manually Operated Hand Pump for Rural Water Supply." *AU Journal of Technology*, 7: 187–192.
- Ndikumana, L. and Pickbourn, L. 2017. "The Impact of Foreign Aid Allocation on Access to Social Services in Sub-Saharan Africa: The Case of Water and Sanitation." *World Development*, 90: 104–114.
- Nekesa, J. and Kulanyi, R. 2012. "District Hand Pump Mechanics Associations in Uganda for Improved Operation and Maintenance of Rural Water-Supply Systems." *Waterlines*, 31: 172–173.
- Nnaji, C. C. and Mama, N. C. 2014. "Preliminary Assessment of Rainwater Harvesting Potential in Nigeria: Focus on Flood Mitigation and Domestic Water Supply." *Water Resources Management*, 28: 1907–1920.
- Owolabi, A. and Omotola, A. O. 1994. "Borehole Failures in Crystalline Rocks of SW Nigeria." *GeoJournal*, 34: 397–405.

- Parry-Jones, S., Reed, R. and Skinner, B. 2001. “Sustainable Handpump Projects in Africa: A Literature Review, Loughborough University.” Loughborough, UK.
- RCAP (Rural Community Assistance Partnership). 2010. “Still Living Without the Basics in the 21st Century: Analyzing the Availability of Water and Sanitation Services in the United States.” Washington, DC.
- Rural Water Supply Network. 2014. “Water Point Mapping: Indicators, Pump Functionality, Accuracy of GPS, Using and Sharing Data.” <http://www.uwasnet.org/Elgg/file/download/6889>.
- Sangodoyin, A. Y. 1993. “Hand-Pump Equipped Wells for Rural Transformation: Lesson from Oyo State.” *Nigerian Journal of Water Resources*, 1: 1–12.
- Schweitzer, R., Ward, R. and Lockwood, H. 2015. “Wash Sustainability Index Tool Assessment: Ethiopia.” USAID.
- Sene, K. J. and Farquharson, F.A.K. 1998. “Sampling Errors for Water Resources Design: The Need for Improved Hydrometry in Developing Countries.” *Water Resources Management*, 12: 121–138.
- Serrao-Neumann, S., Renouf, M., Kenway, S. J. and Choy, D. L. 2017. “Connecting Land-Use and Water Planning: Prospects for and Urban Water Metabolism Approach.” *Cities*, 60: 13–27.
- Shapley, L. 1953. “Additive and Non-Additive Set Functions.” PhD Thesis, Department of Mathematics, Princeton University.
- Shorrocks, A. F. 1980. “The Class of Additively Decomposable Inequality Measures.” *Econometrica*, 48: 613–624.
- . 1982. “Inequality Decomposition by Factor Components.” *Econometrica*, 50: 193–211.
- ’———. 1984. “Inequality Decomposition by Population Subgroups.” *Econometrica*, 6: 1369–1385.
- SNV. 2013. *Functionality: The Challenge to Sustain Rural Water Supply Services*. Practice Brief, Issue 5, October, The Hague, Netherlands.
- Steele, M.K. Forthcoming. “The Scaling of Urban Surface Water Abundance and Impairment with the City Size.” *Geomorphology*.
- Thibert, M. 2016. “Pump Preparation Project.” Doctors without Borders, MSF-OCA, Bokoro, Chad.
- Vance, J. D. 2016. *Hillbilly Elegy: A Memoir of a Family and Culture in Crisis*. Harper Collins.
- Walters, J. P. and Javernick-Will, A. N. 2015. “Long-Term Functionality of Rural Water Services in Developing Countries: A System Dynamics Approach to Understanding the Dynamic Interaction of Factors.” *Environmental Science and Technology*, 49: 5035–5043.
- WaterAid Tanzania. 2009. “Management for Sustainability: Practical Lessons from Three Studies on the Management of Rural Water Supply Schemes.”
- WHO (World Health Organization) and UNICEF (United Nations Children’s Fund). 2015. “25 Years Progress on Sanitation and Drinking Water: 2015 Update and MDG Assessment.” WHO, Geneva.

- Wilson, P. et al. Forthcoming. “A Hidden Crisis—Defining Functionality. UPGRO A Hidden Crisis—: Unravelling Past Failures for Future Success in Rural Water Supply.”
- World Bank. 2016. “Poverty Reduction in Africa in the Last Decade.” Poverty Global Practice, Washington, DC.
- World Bank. 2017. “A Wake Up Call: Nigeria Water Supply, Sanitation and Hygiene Poverty Diagnostic.” World Bank, Washington, DC.
- World Bank. Forthcoming. “Rural Water Metrics for Sustainability: A Global Framework.” World Bank, Washington, DC.

Table 1. Summary of Water Points' Non-Functionality Rates from Literature Review

Country	Year(s) of Survey	Study	% Non-Functional
Bangladesh	1974	McPherson and McGarry (1987)	50
Thailand	1974	McPherson and McGarry (1987)	50
India	1974	McPherson and McGarry (1987)	75
Global	Late 1970s	Cairncross et al. (1980)	30
Developing countries	1990s	Duti (2012)	30–40
Zimbabwe	1989	Cleaver (1991)	32
Sub-Saharan Africa	2008	Baumann (2009)	30
South Africa	1990s	Hazelton (2000)	50
Greater Afram (Ghana)	2010s	Fisher et al. (2015)	20.6*
Mozambique	2000s	Jansz (2011)	20
Malawi	2010s	Holm et al. (2015)	22*
Malawi	2010s	Holm et al. (2016)	39*
Ethiopia	2010	Schweitzer et al. (2015)	43
Tanzania	2014	Gill (2014)	
		Gill and Flachenburg (2015)	5.9*
Tanzania	2009	WaterAid (2009)	54

Note: *Studies of specific regions or states.

Table 2. Distribution of Improved Water Points

Sources	N	(%)
Protected spring	3,489	3.88
Protected dug well	5,920	6.59
Tube well or borehole	80,462	89.53
Total	89,721	100

Source: Authors' calculation based on NWSS (2015) survey data.

Table 3. Status of Different Sources of Improved Water

Improved Source	Functional and in Use	Functional but Not in Use	Functional and in Use but in Bad Shape	Non-functional	Total
Tube well or borehole	42,574	3,840	2,284	31,764	80,462
Protected dug well	3,603	302	256	1,759	5,920
Protected spring	2,449	183	55	802	3,489
Total	48,628	4,325	2,595	34,325	89,871

Source: Authors' calculation based on NWSS (2015) survey data.

Table 4. Breakdown of Independent Variables by Region for Water Points Aged 1–15 Years

	Total	North Central	North East	North West	South East	South South	South West
Type of Settlement							
Rural	27370	4466	5784	10046	672	2567	3835
Small Town	8075	1299	1470	2541	40	475	2250
Urban	6998	1030	801	1356	62	471	3278
Extraction Type							
Others	637	38	44	166	30	118	241
Hand Pump	27549	4490	6600	10997	235	834	4393
Motorized	14257	2267	1411	2780	509	2561	4729
Promoter							
Donors	3433	252	685	744	72	482	1198
FGN	11380	2413	3494	1621	280	917	2655
Local Government	10663	1591	907	5653	50	448	2014
NGO/CBO	2681	170	308	1596	44	269	294
Philanthropist	1906	657	200	373	71	209	396
State	11811	1567	2390	3822	237	1105	2690
Unknown	569	145	71	134	20	83	116
Is there WASHCOM/WCA in the community?							
No	27500	4876	5442	7466	655	2775	6286
Yes	14943	1919	2613	6477	119	738	3077
Groundwater Productivity							
High	15532	350	2250	9409	205	2026	1292
Low	19966	4150	2993	4454	0	438	7931
Low-Medium	1648	559	226	15	135	630	83
Medium	5139	1712	2567	8	429	397	26
Null	158	24	19	57	5	22	31
Groundwater Storage							
Null	87	11	43	30	0	3	0
High	12083	1	2035	6481	219	2082	1265
Low	19807	4233	3007	4226	2	409	7930
Low-Medium	2730	623	1109	340	166	452	40
Medium	7736	1927	1861	2866	387	567	128
Depth to Groundwater							
Medium	909	0	418	491	0	0	0
Shallow	14333	3540	1652	2132	462	1977	4570
Shallow- Medium	7342	8	1735	5599	0	0	0
Very-Shallow	19859	3247	4250	5721	312	1536	4793
Repairing Agents							
Donor	2757	425	230	1068	87	233	714
Federal Government	1176	118	154	158	83	232	431
LGA	10088	1018	884	6456	64	236	1430
Local Area Mechanics/Artis ans	20233	3995	5811	2961	326	2248	4892
NGO	704	80	58	172	34	72	288
State Water Agency	2386	208	314	567	136	379	782
WASHCOM	5099	951	604	2561	44	113	826
Availability of Spare Parts?							
No	19403	4086	3840	7101	332	1068	2976
Yes	23040	2709	4215	6842	442	2445	6387

Note: CBO = community-based organization; FGN = Federal Government of Nigeria; LGA = local government agency; NGO = non-governmental organization; WASHCOM = water, sanitation, and hygiene committee; WCA = water consumer association.

Source: Authors' calculation based on NWSS (2015) survey data.

Table 5. Regressions on Non-Functionality of Water Points Aged 1–15 Years (0 = functional 1 = non-functional)

	All Water Points	1 Year Old	3 to 6 Years Old	Older than 8 Years
Base Level: Type of Settlement = Rural				
Type of settlement = small town	-0.0140 [0.0282]	-0.0725 [0.0913]	-0.0376 [0.0449]	0.0690 [0.0537]
Type of settlement = urban	-0.176*** [0.0315]	-0.344*** [0.102]	-0.252*** [0.0511]	0.105 [0.0584]
Extraction type = others	0.256** [0.0853]	0.0439 [0.256]	0.450*** [0.133]	0.106 [0.167]
Base Level: Extraction Type = Hand Pump				
Extraction type = motorized	0.123*** [0.0250]	-0.219** [0.0803]	0.168*** [0.0398]	0.245*** [0.0483]
Promoter = donors	-0.323*** [0.0454]	-0.362** [0.131]	-0.219** [0.0689]	-0.431*** [0.103]
Base Level: Promoter = FGN				
Promoter = local government	-0.0861** [0.0330]	0.0258 [0.119]	-0.103 [0.0524]	-0.264*** [0.0631]
Promoter = NGO/CBO	-0.207*** [0.0525]	-0.180 [0.168]	-0.142 [0.0800]	-0.313** [0.117]
Promoter = philanthropist	-0.663*** [0.0585]	-0.439** [0.151]	-0.691*** [0.0927]	-0.600*** [0.127]
Promoter = state	0.117*** [0.0295]	-0.110 [0.0947]	0.0724 [0.0468]	0.129* [0.0598]
Promoter = unknown	0.0776 [0.0906]	0.413 [0.227]	0.119 [0.150]	-0.293 [0.184]
Base Level: WASH = No				
WASH = yes	-0.337*** [0.0263]	-0.321*** [0.0885]	-0.393*** [0.0415]	-0.262*** [0.0505]
GWPROD = low	-0.287*** [0.0735]	-0.0280 [0.244]	-0.438*** [0.116]	-0.125 [0.152]
GWPROD = low-medium	-0.406*** [0.0730]	0.00855 [0.241]	-0.563*** [0.113]	-0.127 [0.158]
GWPROD = medium	-0.0932 [0.0511]	-0.349* [0.172]	-0.161* [0.0811]	-0.00464 [0.102]
GWPROD = null	0.429* [0.180]	1.038 [0.629]	-0.0435 [0.264]	1.241** [0.443]
GWSTOR = null	1.049*** [0.241]	1.021 [0.638]	1.758*** [0.373]	1.139* [0.531]
Base Level: GWSTOR = High				
GWSTOR = low	0.618*** [0.0775]	0.287 [0.263]	0.780*** [0.122]	0.555*** [0.157]
GWSTOR = low-medium	0.756*** [0.0583]	0.738*** [0.209]	0.785*** [0.0902]	0.750*** [0.121]
GWSTOR = medium	0.720*** [0.0452]	0.901*** [0.165]	0.781*** [0.0720]	0.736*** [0.0817]
Base Level: DTGWT = Shallow				
DTGWT = shallow-medium	0.0813 [0.0433]	0.189 [0.152]	0.136* [0.0678]	-0.0493 [0.0835]
DTGWT = very shallow	0.0296 [0.0245]	-0.0689 [0.0767]	0.0214 [0.0391]	0.0627 [0.0480]
DTGWT = medium	-0.383***	-0.239	-0.477**	-0.253

	[0.108]	[0.319]	[0.174]	[0.181]
Who repairs = donor	-0.192***	0.107	-0.415***	-0.112
	[0.0516]	[0.171]	[0.0830]	[0.0963]
Who repairs = federal government	0.511***	0.959***	0.531***	0.409**
	[0.0691]	[0.186]	[0.113]	[0.150]
Base Level: Who Repairs = LGA				
Who repairs = local area mechanics/artisans	0.00389	0.172	0.00455	-0.138*
	[0.0313]	[0.111]	[0.0499]	[0.0580]
Who repairs = NGO	-0.102	0.853**	-0.0836	-0.563**
	[0.0866]	[0.261]	[0.131]	[0.186]
Who repairs = state water agency	0.241***	0.612***	0.0960	0.255*
	[0.0517]	[0.167]	[0.0816]	[0.0993]
Who repairs = WASHCOM	-0.224***	-0.165	-0.207**	-0.210*
	[0.0457]	[0.151]	[0.0743]	[0.0837]
Base Level: Availability of Spare Parts = No				
Availability of spare parts = yes	-0.336***	-0.371***	-0.378***	-0.351***
	[0.0224]	[0.0722]	[0.0360]	[0.0432]
Zone = north central	0.504***	0.0996	0.502***	0.529***
	[0.0384]	[0.121]	[0.0606]	[0.0842]
Base Level: Zone = Northeast				
Zone = northwest	-0.300***	-0.749***	-0.267***	-0.383***
	[0.0404]	[0.141]	[0.0622]	[0.0871]
Zone = southeast	0.378***	-0.0895	0.445***	0.480**
	[0.0833]	[0.259]	[0.131]	[0.174]
Zone = south-south	0.951***	0.613***	0.851***	1.283***
	[0.0510]	[0.158]	[0.0806]	[0.108]
Zone = southwest	0.788***	0.339**	0.765***	0.867***
	[0.0396]	[0.121]	[0.0624]	[0.0853]
Constant	-0.895***	-1.036***	-0.830***	-0.721***
	[0.0567]	[0.190]	[0.0878]	[0.120]
Observations	42443	4945	16823	11741
Pseudo R ²	0.0728	0.0723	0.0691	0.1143

Source: Authors' calculation based on NWSS (2015) survey data.

Notes: Standard errors in brackets. GWSTOR = groundwater storage (depth in mm); GWPROD = groundwater productivity (liters/second); DTGWT = depth to groundwater (mbgl = meters below ground level); CBO = community-based organization; FGN = Federal Government of Nigeria; LGA = local government area; NGO = non-governmental organization; WASHCOM = water, sanitation, and hygiene committee. The base-level category for ordinal variables is displayed. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6. Shapley Values and Groups

Shapley Groups	Variables	Failure of Water Points 1 Year Old		Failure of Water Points Aged 3 to 6 Years		Failure of Water Points 8 Years or Older	
		Shapley Value	Percent Estimate	Shapley Value	Percent Estimate	Shapley Value	Percent Estimate
Political Regions	Political zone	0.0184	0.2553	0.0220	0.3191	0.0471	0.4118
Hydrogeology	GWPROD/ DTWAFRICA/ GWSTOR	0.0127	0.1760	0.0146	0.2109	0.0249	0.2182
Settlement Type	Type of settlement	0.0020	0.0283	0.0009	0.0131	0.0009	0.0081
Promoters	Promoters	0.0080	0.1112	0.0062	0.0900	0.0123	0.1075
Technology Type	Extraction type	0.0009	0.0124	0.0043	0.0618	0.0098	0.0859
WASHCOM	Is there WASHCOM/ WCA in the community?	0.0075	0.1032	0.0080	0.1164	0.0047	0.0408
Repair and Maintenance	Who repairs/ availability of spare parts	0.0227	0.3136	0.0130	0.1886	0.0146	0.1277
Total		0.0723	1.0000	0.0691	1.0000	0.1143	1.0000

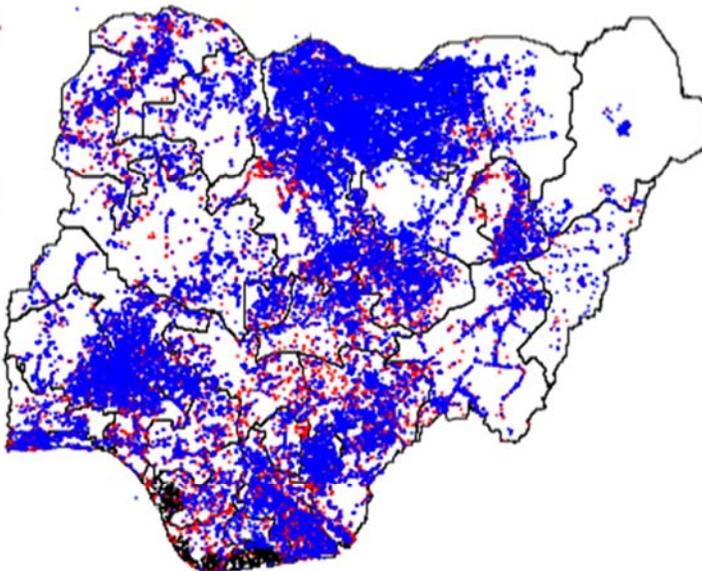
Source: Authors' calculation based on NWSS (2015) survey data.

Note: GWSTOR = groundwater storage (depth in millimeters); GWPROD = groundwater productivity (liters/second); DTGWT = depth to groundwater (mbgl = meters below ground level); CBO = community-based organization; FGN = Federal Government of Nigeria; LGA = Local Government Agency; NGO = non-governmental organization; WASHCOM = water, sanitation, and hygiene committee; WCA = water consumer association.

Figure 1. Map of Water Points Covered by the NWSS Survey

Map of Water Points in the NWSS Survey

Water Point (N) = 89358

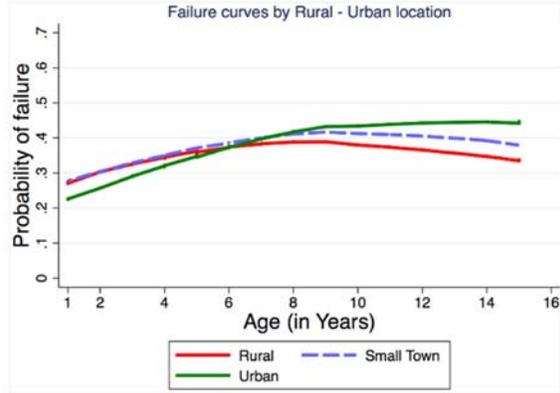


- Non-Functional (N= 34148)
- Functional (N =55210)

The graph includes only those water points
which have reliable coordinates for latitude and longitude

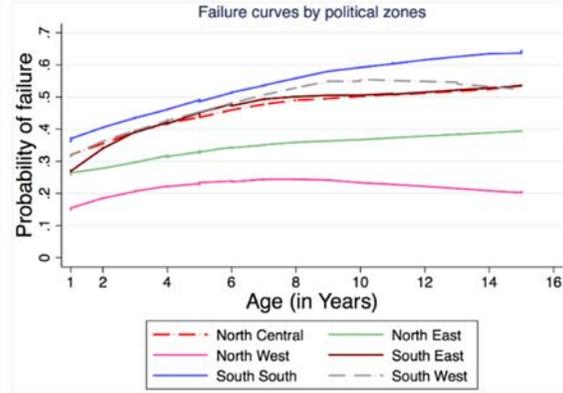
Source: Authors' calculation based on NWSS (2015) survey data.

Figure 2. Failure Curves by Rural-Urban Location



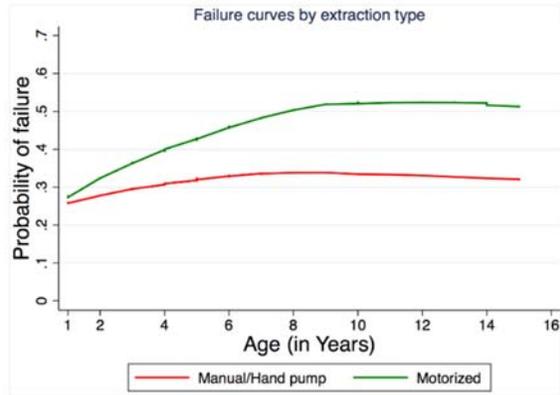
Source: Authors' calculation based on NWSS (2015) survey data.

Figure 3. Failure Curves by Political Zone



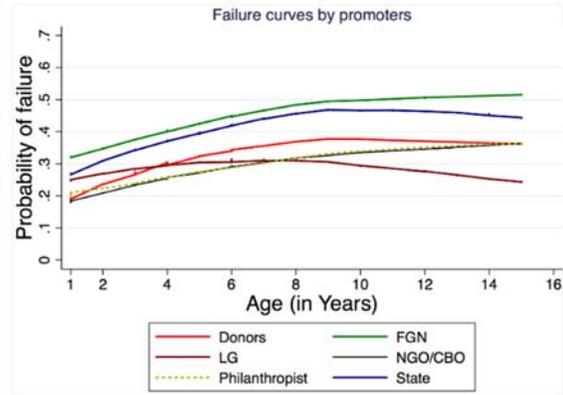
Source: Authors' calculation based on NWSS (2015) survey data.

Figure 4. Failure Curves by Extraction Type



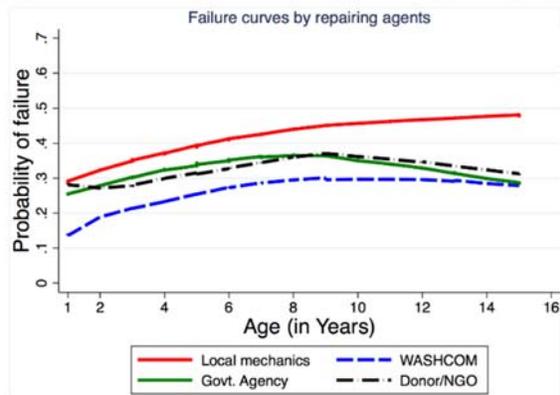
Source: Authors' calculation based on NWSS (2015) survey data.

Figure 5. Failure Curves by Promoter Type



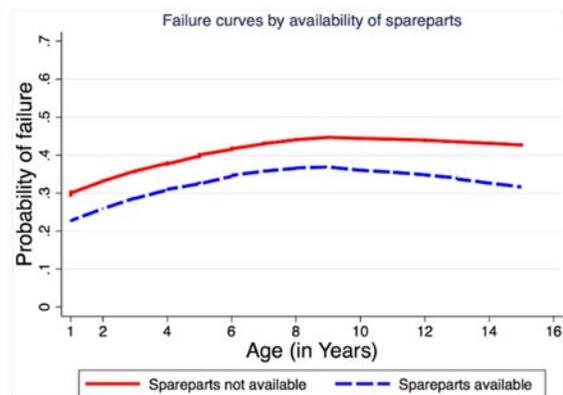
Note: CBO = community-based organization; FGN = Federal Government of Nigeria; LG = local government; NGO = non-governmental organization.
Source: Authors' calculation based on NWSS (2015) survey data.

Figure 6. Failure Curves by Type of Repairing Agent



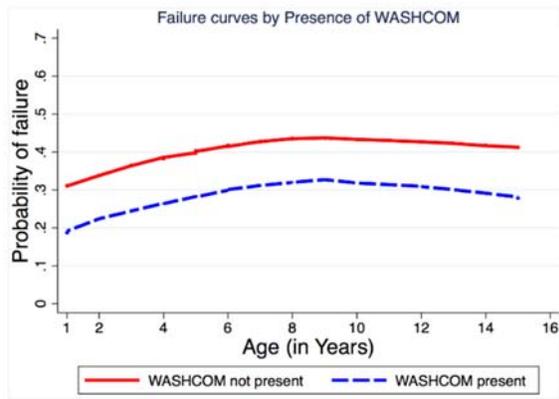
Note: NGO = non-governmental organization; WASHCOM = water, sanitation, and hygiene committee.
Source: Authors' calculation based on NWSS (2015) survey data.

Figure 7. Failure Curves by Availability of Spare Parts



Source: Authors' calculation based on NWSS (2015) survey data.

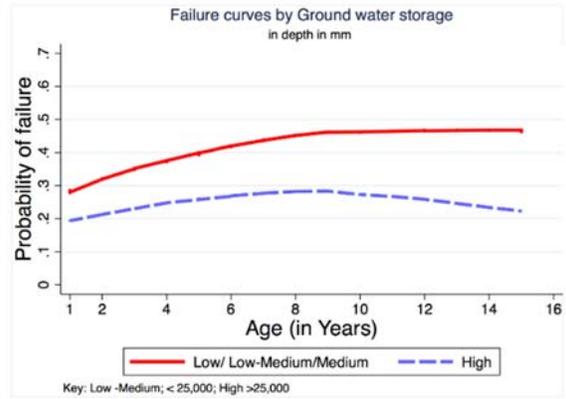
Figure 8. Failure Curves by Presence of WASHCOM



Source: Authors' calculation based on NWSS (2015) survey data.

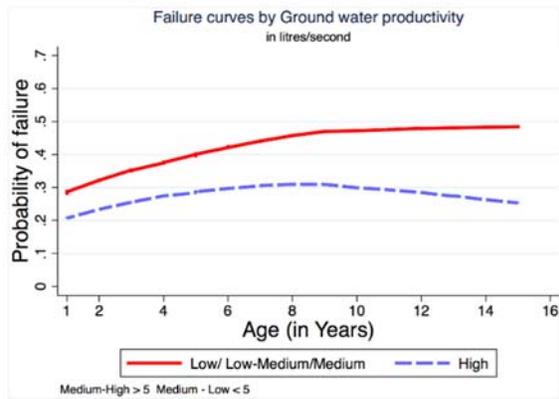
Note: WASHCOM = water, sanitation, and hygiene committee.

Figure 9. Failure Curves by Groundwater Storage



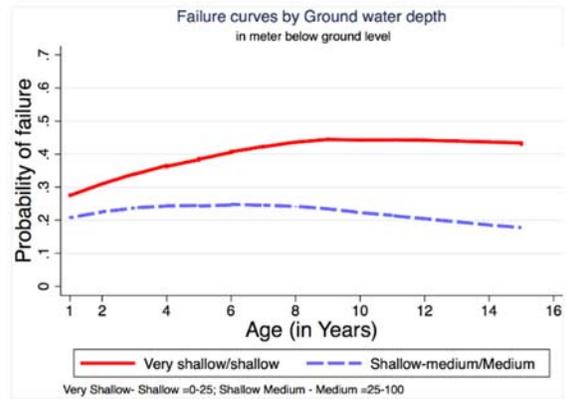
Source: Authors' calculation based on NWSS (2015) survey data.

Figure 10. Failure Curves by Groundwater Productivity



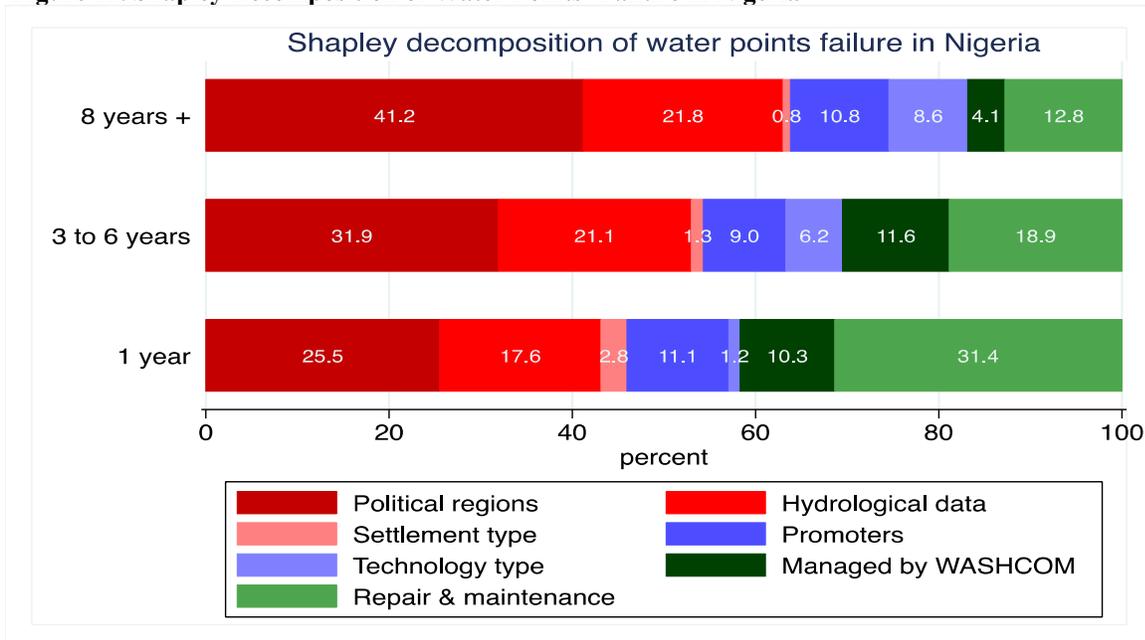
Source: Authors' calculation based on NWSS (2015) survey data.

Figure 11. Failure Curves by Groundwater Depth



Source: Authors' calculation based on NWSS (2015) survey data.

Figure 12. Shapley Decomposition of Water Points' Failure in Nigeria



Source: Authors' calculation based on NWSS (2015) survey data.

Note: WASHCOM = water, sanitation, and hygiene committee.