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Why Do So Many Water Points Fail in Tanzania?

An Empirical Analysis of Contributing Factors

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Abstract

According to the 2015 Tanzania Water Point Mapping data, about 29 percent of all water points are non-functional, out of which 20 percent failed within the first year. This paper analyzes the various factors which impact water point failure and measures the relative contributions of these determinants. The results indicate that water points managed by village committees had a much higher likelihood of failure than those managed by private operators or water authority. Factors that cannot be modified such as hydrogeological factors play a major role in determining water points failure during the first year after installation. However, management type as well as the type of pump and technology matter considerably more in the short and medium term.

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1. Background

Despite the significant economic progress that Tanzania has experienced over the years and considerable investments in water supply infrastructure through both government and donor funding, a significant proportion of its population remains without proper access to improved drinking water. While one of the agreed Millennium Development Goals (MDGs) is to halve the proportion of people that do not have access to water services by 2015, Tanzania only increased its access to improved drinking water from 54 percent to 56 percent (JMP, 2015). The country now faces an even more difficult task of meeting the Sustainable Development Goals (SDGs) to provide universal coverage of safe water by 2030.

Despite its efforts through the two phases of the Water Sector Development Program (WSDP), one persistent problem that has adversely affected the country's effort in increasing access to improved water services is the prevailing high levels of non-functionality or failures of its current water infrastructures and in particular, water points. Technology constraints also play an important role (de Bont et al., 2019). This situation is not unique to Tanzania. Water point failures have been documented by a number of studies across the Sub-Saharan African region. In countries such as Nigeria (Andres et al., 2018) and Ghana (Fisher et al., 2015), water points tend to fail frequently, particularly during the early years after construction. The situation is similar in Mozambique (Jansz, 2011), Uganda (Nekesa & Kulanyi, 2012) and Ethiopia (Alexander et al., 2015; Schweitzer et al., 2015). However, evidence indicates that the problem of water point failures may be relatively more serious in Tanzania with some estimates putting the figure as high as 44 percent (Banks & Furey, 2016)

The importance of access to water supply cannot be overstated. Apart from meeting the human necessity of water, it has immediate health impacts (Hyland and Russ, 2019) which in turn affects other developmental outcomes including education attainment and even long run poverty outcomes (Zhang and Xu, 2016; Mangyo, 2008; Alderman et al., 2001). Evidence indicates that lack of functioning infrastructure will undermine economic growth (Agenor, 2010; Barbier, 2004). Moreover, evidence also indicates that infrastructure—including water and sanitation—is likely to offset moderate macroeconomic shortcomings during the initial stages of economic development (Moller and Wacker, 2017; Gibson and Rioja, 2017; Amann et al., 2016).

In this paper, we utilize information from the Tanzania Water Point Mapping (WPM) compiled in November 2016 to identify the reasons for the failure of water points in the country. Using a variety of statistical methods, we seek to understand the impact of the following factors on water points failure: (i) the age, (ii) technology type; (iii) geographic patterns; (iv) hydrological characteristics; (v) type of promoter; and (vi) day to day management type of these points. The results indicate that water points

managed by village committees had a much higher likelihood of failure than those managed by private operators or water authority. Factors that cannot be modified such as hydrogeological factors play a major role in determining water points failure during the first year after installation. However, management type as well as the type of pump and technology matter considerably more in the short and medium term. These findings highlight the importance of utilizing information on the hydrological characteristics in the design, construction and maintenance of water points. On the other hand, the technology of water points is a more important factor in explaining failure over time, controlling for other factors.

2. Water in the Tanzania Context

Tanzania is the fourth most populous country in Sub-Saharan Africa with more than 55.6 million people[2]. According to UN Water (2013), Tanzania is 'economically water scarce' and in 2012, its annual renewable water resource was estimated to be around 89km^3, about 2000m^3 of per capita availability. This reportedly fell to 1,952m^3 in 2014, and is projected to decrease to 873m^3 by 2035. In addition to its rapidly expanding population, there are also other significant pressures on Tanzania's water resources stemming mostly from its economic activities (Miller and Doyle, 2014; Lein, 2004). As in most other countries, agricultural sector for example, by far consumes a large portion of its withdrawn water (roughly 90 percent of total water withdrawals (UN-Water, 2013)[3].

Despite its economic progress over the years, its water infrastructure has failed to keep pace with population increase. As a result, it is unable to provide adequate service coverage to its population[4]. This is reflected in the mere 2 percentage points increase in the improved water coverage between 1990 and 2015. In fact, in urban areas, due to population growth and migration, improved water coverage actually fell from 92 percent in 1990 to 77 percent by 2015 (JMP, 2015). In rural areas on the other hand, improved water coverage is estimated to be at 45 percent in 2015 (JMP, 2015).

To address the shortfalls in water supply infrastructure and to improve water resource management throughout the country, in the wake of the Millennium Development Goals (MDG) the Tanzania government developed the Water Sector Development Program (WSDP) which is set to run

[2] Data are from World Development Indicators (database). 2016. World Bank, Washington, DC. http://databank.worldbank.org/data/home.aspx

[3] Other than that, the country's climate and hence rainfall pattern also plays a significant role in influencing the supply of water resources. The country experiences a monsoon-type climate with annual rainfall ranging from a high of >1000mm in the coastal and highland areas to a low of around 600mm in the dryer central and northern areas. In the latter, the dry season can last up to 7 months, and rivers tend to run dry (Basalirwa et al., 1999). The El Niño/La Niña South Oscillation (ENSO) phenomenon can also result in substantial impacts on intra-seasonal rainfall variability and inter-annual rainfall variability is a key challenge resulting in droughts and floods (White and Tourre, 2007; Nicholson & Kim, 1997). Projections of Tanzania's future rainfall patterns based on climate change vary widely, which results in a challenging environment for planning and investment (Basalirwa et al., 1999). There is a general consensus that total rainfall is set to increase in parts of the country (Cioffi et al., 2016), although the already dry central area is potentially likely to experience a decrease in annual precipitation levels. (Cioffi et al., 2016)

[4] Reported in UNPD, 2014 from JMP 2015

between 2006 and 2025, with the support of development partners (Carlitz 2017). The WSDP comprises of three smaller programs: 1) water resources management; 2) Rural Water Supply and Sanitation Program (RWSSP); and 3) urban water supply and sewerage. At the time of the initiation of RWSSP, water coverage in rural areas in Tanzania was estimated to be around 53 percent based on its 2002 Population and Housing Census (Ministry of Water, 2006)[5]. The RWSSP aimed at improving water coverage to its rural population to 1) at least 65 percent by 2010; 2) 74 percent by mid-2015; and 3) at least 90 percent by 2025[6]. The program is also largely funded by the World Bank and other international donors and is one of the biggest in the African region (Jimenez and Perez-Foguet, 2010; Gine and Perez-Foguet, 2008; World Bank, 2008).

During the first phase of the WSDP (2007-15) implementation arrangements were decentralized to the district levels (Local Government Agencies- LGAs), with the intention of providing better technical support to the rural communities. The WSDP adopted a Community Driven Development (CDD) approach in the rural water sector, where the village community and its institution, the COWSO (Community Owned Water Supply Organizations), were given full ownership of their rural water system along with the associated management responsibility. Under this arrangement, the Ministry of Water and Irrigation (MOWI) set policies and guidelines and provided technical support to the Local Government Authorities (LGAs). The actual implementation of new water projects is facilitated by the LGAs under the President's Office of Regional and Local Government (PORALG).

One of the more ambitious projects that went hand-in-hand with the country's effort in improving water access was the creation of its Water Point Mapping (WPM) database. With the assistance of Water Aid which has previously done similar work in Malawi (Stoupy & Sudgen, 2003), the country implemented the WPM with the goal of gathering geographical data on all improved water points in an area, in addition to management, technical and demographic information. The information collected was used to create a baseline of accurate, reliable and up to date information on all improved water points in addition to serving as a benchmark for future monitoring efforts, improving decision making as well as allocation of resources for rural water supply services (Welle, 2010).

Through the implementation of the first phase of the WSDP and by extension, the RWSSP, an additional 8,285 water points have been installed covering almost 1.9 million additional beneficiaries. This has increased rural water coverage from 55 percent in 2007 – roughly at the start of the program – to

[5] The figures reported in JMP (2015) were lower than those reported in the 2002 Housing Census. While population growth pressures could have influenced the figures, the difference is most likely due to the different definition of improved water points that were adopted by the two databases. Under the WSDP, the WPM have since adopted the definition of improved water points that is consistent with the internationally accepted definition by WHO/UNICEF (2000). The figures presented in JMP (2015) would be based on this definition.

[6] Goals that were set partly through the commitments of the National Strategy for Growth and Reduction of Poverty also known as MKUKUTA and by the Millennium Development Goals (MDG) respectively.

about 57 percent in 2012. The number of people with improved water access throughout the country on the other hand has also increased from 21.5 million in 2007 to 22.4 million in 2012. While progress has been made, the MDG targets were not met. Meeting the targets will be difficult especially when the country has failed to meet its 2010 target (65 percent of water coverage for its rural population).

Part of the underwhelming success of WSDP's first phase can be attributed to the pressures of rapid population growth as discussed earlier. However, there were several other challenges. Although the WSDP was successful in changing the institutional arrangements in the sector, systemic challenges in terms of capacity, operational costs, data accountability and coordination put the program's implementation and sustainability at risk. At the village level for example, the village committees or the COWSOs have limited technical and managerial capacity while at the central government level, the ministry has struggled to provide timely support, guidelines and budget to its implementation partners (LGAs). Additionally, the high operating costs of certain types of water pumps that were selected by the participating communities resulted in approximately half of the population paying more than 5 percent of their household income for water access[7]. The process of data collection and management through MOWI's ambitious project to map all the water points in the country was not fully institutionalized. Hence it is difficult to hold the district water engineers accountable for dealing with non-functionality. Lastly, while coordination between MOWI and other participating parties such as PORALG and LGAs have steadily improved, local level planners and decision makers rarely receive feedback on implementation issues, thus adversely affecting policy reforms and resource allocations at the national level. WaterAid (2009) provided several recommendations that could potentially improve the country's rural water access: instituting, monitoring and regulation of COWSOs, improvement of the WPM data[8]; promoting more community participation; providing autonomy in managing their water infrastructure; and the provision of technical support for COWSOs to conduct complex maintenance works.

With around 21 million Tanzanians still lacking access to improved water, the country fell short of reaching its Millennium Development Goal (MDG) targets to halve the proportion of people without improved drinking water and sanitation in 1990, by 2015. The new Sustainable Development Goal (SDG) of reaching universal access to safe water and sanitation by 2030, will prove even more challenging. This goal includes not only providing water access to the population, but also ensuring a continuous supply of sufficient, affordable and clean water for all. While the World Bank's support has made headway in improving access to rural water supply in the country through Rural Water Supply and Sanitation

[7] It is reported that some were paying close to 30 percent of the household income. See DFID (2016): "Measuring and Maximizing Value for Money of Rural Water Supply (RWS) Investments in TZ".

[8] Better WPM data is essential to the success of Tanzania's water targets. According to Verplanke and Georgiadou (2017) and Water Aid (2009) the WPM database for Tanzania is riddled with errors and inaccuracies.

Program (RWSSP) there is still an urgent need to reconfigure the institutional framework and retool the sustainability approach to achieve a lasting and high-quality delivery of water services in Tanzania.

3. Literature Review

In recent years, statistics on water points functionality have been collected in a number of countries. One of the more comprehensive database is Akvo (2015) developed by the the Akvo Foundation. It is currently monitoring data for over 120,000 water points across 37 countries. Globally, 20 percent of the water points are not functional while an additional 10 percent are functional but with problems[9]. Other studies indicate that in Sub-Saharan Africa, it is estimated that about 30 percent to 36 percent of water points are not functional (Baumann, 2009; RWSN, 2009) with countries such as Cote d'Ivoire (65 percent) and Sierra Leone (65 percent) experiencing high rates of water points failures and countries such as Madagascar (10 percent) and Benin (22 percent) experiencing lower levels (Table 1, Annex)[10].

Another problem is that there is no widely agreed upon definition of functionality. This is an important aspect of data accuracy, because the inaccuracy of the data collected – especially when the definition of functionality is not clearly defined – could adversely affect programs that are designed based on flawed data (Jimenez & Perez-Foguet, 2010). While most surveys use the binary distinction (Cairncross et al., 1980) of working or not working, which at times is considered insufficient (Carter & Ross, 2016), other surveys included the concept of partial functionality (Wilson et al., 2016). Initiatives such as the Akvo Flow and the Water Point Data Exchange (WPDx)[11] were created to not only collect information and indicators on water points across different countries but also harmonize the data definitions which are often collected and measured differently. A recent World Bank study which analyzes a range of indicators from countries and development partners, including 20 national monitoring systems and 20 monitoring frameworks from donors proposed a shortlist of indicators and associated metrics as a global framework: (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).

[9] Additionally, the Water Point Data Exchange (WPDx) was also launched in May 2015 with the aim of compiling and harmonizing statistics of water points globally which are often collected and shared using unique approaches. Data from Akvo Flow for example will also be shared on WPDx.

[10]

[11] WPDx's website: https://www.waterpointdata.org/

Previous studies in the literature on water point functionality found several factors that contribute to their sustainability in the long run. These include technical conditions such as construction, maintenance and age (O`Keefe-O'Donovan, 2012), social conditions such as competency and autonomy in managing the water points (Marks et al., 2014; Harvey & Reed, 2007), financial conditions such as funds for maintenance (Foster, 2013; O`Keefe-O'Donovan, 2012) and tariffs (Sayre and Taraz, 2019), as well as hydrological determinants such as changing water tables or groundwater productivity (Andres et al., 2018; Fisher et al., 2015; Miller and Doyle, 2014; Harvey, 2004). Additionally, Baumann (2009) suggests that these different conditions could be categorized as "soft" and "hard". "Soft" conditions include community ownership, a perceived need for the water point, and user skills, behaviors, norms, and practices. "Hard" conditions include human resources, financial resources and suitable technologies.

One of the primary factors that can be considered as a "hard" condition is the continuous maintenance or management of water points (Koestler et al., 2010; Morgan, 1993; Mudege, 1993). While the likelihood of water points becoming dysfunctional, increases with age (Banks & Furey, 2016; Foster 2013; O`Keefe-O'Donovan, 2012), it can be mitigated to a large extent by proper maintenance. In Tanzania for example, it is estimated that 27 percent of water points became dysfunctional when they reach year two (Banks & Furey, 2016). Furthermore, Gondwe and Rukiko (1987) documented the lack of maintenance as a contributing factor to water points and schemes failure in Tanzania. Additionally, maintenance itself is more important than technology in sustaining water points functionality (Mudege, 1993). Evidence indicates that lack of maintenance results in water points failure as in in the case of Morocco in the early 1980s (Lynch, 1984). Meanwhile, for Mexico studies indicate a bias towards new water infrastructure rather than maintaining existing ones (Gibson & Rioja, 2017; McNeill, 1985). The reduction of post-installation abandonment would thus improve the functionality and performance of these water points (Carter & Ross, 2016).

The cost of maintaining and sustaining water systems has been also emphasized (Whittington et al., 1989) along with the availability of spare parts when needed (Gill & Flachenburg, 2015; Koestler et al., 2014;).[12] Furthermore it is also potentially cheaper to maintain than to install new water points (Agarwal et al., 2015)[13]. Maintenance activities could be sustained by user fees, thus contributing to the functionality of the water points in the long run (Foster, 2013). For Tanzania, using regression and Bayesian network (BN) analyses, Cronk and Bartram (2017) found that the functionality of water points is better sustained when a steady flow of funds is available (i.e when fees are collected on a monthly basis) for maintaining the water points rather than in response to a system breakdown.

[12] In some cases, politics also play an important role in the maintenance of such infrastructure (Carlitz, 2017).
[13] Notwithstanding transportation costs, the cost of maintaining water points could be as cheap as $10 while the cost of installing new ones could be more than $1000

While the role of maintenance is crucial for the sustainability of water points, the manner in which the water points are maintained or managed is also important. This is the "soft" condition suggested by Baumann (2009) although the evidence is not clear. Cronk and Bartram (2017) found that water points managed by private operators in Tanzania and Nigeria were more functional than those managed by the local communities. Meanwhile, with increasing ownership of the community participation in waterpoints management, sustainability can be improved. Holm et al., (2016) for example suggested that the sustainability of water points in Malawi could be improved if the communities were given autonomy in deciding the type of water points to be installed. This is also supported by Gill (2014) and Gill and Flachenburg (2015) who found that water points were better sustained through increased ownership by communities, and by WaterAid (2009) which found that more autonomous community groups such as Water User Groups and Water User Associations were more successful in sustaining water points. While private operators remain a viable alternative for the management of waterpoints, there is a risk of profiteering which will be detrimental to the expansion of coverage and sustainability of waterpoints in underserved populations (WaterAid, 2009). Finally, community management of water points can also be useful in terms of pooling maintenance and financial risks (Koehler et al., 2015)[14].

A number of studies also found that functionality of water points post installation, is affected by technology or its type. This is a "hard" condition under Baumann's definition. In Tanzania, Cronk and Bartram (2017) found that Nira handpumps were more functional than Afridev and India Mark II handpumps. Similarly, using data mining techniques, Chowdavarapu and Manikanandan (2016) showed that the extraction and water point type significantly predicts functionality. In addition, there could be an endogenous relationship regarding the observed high levels of non- functionality of water points. Certain types of water pumps are more expensive to sustain than others, and this could be challenging for communities which lacked the financial resources and hence are unable to replace or repair water pumps, leaving them dysfunctional. Meanwhile, a survey of 512 water points in Kenya for example found that 44 percent of submersible pumps were not functioning while only 2 percent of handpumps were not (Goodall et al., 2016). Similar results were found for Timor Leste (Willets, 2012).

Finally, a number of studies have also found the importance of hydrological factors in explaining water point functionality. For Tanzania, Fisher (2015) found a statistically significant relationship between functionality and groundwater storage. Water points in areas of low storage is associated with higher functionality. Similarly, using data from the 2015 Nigeria National Water and Sanitation Survey, Andres et al. (2018) found that hydrogeological factors are significant in explaining water point

[14] Additionally, Koehler et al. (2015) also suggested that the sustainability of rural water supply can be further improved by taking advantage of advances in monitoring and payment technologies.

functionality. In fact, among water points that are one-year old, hydrogeological factors such as groundwater productivity, groundwater storage and depth to groundwater have the greatest effect among other factors on their functionality.

4. Data and Methodology

(a) Water Point Mapping Data

This study uses the WPM data compiled in November 2016)[15]. The analysis made use of data on 40,917 water points out of a total of 83,295. This final figure was derived after we 1) restricted our sample to those between 1 and 20 years old; 2) removed other water schemes, defined as a water point with multiple taps; 3) identified other additional duplicates; and 4) dropped water points with incomplete information[16]. Information pertaining to the settlement type, types of pump, types of promoters and water source is found in the WPM dataset, in addition to the functionality status of the water points. Following Andres et al., (2018) and Fisher (2015) a number of hydrological information were combined with the WPM dataset which were obtained from the British Geological Survey (BGS) (MacDonald et al., 2012). The hydrological database included groundwater productivity[17], groundwater storage[18] and depth to groundwater[19]. Each data were presented in the form of a map with a 5km resolution grid and they were geospatially matched to each water point available in the WPM dataset where possible. The water points were matched such that only about one percent of water points in the dataset did not have at least one of those measurements.

(b) Methodology and Empirical Strategy

First, Locally Weighted Scatterplot Smoothing ("Lowess Smoothing" of running-line least squares) is employed to estimate a locally weighted non-parametric regression of 'non-*functionality'* (0,1) on age in years (1<age<15) for the water points in our data. Lowess Smoothing Curves across the different subgroups of the water point characteristics such as the types of pumps and their management type were also estimated to analyze the association between age and the probability of failure.

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[15] The distribution of water points is shown in the Map of Tanzania (figure 17).

[16] As Verplanke and Georgiadou (2017) highlighted, errors in the dataset such as the double counting of water points are common within the WPM data.

[17] The groundwater productivity map indicates the borehole yields that can reasonably be expected in different hydrogeological units (MacDonald, 2012). Definitions can be found at: http://www.bgs.ac.uk/research/groundwater/international/africangroundwater/mapsDownload.html

[18] Groundwater storage was estimated by combining the saturated aquifer thickness and effective porosity of aquifers across Africa. For each aquifer flow/storage type an effective porosity range was assigned based on a series of studies across Africa and surrogates in other parts of the world (MacDonald et al., 2012).

[19] Depth to groundwater was modelled using an empirical rules-based approach, where depth to groundwater was assigned according to rainfall and aquifer type, as well as proximity to rivers (MacDonald et al., 2012).

Second, to investigate the factors contributing to the failure or non-functionality of water points in our study, a series of logistic regression analyses were estimated using the following equation:

$$NON\text{-}FUNCT = \beta_0 + \beta_1 AGE_x + \beta_2 AGESQ + \beta_3 URBAN + \beta_4 ZONE + \beta_5 BODY + \beta_6 PROMOTER + \beta_7 PUMP + \beta_8 GRWPRODUCT + \beta_9 GRWSTORAGE + \beta_{10} DEPTH + \beta + \varepsilon$$

The dependent variable is the likelihood that the water point is non-functional (NON-FUNCT) which is a binary variable where 0 denotes one that is functioning and 1 denotes non-functional. Following O`Keefe-O'Donovan (2012) and Komives et al (2008) , the age (AGE and AGESQ) of water points is expected to be positively associated with higher rates of failures. URBAN denotes household living in the urban areas and there is no particular expectation regarding this variable. Additionally, we also account for the different geographical zones (ZONES) which separates the water points into lake, central, coastal, northern and southern highlands. These zones control for the unobserved characteristics common to them. In addition, we also control for the managing body (BODY) of the water points. These are village committee including COWSO, water authority board and government and private service providers. Similarly, we also account for the promoters (PROMOTER) of the waterpoints who are either private, donors or others. Additionally, we also control for the type of pump (PUMP) for each water point. Finally, following Andres et al (2018) we include several variables that represent the hydrogeological conditions of the terrain where the water point is located. These measures include groundwater productivity (GRWPRODUCT), ground water storage (GRWSTORAGE) and depth to groundwater (DEPTH). For the purposes of the analysis, these potential determinants of failure are grouped together as follows: those that are one year old, between 2 and 4 years old, between 5 and 10 years old and those that are older than 11 years. Subsequently, using the results from our logistic regression estimates, we also apply Shapley (1953) decomposition to analyze the relative contributions of these factors to the probability of failure[20]. Shorrock's (1984; 1982; 1980) application of Shapley decomposition is used to study the contribution of different determinants of water point functionality utilizing regression analysis.

Let S be the aggregate indicator which measures water scheme outcomes, X_k , where k = 1,2, ….m be a set of factors contributing to the value of S. The following equation can be written:

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

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 be equal to the sum of m contributions to water scheme functionality outcomes. These X include the explanatory variables of

[20] In studies of determinants of poverty for example, the Shapley decomposition is often used to evaluate the contribution of each determining factor by analyzing the decomposition of the observed variation or R-squared value.

functionality outcomes used in the linear probability regression. The relative shares of the variation in water point failure of the explanatory variables such as age, hydrology, localities, zones, pump type, promoter and management body are decomposed to explain the contribution of each to the likelihood of failure in each of these three age groups.

(c) Descriptive Statistics

Table 2 presents the characteristics of water points by different geographical zones. 29 percent of all water points are non-functional, and this varies by regions with the Northern zone and Southern highlands zone having the lowest rates at 24 percent and 25 percent respectively while the coastal and central zone was the highest at 33 percent each. 62 percent of the water points are situated in areas with low-moderate groundwater productivity, while 20 percent are situated in moderately productive groundwater areas and 14 percent in highly productive areas. The groundwater productivity of water points also varied considerably by regions. Low-moderate groundwater productivity accounted for 89 percent of water points in the Central zone but only 48 percent in the Northern zone, with others in between. This is not surprising as Tanzania's central zone is typically drier and hotter than the rest of the country,

For groundwater storage, 45 percent of the water points in the dataset are situated in areas with low groundwater storage while another 35 percent are situated in areas with low-medium groundwater storage and additional 19 percent in high groundwater storage areas. Again, there is considerable variation among the regions with only 30 percent of all water points in the Coastal zone having low groundwater storage whereas the same is true for 81 percent of all water points in the Central zone. For depth to groundwater, about 68 percent of water points are situated in areas with very shallow depth to the presence of groundwater. Again there is considerable variation among the regions. 81 percent of the water points in the Southern Highlands zone are in areas with very shallow depth compared to 64 percent in the Central zone and only 46 percent in the Lake Zone.

89 percent of all water points in the dataset are located in rural areas with small variations across the various regions. The additional 11 percent are located in urban areas, but it varied from only 4 percent of water points in the Northern zone to 24 percent in the Central zone. In terms of the ecological class, 58 percent of water points are situated in areas with shrub and herb vegetation and an additional 21 percent are situated in forests and woodlands. Shrub and herbs areas accounted for 64 percent of water points in the Lake zone while it was only 46 percent in the Central zone. Forest and woodland accounted for 33 percent in the Coastal zone but only 1 percent in the Central zone. Finally, desert and semi-desert account for only 2 percent in the Coastal zone but 48 percent in the Central zone.

For types of pumps, gravity water pump accounted for 43 percent of all water points while manual hand pumps accounted for 29 percent and motorized pump 19 percent. However, there are

considerable differences across the regions. 41 percent of the water points in the Lake Zone have manual hand pumps compared to only 8 percent in the Northern Zone. Motorized pumps ranged from a low of 8 percent in the Lake Zone to a high of 50 percent in the Central zone while gravity water pump accounted for 70 percent of water points in the Northern zone but only 20 percent in the Coastal zone.

Among the promoters, 39 percent are public, and 38 percent are private for Tanzania. Donors only accounted for 5 percent across the country and the variation among the zones is also very small. A majority of the water points in the dataset is managed by village committees (79 percent) compared to those managed by water authority boards (11 percent). Private sector service providers only accounted for 6 percent of the total water points. There is very little variation across the zones.

Among the sources, nationally, gravity flow systems accounted for 46% of all systems for Tanzania, while the pump piped system (groundwater based) accounted for 50%. The corresponding figures for Central zone it was 23% and 77%, for Coastal zone it was 21% and 66%, for Lake 40% and 57%, for Northern zone, 73% and 23% and for Southern Highlands zone 61% and 37%. Surface water-based pump piped system and unknown accounted for a very small proportion of all systems for all regions.

Finally, regarding extraction technology, gravity flow system accounted for 43%, other systems accounted for 32% and surface water pump accounted for 17%. However, for the Central zone, surface water pump accounted for 49%, for Coastal zone 37%, and for Lake 45%. For Northern zone it accounted for only 10% and Southern Highlands 23%. Gravity flow system accounted for 70% of all extraction technology in the Northern zone and 60% in the Southern Highland zone. In other regions, gravity flow system accounted for less than 50% of all technology.

Table 3 presents groundwater productivity by various types of pumps. More than half of the water points have low to moderate groundwater productivity and this is the same across all types of water pumps. Similarly, more than half of the water pumps in the dataset are situated in areas with very shallow groundwater depth and this is the same for all the different types of pumps (Table 4). Finally, low and low-medium groundwater storage accounted for most of the water points across the different categories of pumps (Table 5).

5. Results

(a) Functionality Analysis

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<age<20) for water points are presented in Figures 1–15. The Lowess curve presented in Figure 1 clearly indicates that in

general, the probability of water points failures rises steadily with age (years). On average, 20 percent of all water points fail within the first year and over 40 percent fail 20 years after installation.

Around 20 percent of water points in the rural areas are likely to fail within the very first year after installation, while 10 percent are likely to fail in the urban areas (Figure 2). While the likelihood of failure increases with age, it also varies significantly between urban and rural areas. Initially the probability of failure is higher in the rural than in the urban areas, but by the seventh year, they are equal, and by 20 years after installation, it is higher in the urban areas (40 percent) and lower in the rural areas (35 percent).

Regionally, the likelihood of failure is higher in the central zone than in other parts of the country (Figure 3). During the first year, the probability of water point failure is higher in the Central zone at 40 percent while it is much lower in the other zones. However, 20 years after installation, all except the Northern zone converge at a higher level (between 30 and 45 percent). On the other hand, the probability of failure in the Northern zone is around 15 percent during the first year and increases to only 30 percent by 20 years after installation.

The likelihood of failure rises sharply with age for the donor managed water points (Figure 4). During the first year, both public and private managed water points exhibit a higher likelihood of failure at 15 percent and 23 percent respectively. This increases steadily to around 40 percent for both groups twenty years after installation. However, the likelihood of donor managed water point failing is near zero during the first year, but increases sharply to 40 percent by the 10th year (lower than public and private managed water points) before declining to around 30 percent by the 20th year.

In terms of source, systems-gravity flow, pump piped (ground water) and pump piped (surface water) have similar likelihood of failure (around 20 percent) during the first year (Figure 5). However, while there is a sharp rise in the failure rates of pump piped groundwater system to 40 percent by the 10th year and 50 percent by the 20th year, the probability of failure for the other two systems only increase to 30 percent by the 20th year.

Water points managed by village committees had a significantly higher likelihood of failure than those managed by water authority or private operators (Figure 6). The water points managed by village committees have a likelihood of failure of more than 20 percent during the first year of operation rising steadily to 40 percent by year 20. Water points managed by the private sector starts out with a failure likelihood of less than 20 percent in the first year declining to less than 10 percent by the third year, increasing sharply to around 30 percent by the 10th year before falling to below 20 percent by the 20th year after installation. Water points managed by Water Boards start out with a failure likelihood of less than 10 percent in year one and thereafter increasing steadily to 20 percent, 20 years after installation.

Regarding extraction technology, the groundwater pump system shows a probability of failure of around 10 percent during the first year, while both gravity flow and surface water system show twice the rates of failure (20 percent) (Figure 7). However, the failure likelihood of the gravity flow system drops slightly after first year before increasing steadily to 30 percent by 20 years after installation. Meanwhile, the likelihood of failure of the surface water pump increases sharply after the first year before levelling off at around 30 percent by the 12th year and thereafter remaining steady. Finally, the failure rates of groundwater pump increase sharply from 10 percent during the first year to slightly less than 40 percent by the 10th year, and thereafter declining slightly to around 35 percent by 20 years after installation.

Motorized pumps have a consistently higher likelihood of failure over the twenty-year period relative to other pumps (figure 8). Initially, motorized pumps have a 30 percent likelihood of failure in year one, and this increases steadily to around 45 percent by 20 years after installation. Meanwhile, manual hand pumps start out with a failure likelihood of less than 10 percent in the first year, increasing sharply to over thirty five percent by the 10th year, and falling to around thirty percent by the 20th year. Finally, gravity water pumps start out with a 20 percent likelihood of failure in the first year, increasing steadily to a 30 percent likelihood of failure by the 20th year.

Water points with low-medium groundwater storage start out with a high 35 percent failure rate in the first year, initially declining to 25 percent by the 10th year and thereafter increasing to 40 percent by the 20th year (Figure 9). Meanwhile water points with both low and medium storage depth have a similar failure rate of around 10 percent in the first year, and while the failure rate for both increase steadily, it diverges sharply, and is considerably higher for medium, at 45 percent relative to low at around 30 percent by the 20th year.

The likelihood of failure for water points situated at shallow, very shallow and shallow-medium groundwater depth is around 18 percent in the first year and increases at about the same rate until around the 15th year (Figure 10). Thereafter it diverges sharply with the likelihood of failure for water points at shallow-medium areas at over 50 percent, for shallow areas, over 40 percent and for very shallow areas around 35 percent by the 20th year after installation.

Water pumps with different groundwater productivity exhibit almost exactly the same trends over the 20- year period regarding the likelihood of failure (figure 11). However, while they all start out with similar rates of failure - around 20 percent in the first year – highly productive water points have over 50 percent failure rates by the 20th year compared to others which have only 40 percent likelihood of failure.

For the ecological zones, water points located in forest and woodland as well as shrub and herb vegetation have a 20 percent likelihood of failure in the first year while those located in desert

and semi desert areas have a likelihood of failure of around 12 percent (Figure 12). However, while the likelihood of failure for water points located in forest and woodland declines sharply after the first year, before increasing to slightly less than 20 percent by the 20th year, those located in areas with shrub and vegetation show a steady increase in failure likelihood to 40 percent by the 20th year after installation. Finally, the failure likelihood of those located in desert and semi-desert increases from slightly over 10 percent in the first year to slightly over 40 percent in the 20th year after installation.

Figures 13-15 examine how the failure rates vary by the type of pump and the hydrological factors such as groundwater depth, groundwater storage and groundwater productivity to better understand how technology interacts with geography in affecting the non-functionality of water points. **The failure rates of water points by depth to groundwater categories varied by type of pump technology (figure 13).** For instance, manual hand pump failure rates increased sharply from less than 10 percent for all depth to groundwater categories to 35 percent by the 12th year. After that, for hand pumps in both shallow and shallow-medium areas, the likelihood of failure continues to increase reaching over 40 percent by the 20th year after installation. However, for hand pumps in very shallow areas, the failure rate declines to around 30 percent during the same time period. For motorized pumps, the failure rate is around 30 percent during the first year, after which there is a decline for those in very shallow and shallow medium areas. However, after the fifth year both increase sharply. Failure rates of motorized pumps with shallow medium reaches 60 percent by the 20th year after installation. For motorized pumps in very shallow areas it only reaches 35 percent. For shallow depth to groundwater it increases from 30 percent from year one to over 50 percent in year 20. Lastly, for gravity pumps, the failure rate at shallow medium and very shallow areas starts around 20 percent during the first year but declines to around 15 percent by the fifth year. Thereafter, the failure rate at shallow-medium areas increases sharply to 40 percent after 20 years while the failure rate of gravity pumps at very shallow areas increases to 30 percent for the same period. Finally, for gravity pumps at shallow depth to groundwater areas, rate of failure starts at 11 percent increasing steadily over the years, reaching 40 percent after 20 years.

The failure rates of water points by groundwater storage categories also varied by type of pump (figure 14). The likelihood of manual hand pump failure is less than 10 percent in the first year for all cases, but after the third year they all diverge. Those with medium groundwater storage experience a sharp increase in failure likelihood reaching almost 45 percent by the 12th year before declining to 35 percent by the 20th year. Failure rates of manual hand pumps at both low and low-medium areas show parallel increase until the 10th year after which those in low medium areas declines to less than 30 percent while those in medium areas increases to nearly 40 percent. For motorized pumps, failure rate for those with low medium groundwater storage was nearly 40 percent during the first year and for the others it was 20 percent. However, failure likelihood is u-shaped for the former over the years, declining to 25 percent

by the 10th year before increasing to 40 percent by the 20th year. Failure rate for those with medium groundwater storage initially declines reaching 12 percent by fifth year. Thereafter it increases sharply to 40 percent by the 20th year. For those with low groundwater storage, there is a sharp increase from 20 percent failure rate in the first year to about 40 percent by the 10th year and it stays the same until the 20th year. Finally, for gravity pump, the failure likelihood for those with low groundwater storage increases from 5 percent in the first year to 25 percent by the 20th year after installation. For those with medium storage it increases from 12 percent in the first year to over 40 percent by the 20th year. For those with low medium storage it is a u-shaped curve, similar to the motorized pumps and the failure rates by year are also similar.

Finally, the failure rates of water points by groundwater productivity also varied by the type of pump (figure 15). For manual handpumps those with low moderate, moderate and high productivity start out with a failure rate of less than 10 percent in the first year while those with very low productivity start out at 15 percent. However, while failure rates for those with very low groundwater productivity increases to 25 percent by the 20th year after installation, those in other categories show a sharp increase. Manual handpumps with low moderate groundwater productivity shows an increase in failure rates to 30 percent by the seventh year and thereafter it remains the same until the 20th year of installation. The failure rates for those with high groundwater productivity increase sharply to 40 percent by the 12th year and thereafter it stabilizes at that rate. Finally, failure rates of those with moderate productivity increase to around 40 percent by the 12th year and thereafter it declines reaching less than 30 percent by the 20th year. For motorized pumps, the failure rates for those with high groundwater productivity exhibits a u-shaped pattern, starting at nearly 50 percent by the first year, declining to around 20 percent by the seventh year, and increasing to nearly 40 percent by the 20th year. Similarly, for motorized pumps with moderate groundwater productivity, failure rates start at near 50 percent for the first year after installation but increases sharply to nearly 75 percent by the 20th year. For very low productivity the failure rates range between 35 and 50 percent during the entire period and do not exhibit a clear pattern. Finally, for gravity pumps, all categories exhibit an upward trend. Failure rates for very low is 5 percent in the first year, increasing to nearly 50 percent in the 20th year after installation. For those with high groundwater productivity, failure rates increase from 5 percent in year 1 to nearly 70 percent by year 20. For low moderate productivity, failure rates start out 20 percent in the first year, initially declining, but sharply increasing to near 30 percent by the 20th year. For those with moderate productivity, failure rates start near 30 percent in year 1, declines slightly to 20 percent by the fifth year before increasing again to near 30 percent by the 20th year.

(b) Empirical Results

Table 6 presents the results of the logistic regression[21] estimates for the determinants of water point failures for the full sample and four sub-samples for water points divided into the following age groups: one year old, two to four years old, five to ten years old and eleven years and older. Analyzing these sub- samples based on age has implications for policy, particularly by providing insights into the types of interventions necessary at various time points during the life of water points.

In general, and as expected, controlling for other factors, all water points experience higher failure rates with age and this is significant at the one percent level. The age squared variable indicates that the effect of age on water point failures increases at a declining rate for all water points and for water points between 5 and 10 years old. For water points between 2 and 4 years old however, the relationship is opposite. Basically, the probability of failure decreases at an increasing rate by age. All in all, there is a complex relationship that is observed between age and water point failures if broken down into different age groups. On the other hand, urban and rural water points are equally likely to fail controlling for other factors in general. However, urban water points are less likely to experience failure at two to four years old but more likely to fail when they are over 11 years old and they are significant at the 1 percent level.

Using water points from the Lake zone as the reference group, failure rates are higher among those in the Central zone, in all cases except for water points between 2 and 4 years old, and all are significant at the one percent level. Those over 11 years old have an insignificant impact. Water points in the Coastal zone also experience higher rates of failures compared to those in the Lake zone. The effect is also significant at the one percent level for all water points, those between 5 and 10 years old and those over 11 years old. The results are similar for the water points located in the Northern zone**.** For the Southern highlands zone the non-functionality is positive and significant at the one percent level for all water points in Tanzania, and for those over 11 years of age, and insignificant for others.

Using village committees as reference, those water points managed by a water authority or government have lower failure rates for all age groups. The results are similar for the private sector. For the other sector, it is negative and significant only for those water points that are one year old, while it has an adverse impact for water points that are over 11 years old. Compared to the public group, other promoters have a lower failure likelihood than either donors or the private sector. Regarding the types of pumps, all kinds of pumps have a higher likelihood of failure for all age groups and they are significant at the one percent level using gravity flow pump as reference.

[21] We have also found that the variance inflation factor for the independent variables we have included in the estimation model to be around 2.90 which is not a serious problem.

For groundwater productivity, water points with moderate productivity have a higher failure likelihood in the full sample, those between 5 and 10 years old and those over 11 years using very low and low to moderate groundwater productivity water points as reference. On the other hand, water points with very high and high groundwater productivity have lower likelihood of failure in the first year, and higher likelihood at over 11 years. For groundwater storage, those with low medium groundwater storage has failure rates that are higher for the full sample, year 1 and those between 2 and 4 years old but are insignificant thereafter. For those with medium storage, they have a higher likelihood of failure for all cases, years 5-10 and over 11 years old. This result supports the findings from Fisher (2015) that water points with low groundwater storage are associated with higher functionality in general. There is clear evidence showing that hydrogeological factors are important predictors of water point failures as in the case of Andres et al. (2018) and Fisher (2015).

Finally, regarding depth to groundwater, using very shallow as reference, shallow groundwater was positive and significant at the one percent level for all groups suggesting higher failure rates, except those which are one year old and under, which was insignificant. The result was similar for those for which no values were available. Finally, shallow medium had higher failure rates for only those water points which are 2-4 years of age and those between 5 and ten years.

(c) Shapley Decomposition of Water Points' Failure

In this section, we use the results from logistic regression to calculate the contribution of various factors to the failure of water points (Table 7). We group together water points that are one year old, two to four years old, five to ten years old and over eleven years old to determine failure by age. The predicted effects of age, hydrogeology, localities, zones, pump types, promoter and management body in explaining the likelihood of water scheme failure in each of these three age groups, along with the Shapley values (Table 7) for each component's contribution to failure, is calculated (Figure 16). The marginal contribution of pump type is at 58 percent for all water points for all age groups while age only accounts for 16 percent. The marginal contribution of hydrological factors accounts for 6 percent for all water points. During the first year, the marginal contribution of hydrological factors is the highest at 53 percent, thus accounting for more than half of all components. However, the contribution of components changes considerably by years 2-4. The pump type contributes more than half of the total when compared to all the other components, accounting for 54 percent and this increases sharply to 63 percent by year 5 to ten years old, and 70 percent for those over eleven years. There is no specific pattern regarding other components as the water points age although hydrological terrain still contribute ten percent of reasons for non-functionality for water points aged over five years. Type of promoters, localities and age make small contributions to failure. Type of management body is important for years 2-4, and thereafter its contribution declines significantly.

6. Conclusions and Policy Implications

The 2015 Tanzania Water Point Mapping data enables us to identify the failure rates of water points and schemes across their lifetimes as well as the factors contributing to these failures.[22] 29 percent of all water points are non-functional, and many failed within the first year. The results indicate that nearly 20 percent of water points are likely to fail in the first year of construction, while nearly 40 percent are likely to fail in the long run (within 20 years).

The empirical results from the logistic regressions confirm the evidence provided in the Tanzania context as well as those found in the literature. Water points managed by village committees had a much higher likelihood of failure than those managed by private operators or water authority. This result is similar to the ones found by Cronk and Bartram (2017). Empowerment of village committees to manage and maintain the water points under their supervision needs to be emphasized as recommended by WaterAid (2009). Alternatively, a movement for more water points to be managed by private operators is also viable although there is a risk of profiteering which would be undesirable especially when the aim is to increase water access among rural populations (WaterAid, 2009). Additionally, following similar results from Foster (2013), it was found that water points technology also affects their functionality. Motorized pumps are more likely to fail than gravity flow pumps. In fact, as shown in the Shapley decomposition, the technology of water points accounts for about 58 percent of the total water point failures. Hence, there is a need to use appropriate technologies that is compatible with the hydrological conditions while also emphasizing the management and maintenance capability of community led user associations. Evidence also supports the recommendations of Holms et al., (2017) that villages should be given more autonomy regarding decision to install and maintain water pumps.

The variables described above such as the manner of how water points are being managed as well as their technology, can be considered "modifiable" as suggested by Fisher (2015). Proper interventions are needed to address the shortcomings contributing to water point failures. On the other hand, this study also highlights the impact of factors contributing to water point failures that are not "modifiable". These are basically the geographic and hydrological factors such as the different geographical zones and groundwater characteristics. These findings are useful to future decision-making processes in designing, constructing or managing the water points at locations with varying hydrogeological characteristics. In fact, the Shapely decomposition shows that the hydrological factors are more important than those of locality and geographic zone types. While interventions cannot be designed to wholly change these

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

factors, with appropriate and accurate hydrological data they can be designed to mitigate or reduce the adverse effects on water points. Finally, the lack of hydrological data is a major impediment to understanding the water point failures especially during the first year after their installation.

It is evident that water points managed by village committees have a much higher likelihood of failure than those managed by other groups, confirming the evidence discussed in the Tanzania context. During the first years of the water points installation, hydrogeological factors play a major role in determining their functionality. However, the type of pump matters over time with evidence showing that gravity pumps have a much higher likelihood of failure over the long term. Overall, there is a need to improve the capacity at the village level to manage and maintain water pumps as suggested. This can be done through appropriate technical support and financial transfers from the LGAs to the villages. Finally, technology as well as hydrological characteristics which affect the water pumps should also be taken into consideration in constructing future water points.

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ANNEX

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

Region/Country	Year(s) of Survey	Study/Compilation	Percent Non-Functional
Global	2010s	Akvo (2015)	20
	Late 1970s	Cairncross et al. (1980)	30
Developing countries	1990s	Duti (2012)	30–40
Asia			
India	1974	Mudgal (1997)	75
Thailand	1980s	McPherson and McGarry (1987)	50
Sub-Saharan Africa	2008	Baumann (2009)	30
	2000s	RWSN (2009)**	36
Angola	2000s	RWSN (2009)**	30
Benin	2000s	RWSN (2009)**	22
Cote d'Ivoire	2000s	RWSN (2009)**	65
Ethiopia	2010	Schweitzer et al. (2015)	43
Ethiopia	2000s	RWSN (2009)**	35
Greater Afram (Ghana)	2010s	Fisher et al. (2015)	20.6*
Madagascar	2000s	RWSN (2009)**	10
Malawi	2010s	Holm et al. (2015)	22*
	2010s	Holm et al. (2016)	39*
	2000s	RWSN (2009)**	40
Mozambique	2000s	Jansz (2011)	20
South Africa	1990s	Hazelton (2000)	50
Sierra Leone	2000s	RWSN (2009)**	65
Zimbabwe	2000s	RWSN (2009)**	30
	1989	Cleaver (1991)	32

Notes:

****Studies of specific region or states within country***

****Statistics compiled from multiple sources/studies***

Table 2. Breakdown of Independent Variables by Region for Water Points

Variables	Frequency	%	Central Zone (%)	Coastal Zone (%)	Lake Zone (%)	Northern Zone (%)	Southern Highlands Zone (%)
Functionality							
Functioning	29,230	71 %	67 %	67 %	70 %	76 %	75 %
Non-Functioning	11,687	29 %	33 %	33 %	31 %	24 %	25 %
Groundwater Productivity							
No-Value-Available	546	1 %	0 %	5 %	0 %	1 %	1 %
Very low	618	2 %	2 %	0 %	3 %	1 %	1 %
Low-Moderate	25,560	62 %	89 %	67 %	58 %	48 %	66 %
Moderate	8,049	20 %	0 %	8 %	28 %	29 %	20 %
High	5,667	14 %	9 %	20 %	7 %	22 %	11 %
Very High	66	0 %	0 %	0 %	1 %	0 %	0 %
Null	411	1 %	0 %	0 %	3 %	0 %	1 %
Groundwater Storage							
No-Value-Available	404	1 %	0 %	3 %	0 %	1 %	1 %
Low	18,380	45 %	81 %	30 %	45 %	34 %	54 %
Low-Medium	14,156	35 %	16 %	13 %	44 %	61 %	28 %
Medium	7,691	19 %	3 %	53 %	9 %	5 %	17 %
Null	286	1 %	0 %	0 %	2 %	0 %	0 %
Depth to Groundwater							
No-Value-Available	198	0 %	0 %	1 %	0 %	1 %	1 %
Very-Shallow	27,888	68 %	64 %	80 %	46 %	72 %	81 %
Shallow	10,894	27 %	28 %	14 %	49 %	21 %	16 %
Shallow-Medium	1,934	5 %	8 %	5 %	5 %	6 %	2 %
Medium	3	0 %	0 %	0 %	0 %	0 %	0 %
Settlement Type							
Rural	36,291	89 %	76 %	86 %	92 %	96 %	86 %
Urban	4,626	11 %	24 %	14 %	8 %	4 %	14 %
Ecological Class							
Forest & Woodland	8,393	21 %	1 %	33 %	7 %	23 %	30 %
Shrub & Herb Vege	23,733	58 %	46 %	60 %	64 %	49 %	61 %
Desert & Semi-Desert	5,825	14 %	48 %	2 %	20 %	19 %	2 %
Open Rock Vegetation	3	0 %	0 %	0 %	0 %	0 %	0 %
Water	389	1 %	0 %	0 %	3 %	0 %	0 %
Missing	2,574	6 %	5 %	6 %	6 %	9 %	6 %
Types of Pump							
Manual Hand Pump	11,718	29 %	23 %	33 %	41 %	8 %	30 %
Motorized Pump	7,713	19 %	50 %	37 %	8 %	17 %	4 %
Gravity Water Pump	17,486	43 %	19 %	20 %	35 %	70 %	60 %
Other	4,000	10 %	8 %	10 %	17 %	5 %	7 %
Promoters							

Public	15,800	39 %	32 %	34 %	50 %	37 %	33 %
Private	15,370	38 %	50 %	28 %	30 %	47 %	42 %
Donor	2,249	5 %	2 %	9 %	4 %	3 %	7 %
Other	7,498	18 %	15 %	29 %	15 %	13 %	17 %
Managing Body							
Water Authority Board	4,692	11 %	4 %	3 %	11 %	33 %	4 %
Private	2,541	6 %	5 %	15 %	3 %	8 %	1 %
Village Committee	32,523	79 %	90 %	78 %	81 %	59 %	93 %
Other	1,161	3 %	1 %	4 %	5 %	1 %	2 %
Source							
Gravity Flow System	18,627	46 %	23 %	21 %	40 %	73 %	61 %
Pump Piped System - Groundwater based	20,304	50 %	77 %	66 %	57 %	23 %	37 %
Pump Piped System - Surface water based	1,883	5 %	0 %	13 %	3 %	3 %	2 %
Unknown	103	0 %	0 %	0 %	0 %	1 %	0 %
Extraction Technology							
Gravity Flow System	17,492	43 %	19 %	20 %	35 %	70 %	60 %
Groundwater Pump	3,548	9 %	13 %	12 %	11 %	3 %	6 %
Surface water Pump	6,948	17 %	49 %	37 %	45 %	10 %	23 %
Other	12,929	32 %	20 %	31 %	9 %	17 %	12 %
Total	**40,917**						

Table 3. Type of Water Pumps and Groundwater Productivity (liters/second) for Water Points 20 Years Old or Younger

	No Values Available	Very Low	Low-Moder	Moderate	High	Very High	Null	Total
Manual Hand Pump	97	258	7,371	2,354	1,433	26	179	11,718
Motorized Pump	359	75	5,357	370	1,514	6	32	7,713
Gravity Water Pump	53	173	10,233	4,759	2,135	24	109	17,486
Other	37	112	2,599	566	585	10	91	4,000
Total	546	618	25,560	8,049	5,667	66	411	40,917

Key: Very Low: <0.1; Low: 0.1-0.5; Low-Medium: 0.5-1; Medium: 1-5; High: 5-20; Very High: >20

Table 4. Type of Water Pumps and Depth to Groundwater (mbgl) for Water Points 20 Years Old or Younger

	No Values Available	Very Shallow	Shallow	Shallow-Medium	Medium	Total
Manual Hand Pump	45	7,699	3,511	463	0	11,718
Motorized Pump	75	5,247	1,885	506	0	7,713
Gravity Water Pump	50	12,476	4,193	764	3	17,486
Other	28	2,466	1,305	201	0	4,000
Total	198	27,888	10,894	1,934	3	40,917

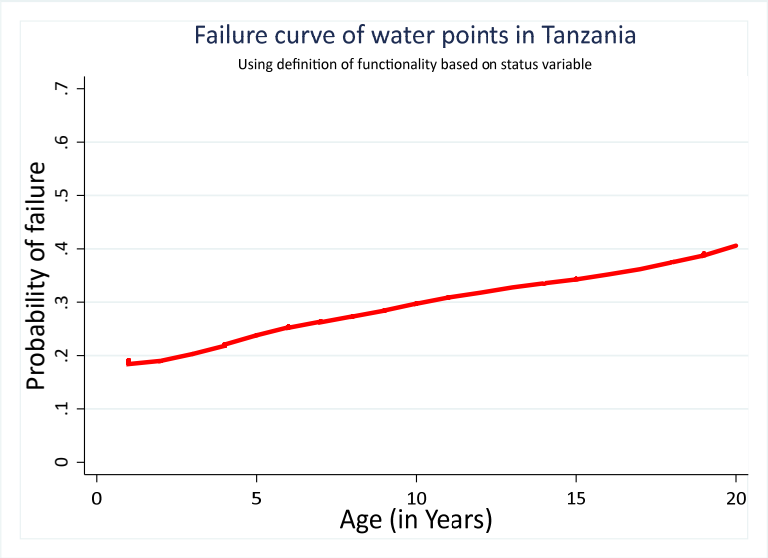
Key: Very-Shallow: 0-7; Shallow: 7-25; Shallow-Medium 25-50; Medium 50-100

Table 5. Type of Water Pumps and Depth to Groundwater Storage (mm) for Water Points 20 Years Old or Younger

	No Values Available	Low	Low-Medium	Medium	Null	Total
Manual Hand Pump	74	5,625	3,009	2,890	120	11,718
Motorized Pump	244	3,111	1,728	2,621	9	7,713
Gravity Water Pump	52	7,839	8,149	1,377	69	17,486
Other	34	1,805	1,270	803	88	4,000
Total	404	18,380	14,156	7,691	286	40,917

Key: Low: <1000; Low-Medium: 1,000-10,000; Medium:10,000-25,000

Figure 1. Failure Curve of Water Points in Tanzania



Figures 2 - 5. Distribution and Failure Curve of Water Point in Tanzania: Across Settlement Type, Zones, Promoters, Source and Extraction Technology

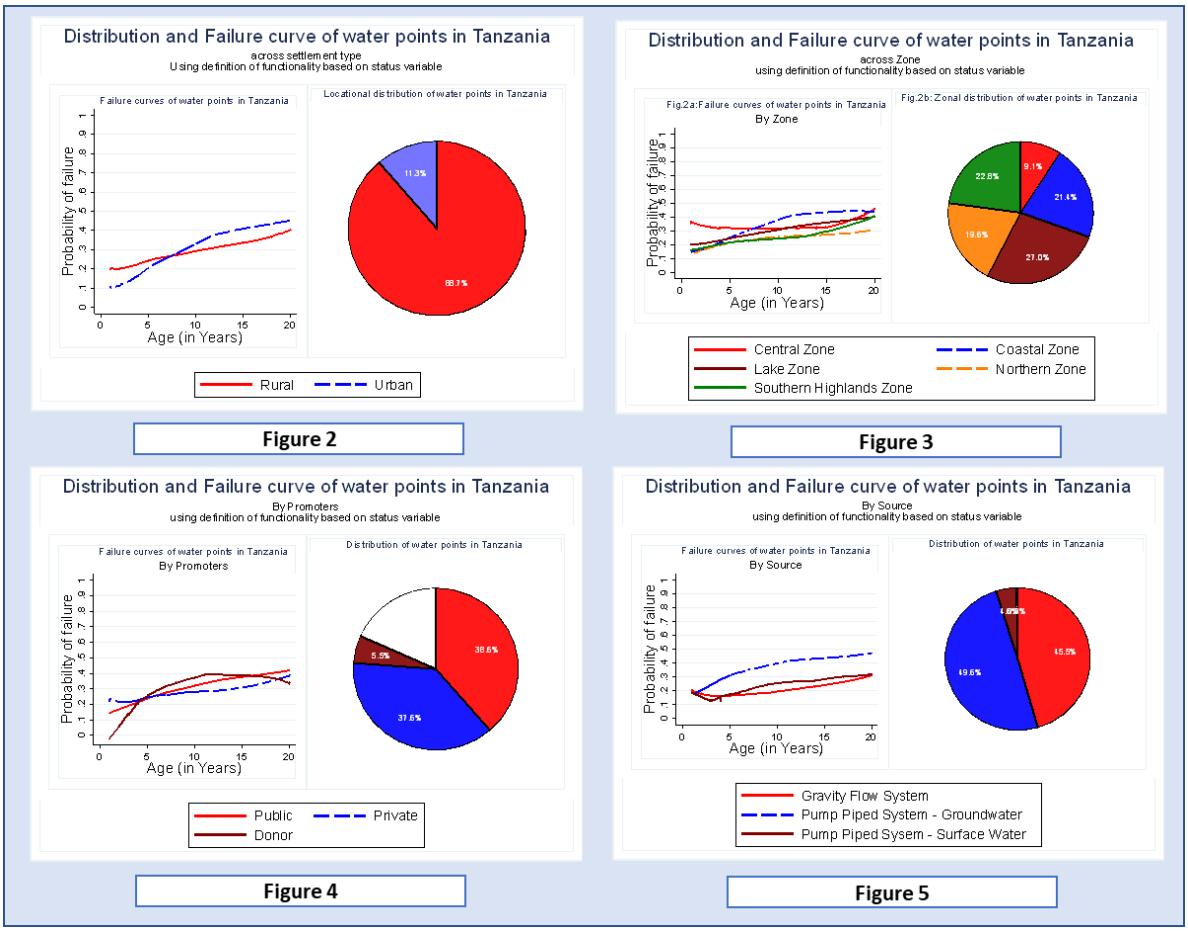


Figure 6 - 8. Distribution and Failure Curve of Water Point in Tanzania: Across Settlement Type, Zones, Promoters, Source and Extraction Technology

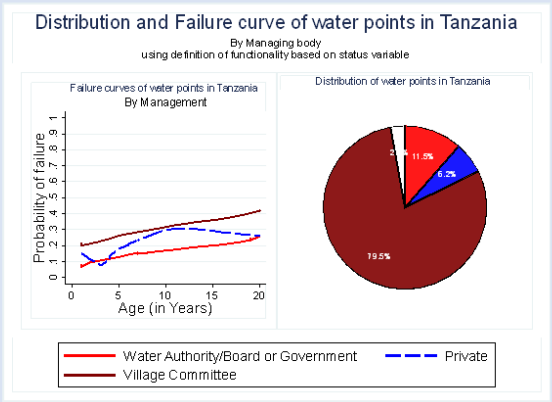


Figure 6

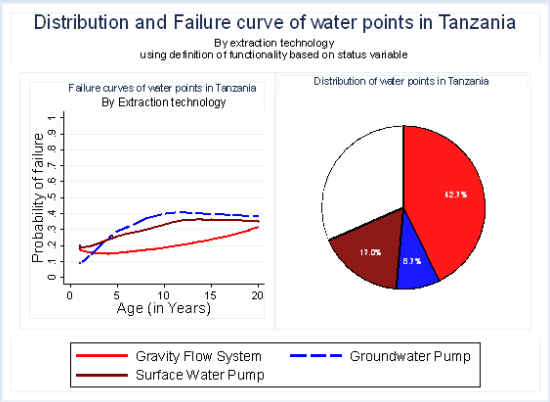


Figure 7

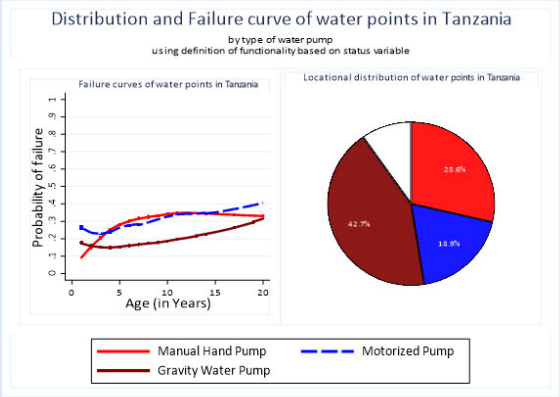


Figure 8

Figures 9-11 Distribution and Failure Curve of Water Points in Tanzania by Hydrological Factors

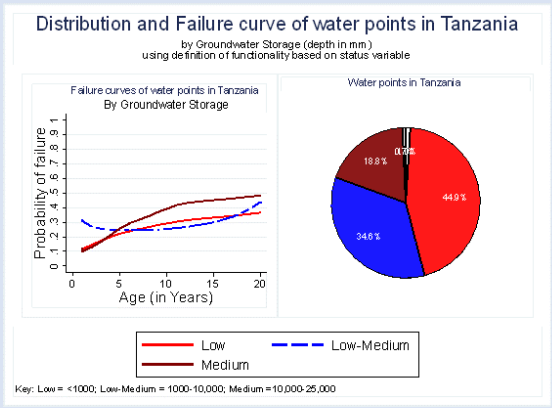


Figure 9

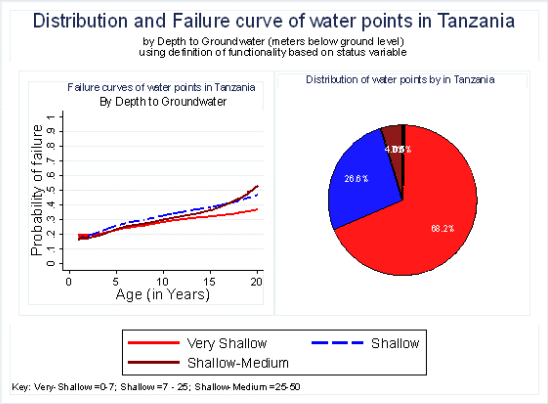


Figure 10

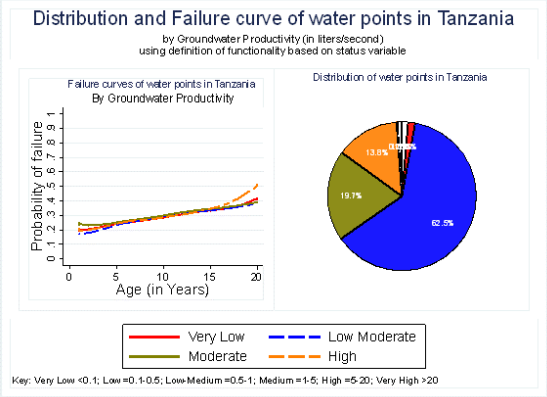
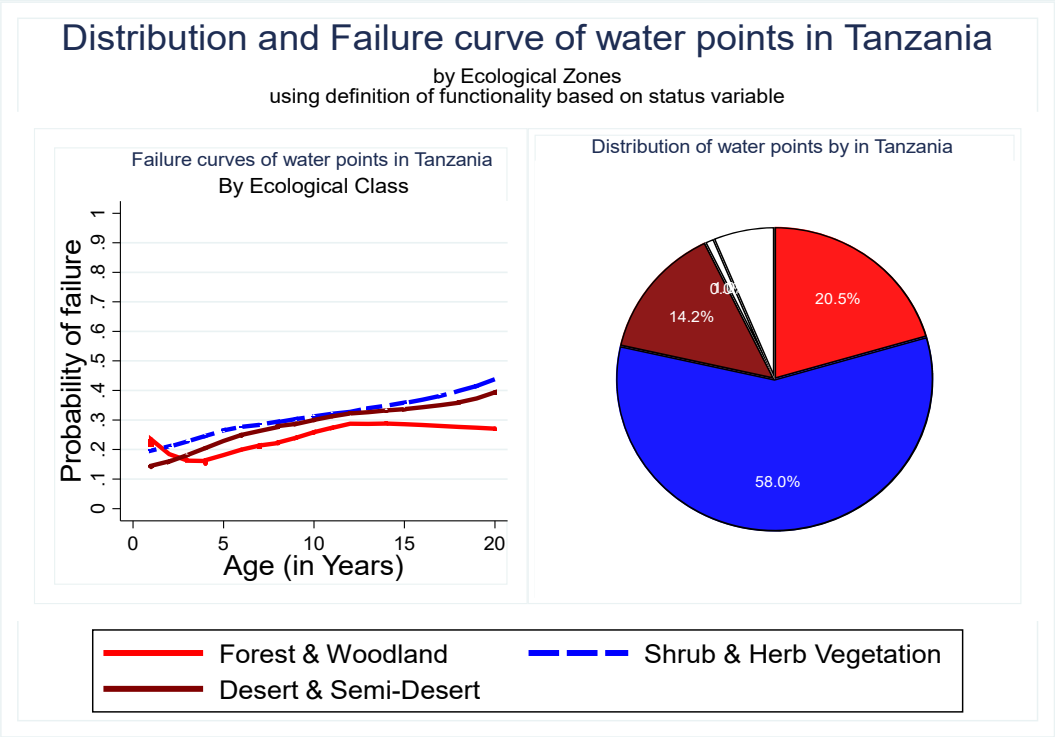


Figure 11

Figure 12. Distribution and Failure Curve of Water Points in Tanzania by Ecological Zones



Figures 13-15. Curves by Hydrological Factors and Pump Type

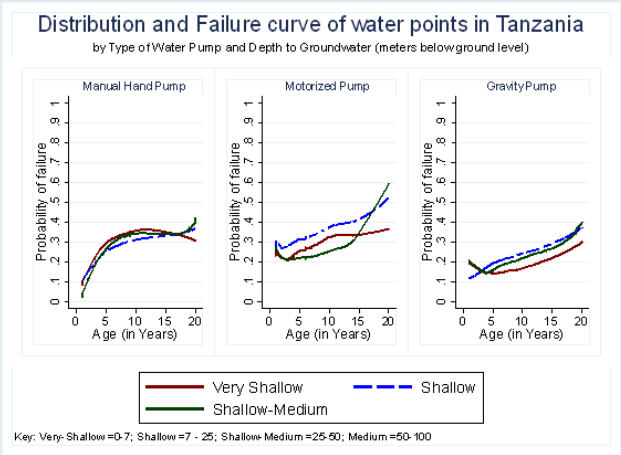


Figure 13

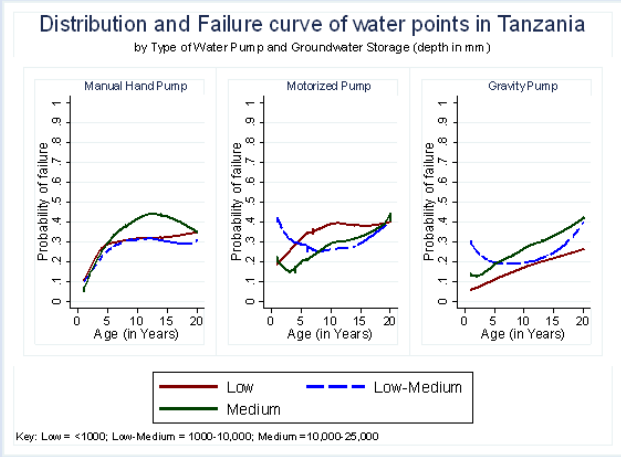


Figure 14

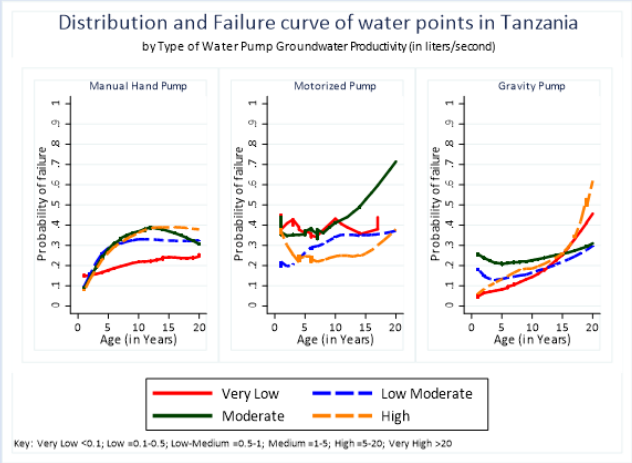


Figure 15

Table 6. Regressions on Non-Functionality of Water Points Aged 1-20 (0=functional; 1= non-functional)

VARIABLES	(1) all water points	(2) 1 yr old	(3) 2 to 4 yrs old	(4) 5 to 10 yrs old	(5) over 11 yrs old
Age	0.016***		-0.258***	0.079***	-0.024
	(0.002)		(0.075)	(0.021)	(0.015)
Age Squared	-0.000***		0.044***	-0.004***	0.001***
	(0.000)		(0.012)	(0.001)	(0.000)
Settlement Type					
Urban	-0.007	-0.053	-0.034***	-0.010	0.040***
	(0.007)	(0.038)	(0.014)	(0.012)	(0.012)
(Reference Group: Rural)					
Geographical Zone					
Central Zone	0.044***	0.184***	-0.078***	0.045***	0.019
	(0.009)	(0.027)	(0.024)	(0.015)	(0.015)
Coastal Zone	0.049***	0.027	0.014	0.050***	0.085***
	(0.007)	(0.032)	(0.015)	(0.012)	(0.012)
Northern Zone	0.059***	-0.032	0.006	0.078***	0.074***
	(0.007)	(0.027)	(0.016)	(0.012)	(0.013)
Southern Highlands Zone	0.015***	0.013	0.033***	0.007	0.018
	(0.007)	(0.030)	(0.014)	(0.012)	(0.011)
(Reference Group: Lake Zone)					
Managing Body					
Water Authority Board or Government	-0.136***	-0.471***	-0.034***	-0.154***	-0.131***
	(0.009)	(0.106)	(0.016)	(0.014)	(0.015)
Private	-0.095***	0.072	-0.174***	-0.029***	-0.067***
	(0.010)	(0.056)	(0.023)	(0.015)	(0.021)
Other	-0.016	-0.111***	-0.040	-0.048	0.057***
	(0.013)	(0.046)	(0.026)	(0.025)	(0.022)
(Reference Group: Village Committee)					
Promoter					
Private	0.001	0.017	0.015	-0.018***	0.004
	(0.005)	(0.029)	(0.011)	(0.008)	(0.009)
Donor	-0.012		-0.120***	-0.007	0.010
	(0.009)		(0.027)	(0.016)	(0.014)
Other	-0.071***	0.045	-0.046***	-0.106***	-0.078***
	(0.007)	(0.025)	(0.014)	(0.014)	(0.011)
(Reference Group: Public)					
Types of Pump					
Manual Hand Pump	0.102***	-0.148***	0.132***	0.153***	0.074***
	(0.006)	(0.036)	(0.012)	(0.009)	(0.009)
Motorized Pump	0.123***	0.070***	0.137***	0.145***	0.099***
	(0.007)	(0.019)	(0.014)	(0.011)	(0.013)
Other	0.336***	-0.119***	0.223***	0.346***	0.422***
	(0.007)	(0.057)	(0.014)	(0.011)	(0.011)
(Reference Group: Gravity Flow Pump)					

Groundwater Productivity					
Moderate	0.044***	-0.027	0.019	0.065***	0.059***
	(0.007)	(0.025)	(0.015)	(0.013)	(0.011)
High & Very High	0.003	-0.176***	-0.010	-0.007	0.052***
	(0.008)	(0.030)	(0.015)	(0.013)	(0.013)
No Values Available	0.018	-0.196	0.011	0.001	0.074***
	(0.020)	(0.182)	(0.034)	(0.035)	(0.032)
(Reference Group: Very Low, Low & Moderate)					
Groundwater Storage					
Low Medium	0.014***	0.287***	0.026***	-0.022	-0.016
	(0.007)	(0.020)	(0.013)	(0.012)	(0.011)
Medium	0.038***	0.052	0.005	0.039***	0.039***
	(0.007)	(0.037)	(0.015)	(0.012)	(0.012)
No Values Available	0.090***	-1.687***	0.052	0.092	0.048
	(0.025)	(0.207)	(0.041)	(0.054)	(0.037)
(Reference Group: Low)					
Depth to Groundwater					
Shallow	0.035***	-0.037	0.038***	0.037***	0.048***
	(0.005)	(0.019)	(0.010)	(0.008)	(0.008)
Shallow Medium	0.009	-0.076	0.044***	0.037***	0.015
	(0.010)	(0.048)	(0.019)	(0.017)	(0.016)
No Values Available	-0.057	1.744***	-0.016	-0.159***	0.162***
	(0.034)	(0.184)	(0.048)	(0.069)	(0.072)
(Reference Group: Very Shallow)		-			
Observations	40,917	2,311	6,875	15,503	16,227
Pseudo R-squared	0.079	0.197	0.077	0.078	0.097

Robust standard errors in parentheses
Coefficients reported are average marginal effect/probabilities
Coefficients missing are omitted because of collinearity, or because there were no observations for that particular age range
The reference group for each categorical variable is displayed
* p<0.05, ** p<0.01, *** p<0.001
Full model Variance Inflation Factor is 2.90

Notes on recodings:

Groundwater productivity

Very Low category is coded together with Low Moderate category due to low sample size

Null and No Valuess Available are also coded together

Groundwater storage

Null and No Values Available are also coded together

Depth to Groundwater

Medium is coded with Shallow Medium since the category has only 3 observations

Table 7. Shapley Values and Groups

	Age	Hydrological data	Localities	Zones	Pump Type	Promoter	Management Body
All Water Points	16 %	6 %	0 %	4 %	58 %	1 %	11 %
1 year old	n/a	53 %	2 %	15 %	12 %	3 %	15 %
2 to 4 years old	1 %	8 %	2 %	5 %	54 %	6 %	21 %
5 to 10 years old	3 %	10 %	0 %	6 %	63 %	1 %	12 %
over 11 years old	3 %	10 %	1 %	6 %	70 %	1 %	7 %

Figure 16. Shapley Decomposition of Water Points' Failure in Tanzania

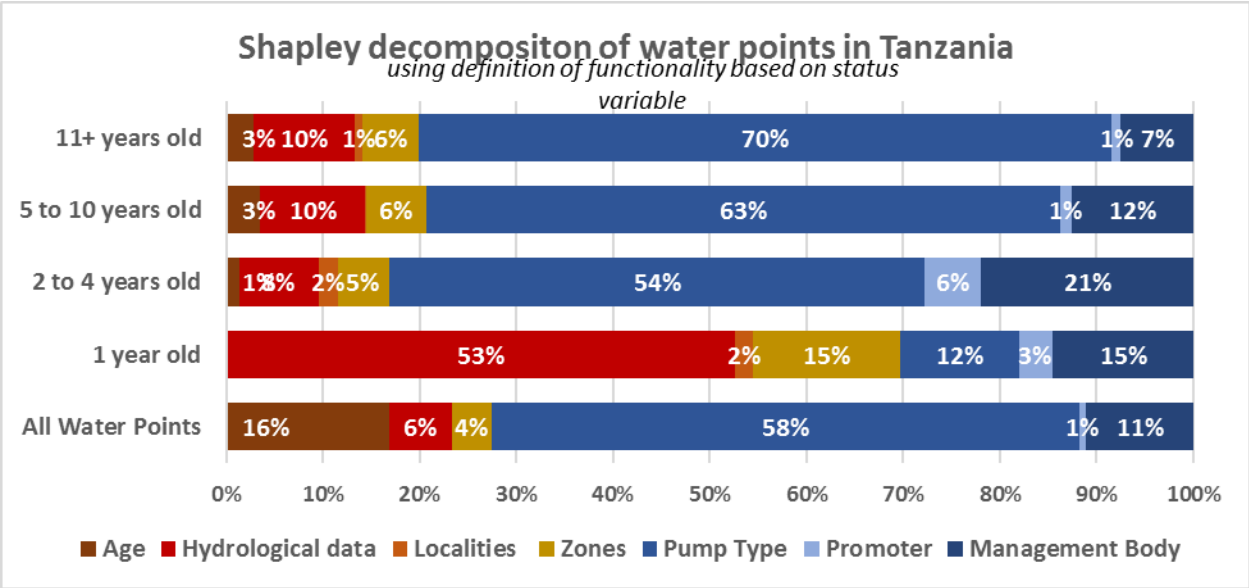


Figure 17: Geographic Distribution of Water Points in Tanzania by Functionality