

The relationship between technology and functionality of rural water points: evidence from Tanzania

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ABSTRACT

This paper presents an analysis of the relationships between technology of water point, management related practices and functionality over time through an extensive water point mapping study made in 15 rural districts of Tanzania, which covered 15% of the total rural population of the country. Results show irregular functionality rates at district level by technology, but reveal statistical dependence between functionality and technology at regional level. Management-related questions show that reported expenditure is the indicator most related to functionality. All categories of water points show very low performance over time. In the first five years of operation, about 30% of water points become non-functional. Only between 35% and 47% of water points are working 15 years after installation, depending on the technology. By categories, hand pumps are the less durable of the technologies studied. We suggest that more emphasis has to be placed on the creation of community capacities to manage the services during and after the installation of water points. At the same time, the role of decentralised government has to be strengthened to provide support to community services in the long term.

Key words | access, Africa, rural areas, sustainability, Tanzania, technology, water supply

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INTRODUCTION

Sustainability of rural water supply programmes in developing countries is a key concern for the sector. Current estimations for Sub-Saharan Africa are that only two out of three water points in rural areas on the continent are functional at any given time (RWSN 2009), recognising at the same time the absence of wide data sets to backup this estimation. Other sources estimate a functionality of 40 to 50% for hand pumps in Africa (Harvey & Reed 2004). In general, the paucity of consistent water-sector related data is a key constraint for effective progress (Biswas & Seetharam 2008). This is a general challenge in the region, as demonstrated by the status of development of Sector Management Information Systems in the Sub-Saharan region (WSP 2007).

The case of Tanzania reflects the general challenges. Between 30% (GoT 2002) and 46% (Wateraid 2009) of the water points are estimated to be not functional. Data published by the ministry, which are based on the coverage reported by districts, are not always reliable. District water

engineers recognise that data are not based on an extensive review of the situation. Inter-annual variability is also very high. For instance, from 2007 to 2008, 30 districts reported a coverage variation of at least 10% on the previous year. Of these, 16 reported a variation of over 20%, and seven reported one of over 30% (GoT 2008).

Water Point Mapping (WPM) approach has been specifically designed as a procedure to provide reliable information about the status of water services in the rural areas. It has been applied extensively by Water Aid and other NGDO in some African countries for a number of years. Water point mapping (WPM) can be defined as an “exercise whereby the geographical positions of all improved water points in an area are gathered in addition to management, technical and demographical information. This information is collected using GPS and a questionnaire located at each water point. The data is entered into a geographical information system and then correlated with available demographic,

administrative, and physical data. The information is displayed using digital maps” (Wateraid, ODI 2005). The main function of WPM is to simply and objectively demonstrate how water points are distributed within a territory; thus, it helps to define reliable access indicators constructed from the lowest geographical level using the available demographic data (Jiménez & Pérez-Foguet 2008) and it serves as a valuable analysis and planning tool for government, both at decentralised (Jiménez & Pérez-Foguet 2010a) and national level.

The aim of the study is to establish the relationships between technology, functionality and durability of rural water points, based on the review of WPM data from 5,921 improved water points. Data were collected between 2005 and 2006 by Wateraid.

The structure of the paper is the following. First, the methodology used for the analysis is explained. Afterwards, the results are discussed making three distinctions: i) the relationship between functionality and category of water point; ii) the relationship between functionality and management related information; iii) the functionality of water points over time. The Discussion points out some reasons for the results obtained. The Conclusions give some recommendations and suggest further research.

METHODS

Water point mapping

As has been said, WPM surveys all improved water points in a certain area (a district, in this case). The definition of improved water point is consistent with that internationally accepted (WHO/UNICEF 2000). The surveys are done with the collaboration of local authorities down to village level. All villages are visited, even if official data do not register any improved water point there. The participation of local authorities at various levels reduces the risk of leaving certain parts of the villages without surveying.

The information is collected through a questionnaire for each improved water point. This contains essentially the following:

- General information about each water point: location, position, name, type of water point, condition (functional, not functional, stolen, under repair), year of construction, funding agency and installer.
- Management information: institution in charge of the management, seasonality of service, operation and maintenance (O&M) practices (if meetings related to these aspects were celebrated, and whether income and expenditure were collected in the previous year to the survey).
- Users, perception about the quality and quantity of the service.

One water point (WP) is considered to be functional if it yields water regularly and is being used by people as a water source on a day to day basis. A WP is non-functional if it does not yield water for any reason, whether due to a hardware problem, to the source being dry, or to poor management. In our analysis, non-functional water points also include those that are under construction and/or were stolen.

Different WPM campaigns sponsored by different stakeholders include variations in the questions included. In recent years we observe a tendency to reduce the number of questions to those that could be answered with precision at local level and/or that can be analysed when aggregated. In our analysis, this same principle is observed, as explained hereinafter.

Category of water points

Type of water point is recorded in WPM including detailed description of technological elements and source (Figure 1). Table 1 describes the four main categories used in this work to aggregate water points (WP). The three main categories are the same as those used by the Ministry of Water to allocate funds for recurrent costs at the district level (GoT 2006). As a

Source Type	Extraction System		Water Point Type
<input type="radio"/> Shallow well	<input type="radio"/> None	<input type="radio"/> Afridev	<input type="radio"/> Hand pump
<input type="radio"/> Hand-drilled tube well	<input type="radio"/> Mono	<input type="radio"/> Nira/Tanira	<input type="radio"/> Communal standpipe
<input type="radio"/> Machine-drilled borehole	<input type="radio"/> Cemo	<input type="radio"/> SWN 80	<input type="radio"/> Communal standpipe multiple
<input type="radio"/> Dam	<input type="radio"/> Climax	<input type="radio"/> India mark II	<input type="radio"/> Cattle trough
<input type="radio"/> River/lake	<input type="radio"/> KBB	<input type="radio"/> Windmill	<input type="radio"/> Dam
<input type="radio"/> Spring	<input type="radio"/> Submersible	<input type="radio"/> Windmill	<input type="radio"/> Improved spring
<input type="radio"/> Rainwater harvesting	<input type="radio"/> Gravity	<input type="radio"/> Other	<input type="radio"/> Windmill
<input type="radio"/> Other			<input type="radio"/> Other

Figure 1 | Information related to water point category recorded in Water Point Mapping campaigns.

Table 1 | Water points analysed grouped by category

Category	Definition	Central regions	
		Number of WP	% of sample
All handpumps	All water points providing water through a handpump, regardless of its brand and the type of well/borehole.	2,326	39.3%
Motorised pumping systems	All water points fed by a pumping device operated through any kind of non-manual extraction system, excluding windmills.	2,180	36.8%
Gravity Fed	All water points fed by gravity systems, regardless of the type of source.	1,263	21.3%
Others	Protected springs and rainwater-harvesting not feeding networks; water points fed by windmills.	152	2.6%

result of that, these three categories are the ones used officially for the analysis of water situation at the district level. Others include a quite heterogeneous number of water points. They were not further split as all together they represent only 2.6% of the water points mapped. The sample is still too small to make conclusions on this category.

These categories help to group in a meaningful and understandable way all the possible combinations of water types, type of sources and extraction systems, facilitating the analysis of data. Apart from the abovementioned, there were 511 cattle troughs mapped, and 382 points could not be put in any category because of contradictions or absence of answers in the questionnaires. It is important to notice that only 49 of them were functional water points. Hence, the sample that was used is of 5,921 water points. From those, 5,852 contain the information of the year of construction. These are used for the analysis of functionality over time.

Methodology for the analysis

The functionality of each technological category of water point was established by dividing the number of functional WP by the corresponding total number of WP. The values are analysed at different geographical levels, using corresponding variables to segment the data set.

The results of the management-related questions are analysed in comparison to category of WP and functionality, also at different geographical levels.

Pearson's chi-square test was used to assess if a couple of the characteristics of the water points can be considered independent or not. The two-sided exact significance of the test was computed. Values greater than 0.10 are associated to independence of both variables, i.e. the differences observed

are probably due to chance, and values lower than 0.05 are associated with a real relationship between both. Cross-tabulation is layered using geographical variables. The statistical computations were done using the SPSS v15.0 software.

Afterwards, the relationship between functionality rates, years after construction and category is defined. The decay of functionality over time for each category is estimated by disaggregating water points (WP) in five year-groups, and computing the average functionality for each group. WP constructed before 1974 were grouped together. Descending functionality-time functions were represented by category of water point (Figure 4).

RESULTS

This section provides the results for the 15 districts studied. First, the functionality by category of WP is assessed in every district. Afterwards the relationship between the functionality of WP and the management related questions included in the study is described. Finally the relationship between the functionality and the years passed after construction of the WP is analysed.

Functionality by category of water point

Functionality by category does not vary greatly among categories. The functionality rates were 45.31% for hand pumps, 48.61% for gravity-fed systems, 44.36% for motorised systems, and 36.18% for other systems. In aggregated terms we obtain a functionality of 45.4%. Results show a very different functionality rate by category of water point in each of the districts studied, as shown in Table 2 (districts are named by numbers

Table 2 | Rate of functionality by category of water point and district

Category of WP	Districts														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
All technologies	79%	76%	67%	53%	40%	58%	37%	43%	16%	29%	9%	86%	37%	43%	34%
Handpumps	80%	69%	49%	42%	47%	<u>61%</u>	<u>67%</u>	<u>51%</u>	<u>19%</u>	13%	<u>11%</u>	<u>86%</u>	<u>38%</u>	<u>59%</u>	46%
Gravity-fed	82%	<u>76%</u>	71%	65%	<u>31%</u>	35%	22%	23%	6%	36%	27%	0%	42%	41%	88%
Motorised	<u>77%</u>	79%	<u>76%</u>	<u>58%</u>	56%	66%	4%	36%	14%	<u>40%</u>	3%	100%	34%	17%	<u>22%</u>
Others	50%	100%	20%	56%	0%	–	–	–	–	0%	0%	100%	43%	11%	41%

Note: Underlined values correspond to the predominant category in each district.

in the graphic). Values for Others category have to be taken with caution, due to the low number of points that fall into this category when analysed per district.

Given this fact, the statistical dependence relationships between functionality and technology category of WPs were determined at different spatial scales. A clear relationship (significance equal to 0.01) was found with grouped data, as well as with data disaggregated by region (zero significance in all three regions). When information was disaggregated by district, nine out of 15 were found to have a statistical relationship with a significance level of less than 0.05. Hence, it can be concluded that the functionality and category of WPs can be considered statistically dependent at the supra-regional and regional scales and, to a lesser extent, at the district scale.

Relationship between functionality of WP and management related questions

The analysis of the questions dealing with management at the community level did not yield conclusive results. Positive management practices were not exclusive of functional WPs, and, conversely, negative ones were not exclusive of non-functional WPs, as one might expect *a priori*. Table 3

Table 3 | Answers to management related questions of functional and non-functional water points for the 15 districts studied, regardless of category of WP

	Held meetings last year	Had income last year	Had expenditure last year
% of Functional WP that	79.3%	54.5%	35.3%
% of Not Functional WP that	68.7%	43.3%	17.1%

shows that meetings were held at a quite similar rate regardless of functionality. Income was reported to be slightly above 50% for functional WPs but 43% for non-functional ones. Only 35.3% of functional WPs and 17.1% of not functional WPs reported expenditures for the year prior to the survey.

Fewer than 10% of respondents overall said they did not know whether there had been expenditures. Fewer than 3% declared that the system had expenditures but no income, which could be interpreted as meaning that there is no contradiction between the answers. Finally, 62% of the functional WPs that reported income also had expenditures, which seems reasonable for a functional service.

Questions were further disaggregated by category (Figures 2 and 3). Functional motorised systems had the highest rates of income and expenditure (66% and 54%, respectively). Gravity-fed systems had low scores in both income (44%) and expenditure (35%). Functional hand pumps reported expenditures in only 19% of the cases. The results for non-functional WPs (Figure 4) show less management practices. Meetings took place at a similar rate regardless of the category of WP. Income was collected in 43% of the cases for not functional WP. Unfortunately, the data do not tell us whether this money was to be used for reconstruction, as an initial contribution for another WP, or for other purposes. Expenditures were lower in all categories when WPs were non-functional, and the difference is especially big for motorised systems. It is remarkable that expenditure is significantly lower for handpumps than for other categories in both the functioning and non-functioning status. As has been already explained, the data are based on self-reporting of communities through the water point mapping surveys.

Management-related questions and functionality were statistically dependent at the supra-regional and regional scales, without considering data disaggregated by technology category, but not at the district scale. When disaggregated by

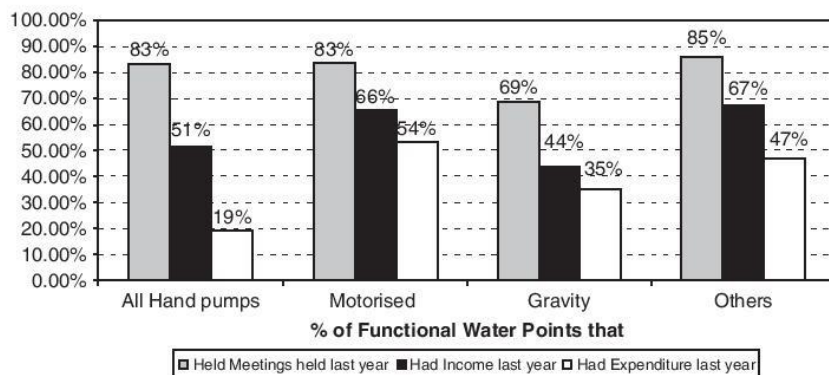


Figure 2 | Answers to management related questions for functional water points, grouped by category of water points.

district, only one-third of the districts showed a dependence relationship between functionality and meetings and functionality and income. Expenditure showed a slightly higher dependence, with a significance of less than 0.05 in eight out of 15 districts.

Analyses carried out with data disaggregated by technology category showed that most combinations give dependence associations at the supra-regional level (all but the “other” category and the question about meetings), but significances of less than 0.05 are found in just one-third of the combinations, when analysis is downscaled at the regional level. Thus, if disaggregated technology categories are considered (Figures 3 and 4), the relationship between functionality and management questions should be established at the supra-regional scale.

Analyses also confirmed that expenditure is the most suitable question for ascertaining how management affects functionality, and, in all three regions, the functionality of the motorised WPs was found to be related to the reported expenditure.

Functionality by category over time

The following methodology was used to analyse the relationship between category and time after installation of the WPs. The WPs were grouped by five-year periods after construction regardless of location. Figure 1 shows the average functionality for each group and a trend curve for each category. Hand pumps and motorised WPs have very regular descending functionality–time curves, with R^2 values of 0.99 and 0.98, respectively. Gravity-fed WPs show a more irregular trend: the functionality of those built in the early 1990s was very low (43%), while those built between 1985 and 1990 were performing better (with a functionality of 50%), and those built between 1980 and 1985 remained functional in below 20% of the cases. As a result, the trend curve ($R^2=0.77$) for gravity-fed WPs starts with an initial low functionality rate but it has a flatter slope than the others. For the “other” category, the oldest WPs (more than 25 years old) were functional in 24% of cases, whereas those built in the past five years had a functionality rate of 86%. The trend

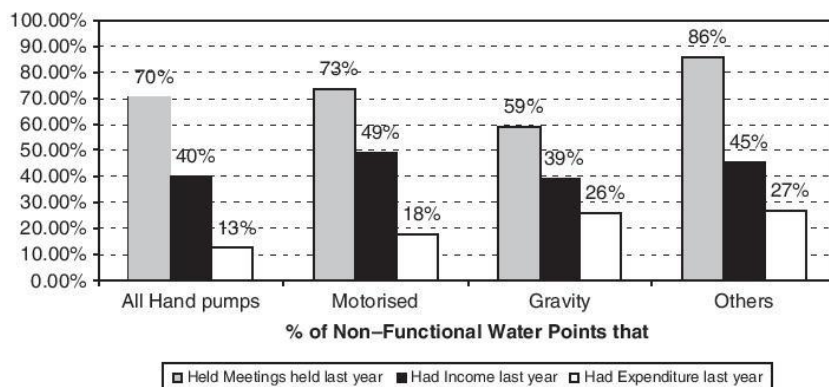


Figure 3 | Answers to management related questions for non-functional water points, grouped by category of water points.

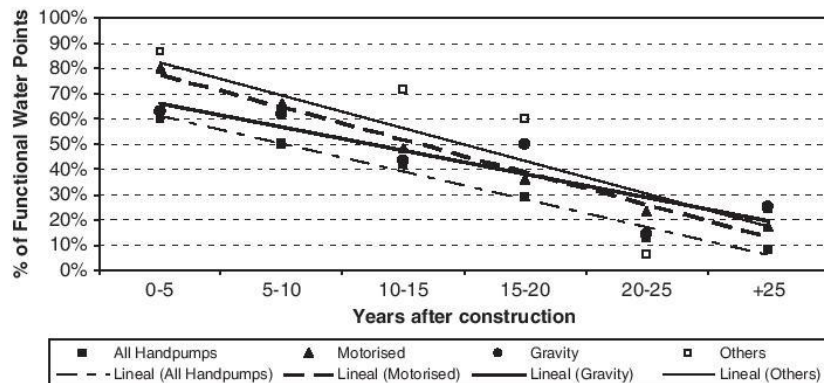


Figure 4 | Rate of functionality by category of water point over time.

curve ($R^2 = 0.68$) shows a good performance of this category of WP over time, though the size of the sample in this category is small to extract conclusions (Table 1).

Simple linear regressions by category yielded interesting results. Hand pumps had the least favourable functionality-time function, dropping from 61% in the first five years to 6% in the 25-year period. Motorised systems started at 77% and dropped to 13% in the same period. Gravity-fed systems worked better in the long run than any other category of WP, dropping from 66% to 20%. In all three categories, just 35 to 47% of WPs were working 15 years after installation. WPs in the “other” category had better scores, but this category included very few WPs (just 152 out of 6,814) and, as explained above, grouped WPs of very different types.

DISCUSSION

Functionality by category of water point

The very different rates of functionality found for the same technology in neighbouring districts confirm that many factors other than technology affect sustainability. For the case of Tanzania, the literature points out the limitations of community management of funds (World Bank 2008), the difficult relationship between water user entities and elected village representatives (Cleaver & Toner 2006), the low professionalism in the management of services (Giné & Pérez-Foguet 2008), and the ability to meet operation and maintenance costs (Harvey 2007).

Since the governance structure is the same for all regions, we analysed the relationship with general poverty indicators. We checked the functionality of water points against the proportion of people below the poverty line, and the propor-

tion of adult literate people. We did not find any statistical relationship either at district or at regional level. Hence, we attribute the variability of functionality by region to the differences in the political stability and the social cohesion of the communities. The absence of local conflicts, both social and political, and the degree of ownership of the services among their members have great impact on the durability of the services.

Functionality versus management related questions

The three questions analysed show different degrees of usefulness. The results show that the celebration of meetings does not have any relationship with the functionality of the water points concerned.

As regards income and expenditure, both have a more direct relationship with the functionality of the water point. The statistical analysis pointed out that expenditure is the indicator more related to functionality of water points. In aggregated terms, only 35.3% of functional WPs reported expenditures for the year prior to the survey, which indicates poor preventive maintenance of the systems. This percentage comes down to 17.1% for non-functional water points. Regular payment is a good indicator for sound management. Collection of funds ad-hoc when the system breaks down has significant risks. When a technical problem arises, the money needed to repair it is frequently above what can be collected in a short period of time in the community. Also, income is quite seasonal in many rural areas. When analysed by category of water point, the results of management questions are coherent with the functionality-time functions obtained: functional hand pumps declare making expenditure in only 19% of the cases, while motorised in 54% of them.

Functionality of water points over time

In general terms, more than 30% of water points become not functional in the first five years of operation. After this period, the functionality decreased at a slower rate (another 30% of WP became non-functional in the following 15 years), which points out the crucial importance of the first period after construction for the success of the service.

We highlight that hand pumps show the least favourable functionality–time behaviour of all categories. Management requirements are lower than in any other category, but handpumps are usually installed for a reduced number of users in fairly isolated places. Lack of spare parts and local technical capacities is a challenge. Moreover, the focus on installing a simple technology might have led to the scant attention paid by the programs to building organisational capacities at community level, which remain critical when a maintenance problem arises (either to collect funds, to buy the spare parts or to contract a technician).

Gravity systems show an irregular trend between periods but the best performance in the long run. We presume that the ease of the technology and low operational costs of this category of water point are determinant for the durability over time. The management related questions do not reveal specially good performance in this category. It is remarkable that the WPs of this category constructed between 1985 and 1990 show the best performance over time. This corresponds to the second half of the International Decade for Water and Sanitation, which targeted full coverage of services for 1990. During the early 1980s many international donors had been supporting detailed plans and capacity building for increasing rural access at regional level (Therkildsen 1988). The 1985–1990 period saw the implementation of part of those plans with technical support from donors. From 1991, the failure of the targets of the Decade reduced the support given by international actors. At the same time, the new water policy shifted more responsibilities to end users (GoT 1991), while the systems were still centrally designed and implemented, which did not enhance ownership and willingness to pay from the end users (Jiménez & Pérez-Foguet 2010b). This transition period from a supply led approach to a community owned approach showed unusually low performance in this category (Figure 4).

It is also significant that motorised pumping systems have a very good performance in the first period, and maintain a similar descending slope as the others in the long term. We presume that the high degree of community organisation which is needed to manage the service from the

starting point (either to give direct service provision or to manage its subcontracting) balances the technical challenges for O&M.

CONCLUSIONS

This study showed how water point mapping data can be used to increase the knowledge about the various factors affecting durability of rural water points. The results show that hand pumps are the less durable of the categories over time, while motorised services perform better. This shows how the investment to create community social capital for management is as important as the technology itself for the sake of sustainability; unfortunately, this aspect seems to be overlooked when it comes to implementation of programs.

In any case, the general functionality of water points over time is very low. Service delivery management approach has to be reviewed; neither the centralised supply led approach used in the country until the 1990s, nor the community full management model used thereafter, seem to obtain good results in the long term. The role of decentralised government is crucial and needs to be strengthened to improve their support and regulation role and increase sustainability in the long term. At the same time, alternative management systems, including the participation of local private sector, have to be promoted in the rural areas, in order to provide communities with choices for managing the services.

The analysis of the management related information provided in the Water Point Mapping (WPM) showed that the existence of O&M expenditure can be taken as the better indicator related to the functionality of water point.

Different sustainability rates were found for each category of water points in neighbouring districts. Further research and new questions in the WPM are needed to understand the reasons, to be able to promote the right type of water point for each place.

ACKNOWLEDGEMENTS

The authors would like to extend thanks to WaterAid Tanzania, for the data provided. R. Giné's comments and valuable collaboration are also gratefully recognised. Research grants provided by the UPC-CCD 2009 and the ACCD U2008 are also acknowledged.

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