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Perspective

Increasing Functional Sustainability of Water and Sanitation Supplies in Rural Sub-Saharan Africa

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Abstract

Lack of universal access to water and sanitation results in well over a million preventable deaths each year, and in both the water and sanitation sectors, there is critical need for greater sustainability. Objectives of this perspective paper are to distill the foundational components of sustainability in water and sanitation, to analyze the main barriers toward establishing these components, and to suggest feasible solutions for overcoming barriers within the context of rural Sub-Saharan Africa. To identify these key components, we extracted the necessary and universal sustainability factors for rural water and sanitation supplies from existing literature. We identify these components as (1) effective community demand, (2) local financing and cost recovery, and (3) dynamic operation and maintenance. We briefly illustrate with examples from the field how the presence of these components leads to long-term functioning water and sanitation supplies, while lack of these components undermines sustainability. Dynamic operation and maintenance is especially critical, and has largely been overlooked by providers, operators, and managers of water and sanitation supplies. We encourage the research community of engineers and scientists and field practitioners to use these three components as a basis for rigorous inquiry into sustainability of water and sanitation supplies. Ultimately, improving sustainability of water and sanitation supplies will result in *salient* and *lasting* gains in health and economic development throughout Sub-Saharan Africa.

Key words: rural water and sanitation; Sub-Saharan Africa; sustainability; operation and maintenance; Millennium Development Goals

Introduction

One of the most significant measures to improve public health, spur economic development, and reduce poverty is universal access to and use of clean water and sanitation supplies. A legacy of insufficient and unsustainable investments means that 884 million individuals still lack access to improved drinking water, and 2.5 billion individuals lack access to improved sanitation (WHO/UNICEF, 2008). Improved water supplies are protected from contamination, but are not necessarily free of pathogens, and improved sanitation facilities ensure hygienic separation of human excreta from human contact (WHO/UNICEF, 2008). The multitude and depth of problems associated with a lack of water and sanitation services and the benefits from obtaining access offer compelling incentives for taking action. Nearly 10% of the total burden of disease worldwide is attributable to unsafe water, sanitation, and hygiene, and the associated diseases claim 3.6 million lives annually (Pruss-Ustun *et al*., 2008). Access to improved water and sanitation is important because it is the foundation for healthy communities, and results in significant health, economic, and social gains (Bartram *et al*., 2005; Hutton *et al*., 2007; Montgomery and Elimelech, 2007). Realizing these gains, which have, in the least-developed countries, an estimated value of five USD for every dollar invested (Hutton *et al*., 2007), depends on reliable and sustained access to water and sanitation services.

For nearly two decades, since the signing of *UN Agenda 21* in 1992, the first formal, global commitment to sustainability, the world has struggled with how to integrate sustainability measures into development efforts, especially those of drinking water and sanitation. The large percentage of nonfunctioning wells and unused latrines is a stark marker of inadequate operation and maintenance and lack of sustainable services. In a survey of 11 countries in Sub-Saharan

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Africa, the percentage of functioning water systems in rural areas ranged from 35–80% (Sutton, 2004). A study in South Africa documented that as many as 70% of the boreholes in the Eastern Cape were not functional (Mackintosh and Colvin, 2003). In a survey of 7,000 wells and boreholes in Tanzania, on average, 45% were in operation, and only 10% of systems that were 25 years or older were still functioning (Haysom, 2006). Examples of sanitation schemes in disrepair have also been documented, such as in rural Ghana, where nearly 40% of latrines constructed through the assistance of a sanitation program were unfinished or not utilized (Rodgers *et al*., 2007). What is urgently needed to stem the trend of disrepair and accelerate progress in achieving the United Nation's Millenium Development Goals (MDGs) is a coherent focus on sustainability. The MDGs, which aim to "halve from 1990 figures, the proportion without access to water and sanitation by 2015" (UN, 2000) have been important in galvanizing global attention and support for water and sanitation. However, efforts such as the MDGs, which focus on expansion of new services, run the risk of undermining functional sustainability by encouraging rapid construction of infrastructure rather than long-term, critically needed, investments in operation and maintenance.

We focus specifically on rural Sub-Saharan Africa. Not only does the region lay claim to some of the world's greatest water and sanitation challenges (WHO/UNICEF, 2008), but over half of its population is expected to remain rural until at least 2030 (UN, 2007). Although some of the institutional and technical challenges in sustaining water and sanitation are shared by urban and rural areas, efforts in rural areas, in particular, must contend with a lack of roads, telecommunications, electricity, and the general absence of a formal small business sector.

The objectives of this perspective paper are twofold. The first is to concisely distill the key components of sustainability from existing water and sanitation literature. The second is to demonstrate the components in practice through selected examples from Sub-Saharan Africa. In doing so, we present a foundation for sustainability that can be researched, expanded, and refined by engineers, scientists, and practitioners in order to inform evidence-based policies that promote long-term functionality in water and sanitation supplies.

Basis for Sustainability Components

Agenda 21 provides a general framework for examining sustainability of water and sanitation. The document declares that "sustainability is the integration of environmental and development concerns for the fulfillment of basic needs and improved living standards for all" (UN, 1993). For the purposes of this paper and given the inadequacy of operation and maintenance in some previous water and sanitation efforts, we utilize the more specific, function-oriented definition provided by Carter *et al*. (1999), which states that "sustainability is constancy in water and sanitation services which may be achieved through evolving and adaptive mechanisms." Thus, environment, development, and long-term functionality and reliability of service serve as the boundaries for distilling the key components of sustainability.

The literature on the framework for sustainable water and sanitation supplies in developing countries emphasizes varying but related themes. In an extensive examination, Harvey and Reed (2004) identify eight main sustainability factors. These factors are presented as building blocks and include: policy context, institutional arrangements, financial and economic issues, community and social aspects, technology and natural environment, spare parts supply, maintenance, and monitoring. For each of these factors, issues relating to planning, effective demand, financing, and management are explored along with guidance for addressing sustainability. Carter *et al*. (1999) offer a "sustainability chain," consisting of motivation, maintenance, cost recovery, and continuing support as the means to evaluate and sustain water and sanitation supplies in developing countries. McConville and Mihelcic (2007) propose planning for and evaluating sustainability by dividing water and sanitation projects into the following five sequential stages: (1) needs assessment, (2) conceptual design, (3) design and action planning, (4) implementation, and (5) operation and maintenance. Each stage is represented as an element in a sustainability matrix and scored according to specific guidelines. A team of United Nations Development Program (UNDP) and World Bank specialists offer another approach to determining sustainability using qualitative and quantitative measures. The team conducted research in 16 countries in Sub-Saharan Africa and found that the measure that improved rural sustainability in nearly all countries was operation and maintenance. Specifically, the study highlighted the importance of establishing reliable spare part supply chains, training skilled technicians to repair wells and latrines, and providing ongoing technical and management support (UNDP-WSP, 2006). Finally, Sutton (2004) advocates self-supply of water for individual households and small groups as a complement to community supplies and a means to achieve sustainable services. The main aspects of self-supply are the promotion of enabling policies, provision of information regarding various water supply and treatment technologies, and development of maintenance and management skills to households and communities that wish to invest in their own supplies (Sutton, 2004). The author argues that self-supply allows for choice in technology, progressive upgrading, and reproducibility with little outside investment.

In summary, the literature offers comprehensive reviews, analytical frameworks, and more specialized, complementary sustainability approaches, but there lacks a concise, practical basis for improving sustainability of rural water and sanitation supplies. With the aim to fill this gap, distilling the common themes from the literature combined with our own field experiences, we propose that there are three universal and necessary sustainability components. These are (1) effective community demand, (2) local financing and cost recovery, and (3) dynamic operation and maintenance. Table 1 outlines these components and the enabling factors, which are discussed in further detail in the proceeding paragraphs, along with the main obstacles and trouble-shooting approaches. We recognize that there are real differences in the scale of and motivators for water and sanitation supplies in rural areas that are not reflected in Table 1. However, in the spirit of this perspective paper, we have chosen to focus on the broader issues that are relevant to both water and sanitation, and leave more specific analyses to focused, research papers.

Effective community demand is the foundation for understanding and prioritizing community and household water and sanitation needs. This component is fostered by a demand-responsive approach and related participatory

Table 1. Three Components of Sustainability in Practice

Sustainability component	*Enabling factors*	*Main obstacles*	*Overcoming the challenges*
Effective Community Demand	Participatory planning Appropriate technology choice Social marketing	• Physical isolation • Limited time and resources • Lack of incentives • Technology based on donor preference • Little awareness regarding social marketing approaches	• Earmark sufficient planning funds in project budget • Select technology based on local choice and socioeconomic conditions • Promote neighborhood, person-to-person behavior change messaging • Develop local critical thinking skills in schools
Local Financing and Cost Recovery	Local borrowing and saving schemes Financial planning Community cross-subsidies	• Lack of financing services • Bureaucratic process for obtaining loans • Limited knowledge • Mistrust of local water/sanitation (wat/san) funds	• Enable communities to establish their own funding schemes • Provide training and ongoing support for financial planning • Create system to allow for equitable access to water and sanitation services
Dynamic Operation and Maintenance	Clear management responsibilities Accessible spare parts/technical expertise Monitoring/evaluation (M&E) Ongoing outreach and support	• Lack of consensus on responsibilities • Isolation of rural communities • Local technicians not supported financially or provided with ongoing support • Lack of incentives for funders to provide long-term support	• Facilitate open discussion • Create community-based financial plan • Including main users in decision-making process • Allocate funds for M&E in project budget • Formalize operating procedures, including through private entity

planning methods that result in systems based on what individuals want, what they are willing to pay, and what they are able to sustain (Chambers, 1994; Ramaswami *et al.,* 2007). In contrast, supply driven approaches are often associated with a lack of funds for operation and maintenance, and may disproportionately benefit wealthier individuals who are better connected (politically and physically), and therefore, more likely to receive services (Jenkins and Sugden, 2006). Appropriate technology choice cultivates effective community demand by providing consumers with information about the potential water supply and sanitation solutions that consider local technical capacity and are suitable for local environmental, cultural, and economic conditions. Social marketing can serve as an important motivational tool in helping communities make informed choices and can help foment desire for and commitment to long-term hygiene behavior changes (Jenkins and Scott, 2007). It is clear that improved hygiene is essential for maximizing health benefits from water and sanitation services (Bartram *et al.,* 2005; Mara, 2003).

Local financing and cost recovery refers to local access to capital and savings. Water and sanitation have not typically been included in the suite of local financing investments. Often the borrower (communities and/or households) cannot meet initial loan requirements, and the period for loan repayment is significantly longer compared to that of other sectors. Recently, however, local financing approaches that allow for lenient repayment periods, permit nonmonetary collateral, and are linked to business development have become available to some rural communities (Fonseca *et al.,* 2007). This second component also includes strategic financial planning and revenue collection, as well as intracommunity cross-subsidies to allow for equitable access to services (Harvey and Reed, 2004).

Finally, dynamic operation and maintenance is based on clear benchmarks of performance that allows for adaptations in hardware and software based on changing, technologies, user demand, and economics. This component relies on establishing clear responsibilities that may be held by the community, an external provider, or through a collaborative arrangement (Harvey and Reed, 2007). Dynamic operation and management also includes establishing supply chains, conducting monitoring and evaluation, and collaborating with internal and external organizations for ongoing technical training and support, as well as hygiene and sanitation advocacy (Harvey and Reed, 2004; McConville and Mihelcic, 2007).

Sustainability Components in Practice

Given the limited evidence on sustainability of rural water and sanitation supplies, the evidence offers largely examples and areas for further research regarding the three components. In a small pilot study in rural Kenya, effective community demand for chlorine disinfection, facilitated through social marketing resulted in up to 64% of households using the product, thereby reducing the risk of diarrhea in children as much as 50% (Quick, 2003). Regarding sanitation, a community-driven sanitation demand program in Ethiopia fueled the construction of 22,385 latrines by households without any subsidy (Loughlin *et al.,* 2006). A relatively new, participatory approach known as Community-Led Total Sanitation offers further evidence regarding the importance of effective community demand. Rather than educating a

community about health hazards from poor sanitation or prescribing latrine designs, the approach facilitates community sanitation analysis by calculating volumes of feces produced and visiting open defecation areas within the community (Kar, 2005). Although critical reviews are forthcoming and the approach has been tested less in Sub-Saharan Africa than in other regions, initial reports claim that Community-Led Total Sanitation has transformed thousands of sanitation-deficient communities in Bangladesh, Cambodia, Indonesia, and Nepal into open defecation-free areas (Kar, 2005). Regarding local financing and cost recovery, a study of the sustainability of rural water supplies in 38 villages in Tanzania found a direct correlation between local contributions, a community water savings account, and functionality. None of the communities with a failed system had a water account, while over 85% of communities that deposited local contributions into a water account were regularly operating and repairing their water systems (Haysom, 2006). Although there is scant rigorous research regarding dynamic operation and maintenance (Baumann, 2005), there is consensus that this component is critical for sustainability (Cairncross, 2003; Harvey and Reed, 2004; Jenkins and Sugden, 2006; McConville and Mihelcic, 2007; UNDP-WSP, 2006).

Challenges in Establishing Components of Sustainability

Although the need for water and sanitation services is widespread, local demand for such services, especially given the large number of pressing development needs in rural communities, is not well documented. One reason for this is that community articulation of demand requires a facilitation process, which is hindered by expansive physical distances and a lack of road and telecommunication infrastructure in rural areas. This prevents regular communication between water and sanitation providers and communities that desire support (Harvey and Reed, 2004). In addition, effective community demand may be eroded by internal and external pressures felt by both service providers and communities to quickly construct infrastructure (Jenkins and Sugden, 2006). This may lead to conducting perfunctory demand assessments that do not allow for prioritization of needs or local empowerment. Insufficient postconstruction communication and support is also problematic (Carter *et al.*, 1999). Few funding or monitoring incentives exist for external water and sanitation partners to maintain regular contact with, and offer support to, communities once projects are completed. Furthermore, there is often not systematic documentation of failed schemes or consequences for providers who invest in, and are at least partially responsible for, poorly functioning or unsustainable water and sanitation systems.

The lack of financing services and cases of misappropriation of water user fees pose considerable challenges to local financing and cost recovery. Only 6% of families in Sub-Saharan Africa have access to banking and financing services (Harris, 2002). Where there are such institutions, many individuals do not apply for loans due to a lack of collateral or information, and those that do often face a web of bureaucracy and restrictions that prevent prompt deposit and withdrawal of funds (Buckely, 1997). Consequently, communities may resort to storing water user fees and community collections in preestablished general village accounts or even entrusting them to individuals. Although water and sanitation accounts are not impervious to misuse, the transparency associated with formally established funds provides safeguards and encourages rather than dissuades users from contributing to current or future water/sanitation activities (Haysom, 2006).

Insufficient financial planning and lack of spare part suppliers are two major barriers to dynamic operation and maintenance. Managers of rural systems without sufficient know-how and training may grossly underestimate recurrent and future costs (Harvey and Reed, 2004). This can result in unreliable service and inefficient use of initial investments. The importance of fully accounting for operation and maintenance costs was highlighted in a comprehensive global cost benefit analysis. The analysis concluded that funding needs for maintaining current water and sanitation systems are three times greater than the amount required to extend coverage to new areas (Hutton and Bartram, 2008). The lack of easily accessible replacements for commonly broken well and pump components in rural areas compounds the problem of insufficient financial planning, and results in straightforward repairs requiring weeks or months to complete (Oyo, 2006; UNDP-WSP, 2006).

Overcoming the Challenges

Increasing and sustaining rural water and sanitation services is a complex challenge that will require engineers, public health practitioners, and policymakers to collectively consider the technical details of construction and infrastructure alongside the dynamic social, economic, and institutional aspects of operating and maintaining supplies. Accounting and allocating responsibility for the true costs of sustainability, including the operation and maintenance of supplies, is especially important to prevent the collapse of current systems and a reversal of progress made in extending global water and sanitation coverage.

Improving communication-idea transfer and stimulating behavior change

Improving communication requires first fostering the transfer of ideas and conducting comprehensive demand assessments to understand local priorities. Rather than villagers waiting passively for external aid, measures must be taken to increase their ability to articulate demand and assure their negotiating power among donors and providers. This can be addressed, in part, through flexible arrangements with providers that allow for choice in service and technology, rather than an externally prescribed package. Furthermore, donor and provider accountability should include measures to promote and document villager involvement in developing schedules for planning, implementation, and operation. Development of critical-thinking skills and independent decision-making abilities in primary and secondary school students will serve, in the long term, to empower rural individuals to take a principal role in demand assessment and project planning. Second, it is important to facilitate the physical flow of communication even where postal and phone services do not exist. This can be done, for example, through providing incentives for cellular providers to extend existing networks and/or collaborating with sales people, medical attendants, and government officials who regularly travel

between villages and larger towns, and who may, therefore, serve as conduits of information.

Behavior change research regarding HIV/AIDS prevention in Sub-Saharan Africa provides insight into potentially useful communication methodologies for improving and sustaining the uptake of important water and sanitation messages. The common thread in this literature is the value of community networks and local social ties in effecting change. A review of HIV/AIDS prevention strategies in Uganda, where HIV prevalence ranged from 15–21% in the early 1990s and was reduced to 4–10% by 2003, attributed this striking decrease to several approaches used more often in Uganda, compared to neighboring countries (Green *et al*., 2006; Low-Beer and Stoneburner, 2003). These approaches included gaining the support of national and local leaders, collaborating with religious and traditional healers, conducting comprehensive surveillance, face-to-face community awareness raising, and deliberately promoting fear arousal (Green *et al*., 2006). Another review of the Uganda case emphasized the importance of personal channels of communication, as opposed to impersonal radio and newspaper campaigns (Low-Beer and Stoneburner, 2003).

The success of local and targeted approaches indicates that the most effective water and sanitation promotional activities occur at the neighborhood or clan level, as opposed to village or district-wide venues. Once initial adopters are engaged, it is important to cast them as champions of change through personal networks to stimulate more reluctant community members and even neighboring communities to take action. Empirical evidence regarding the adoption of solar water disinfection technology supports this strategy. Initial adopters are most influenced by direct involvement with the specific issue, while middle and late adopters are more likely to be persuaded by majority influence and local opinion leaders (Moser and Mosler, 2008). Engaging even apathetic local government officials in water and sanitation activities is important to gain community trust and possible access to human and financial resources. Inviting leaders to participate in hygiene and sanitation seminars and strategic planning meetings may stimulate their active participation.

Increasing access to capital and financial sustainability

Utilizing creative methods of loaning, saving, and managing funds can allow households and communities to overcome financial hurdles in water and sanitation. An example of these are rotating savings and credit associations (ROSCAs) known as "merry-go-rounds" in Kenya or "susu" in Ghana, which allow households to invest in improved sanitation or water treatment (Buckely, 1997). These systems, which are growing in popularity throughout Sub-Saharan Africa, consist of a small group of members bound by a common bond (village, ethnic group, trade), who contribute a fixed sum periodically, which is then sequentially disbursed to members in a set rotation (Buckely, 1997; Ramaswami et al., 2007). A mechanism for increasing financial sustainability while providing equitable access to improvements in water and sanitation is an intracommunity cross-subsidy (Harvey and Reed, 2004). Such an arrangement capitalizes on the rural African culture of communalism by subsidizing the most vulnerable members of a community with funds from the wealthiest or even the entire community. A less formal approach to this has occurred in Tanzania, where the elderly and most impoverished are the first recipients of water from a community scheme (Sokile and van Koppen, 2004).

Establishing dynamic operation and maintenance practices

Establishing long-term, dynamic operation and maintenance practices requires a financial plan and enforceable operation standards. Depending on local capacity, those responsible for the plan may be a community water group, a private entrepreneur, local government, or some combination of the three. Most importantly, community members should serve a meaningful role in developing the plan structure and content. The financial plan should calculate and determine sources of funding for direct operation costs, future repair costs, and institutional/training costs, including monitoring, and expansion costs (Harvey and Reed, 2004). Second, the plan should describe standards of operation that are enforceable. An allowable length of time, decided upon by the community, could be allocated for servicing broken equipment. If repairs are not made, arbitration through a local water board could take place to devise a solution to the insufficiencies and, if necessary, assign penalties. The board should be collaborative and composed of local leaders, key community stakeholders, and have the support of district officials. Furthermore, sponsoring managers, operators, promoters, and representative households to participate in skill development training seminars is important for ongoing skill development and enabling continual improvement of services in light of changing needs and demands.

Sustaining operation of rural water and sanitation requires committed and accountable system managers and technical operators. One measure to increase accountability is to consider provision of water as a business enterprise and to assist in developing or hiring a private operating entity, such as a village water user group or a local entrepreneur to collect user fees, make repairs, and conduct regular maintenance. The success of such arrangements in water and sanitation systems has been documented in small towns in Mauritania, Mali, Niger, and Uganda (WorldBank, 2002), and rural villages in Tanzania (Haysom, 2006). Second, including the primary users of the water system or caretakers of latrines in the management decision-making process will increase the relevance of operation, thereby increasing sustainability. This is supported by achieving gender parity in decision making and compensation for time spent on community water and sanitation initiatives commensurate with tasks performed.

Call for assessing sustainability in water and sanitation services

To effectively utilize and allocate scarce global funding, coordinate efforts of the numerous external water and sanitation providers, and engage the small, but growing private enterprises in Sub-Saharan Africa, it is important that global and national water and sanitation assessments mature from only measuring access to measuring use and sustained coverage. Assessment of use may be more relevant to global targets and determining benefits from water and sanitation, while sustained coverage is likely more applicable at the national level, where countries are tasked with collaborating with external providers and supporting private enterprise.

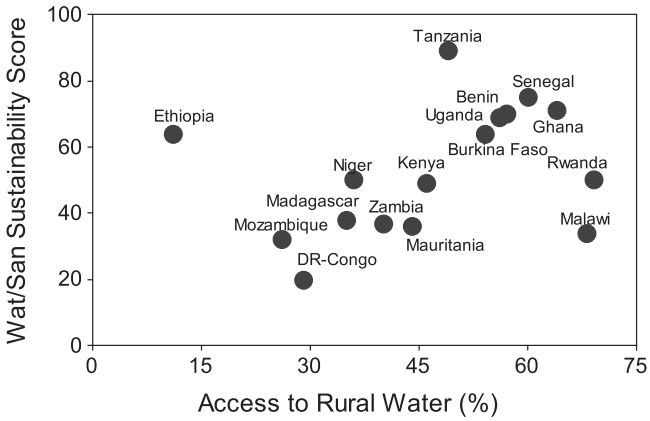

FIG. 1. Access to rural water vs. sustainability score of rural water and sanitation in 16 Sub-Saharan African countries. The data for the access to rural water (x-axis) was extracted from WHO/UNICEF (2008) and the data for the rural wat/san sustainability score (y-axis) was obtained from UNDP-WSP (2006).

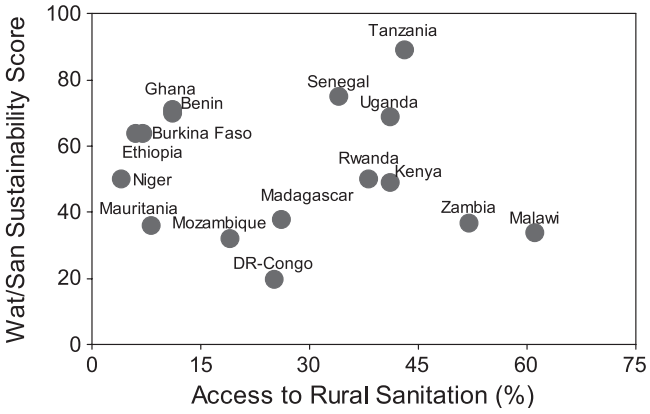

FIG. 2. Access to rural sanitation vs. sustainability score of rural water and sanitation in 16 Sub-Saharan African countries. The data for the access to rural sanitation (x-axis) was extracted from WHO/UNICEF (2008) and the data for the rural wat/san sustainability score (y-axis) was obtained from UNDP-WSP (2006).

Although proposing water and sanitation sustainability indicators is outside the scope of this paper, it is informative to highlight trends in the relationship between access and sustainability. Scatter plots of the sustainability score for rural water and sanitation supplies vs. the percentage of rural populations with access to improved water and improved sanitation are presented in Figs. 1 and 2, respectively. The "sustainability score" is meant to predict whether access, once provided, will endure, and is based on responses from water and sanitation leaders in each country to questions regarding (1) institutional and (2) financial aspects of the sector. For each, the total score out of 100 was computed, with institutional aspects receiving a weight of 70 and financial aspects a weight of 30. These two scores were then added to obtain the final cumulative sustainability score (UNDP-WSP, 2006).

Two striking trends emerge from these figures. First, in Fig. 1 there appears to be an upward trend of increasing rural access to water and increasing rural sustainability, but the same is not true for sanitation. This could be due to the lack of attention and investment in sanitation or simply that the sustainability assessment was less focused on and therefore less closely correlated with sanitation. Regardless, the absence of a trend between sustainability and sanitation highlights the importance of accurately tracking sustainability for both water and sanitation. Second, those countries in the upper right-hand portion of both plots with relatively high coverage and sanitation, namely Senegal, Tanzania, and Uganda, highlight examples where investments are likely to have a beneficial impact on increasing access and could serve as examples for the region. Conversely, countries with poor sustainability and high coverage located in the lower right-hand portion, the most obvious being Malawi, offer cause for concern because investments in the current infrastructure may be squandered by services that quickly fall into disrepair. Furthermore, the high proportion of the population served may dissuade donors from investing in these countries, when in fact, more resources, alongside a more sustainable focus for action, are required. Finally, some countries are in desperate need of increases in both service and sustainability, including the Democratic Republic of Congo and Mozambique.

Concluding Remarks

Progress toward attaining and ideally surpassing MDG targets for water and sanitation will require a shift from singularly focusing on expanding infrastructure in areas without service, to dually concentrating on achieving long-term functionality goals through improved operation and maintenance of existing supplies. The foundational components of sustainability—effective community demand, local financing and cost recovery, and dynamic operation and maintenance—provide a structure that enables engineers, scientists, and managers of water and sanitation supplies to plan and implement or revitalize water and sanitation initiatives. Equipping the current generation of Africans with the capability to operate and sustain improved water and sanitation supplies will result in substantial health, education, and economic benefits, and provide future generations of Africans with a realistic opportunity to escape the devastating cycle of poverty.

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