Doctoral Thesis

Monitoring water, sanitation and hygiene services: Developing tools and methods to measure sustainable access and practice at the local level

by

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Advisor: Agustí Pérez Foguet

Barcelona, June 2015

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ABSTRACT

Water and sanitation improvements together with good hygiene (WaSH) have well-known positive impacts on human development and poverty alleviation. However, universal access to safe drinking water and basic sanitation remains a huge challenge in many low income countries, where vast numbers of people lack these basic services. To help end this appalling state of affairs, the Millennium Development Goals and other international initiatives have been launched to reduce the proportion of underserved people. These efforts, however, have been hampered by the lack of meaningful indicators to measure coverage and to establish progress towards the goals and targets set out by the international community. From an institutional viewpoint, the competences for many sector-related responsibilities have been delegated to lower administrative levels of government. It has come to be widely accepted that such decentralization process can help to reduce poverty because local governments are assumed to be more knowledgeable about and responsive to the needs of the poor. The sector also calls for greater transparency and accountability. In all, local decision-makers are being increasingly challenged by the need to take informed decisions and give an objective account of their actions, which rely crucially on adequate monitoring and reporting systems. Amongst others, available data may be employed to i) measure progress and performance; ii) improve transparency in budgetary procedures; and iii) allocate resources to deliver services where they are most needed. Today, reliable information on key WaSH-related variables at the local level is often missing, but even when it is available, the uptake and usage of such data by policymakers is, at best, challenging. Limited capacity of recipient governmental bodies, an inadequate monitoring and reporting framework, and lack of data updating mechanisms are common reasons that hamper an adequate appropriation and continued use of the data for planning and monitoring purposes.

In an effort to address the shortcomings cited above, this thesis discusses methodologies for routine data collection and develops tools and processes to support local planning. In doing so, it covers the monitoring cycle of data collection, data analysis and data dissemination. In Chapter 1, an improved approach for data collection is presented. It combines two different information sources: the water point and the household, and thus provides a more complete picture of the context in which the services are delivered. Chapter 2 reviews four different approaches that are commonly adopted for monitoring purposes: i) health impact indicators; ii) the Joint Monitoring Programme; iii) one multidimensional, water-focused composite indicator; and iv) easy-to-use planning indices designed locally on an ad hoc basis. From a policy-making perspective the usefulness of outcomes produced by each approach is discussed. Chapter 3 introduces a variety of policy tools that may be used to promote decision-making: i) composite indices; ii) a small set of simple thematic indicators; and iii) object oriented Bayesian networks (ooBn). Chapter 4 presents different alternatives to enhance data interpretation and dissemination, which is crucial to promote evidence-based and equity-oriented planning. Overall, results indicate that accurate and comprehensive data, if adequately collected, exploited and visualized through simple instruments, can serve as the basis for effective targeting and prioritization, both central to sector planning. The actual application and implementation of the proposed monitoring and reporting tools and processes in the real world, however, is to a certain extent elusive; and this has been pointed out as a major weakness of this research. Two specific challenges that remain unaddressed, namely the

upgrading of decision support systems, and the design of data updating mechanisms, suggest the way forward.

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LIST OF PUBLICATIONS ARISING FROM THE THESIS WORK

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- **Giné Garriga R**, Jiménez Fdez. de Palencia A, Pérez Foguet A. (2015) Improved monitoring framework for local planning in the water, sanitation and hygiene sector: From data to decision-making. *Sci. Total Environ.* 526:204-214.

- **Giné Garriga R**, Jiménez A, Pérez Foguet A. (2013) Water-sanitation-hygiene mapping: An improved approach for data collection at local level. *Sci. Total Environ.* 463-464:700-711.

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ACRONYMS AND ABBREVIATIONS

ACCD	Catalan Agency for Development Cooperation - Agència Catalana de Cooperació al Desenvolupament
AECID	Spanish Agency for International Development Cooperation
AHP	Analytic hierarchy process
Bn	Bayesian network
CCD	Center of Cooperation for Development - Centre de Cooperació per al Desenvolupament
CC	Correlation Coefficient
CLTS	Community-led total sanitation
CI	Confidence Interval
CPT	Conditional probability table
deff	design effect
DHS	Demographic and Health Survey
eWPI	enhanced-Water Poverty Index
GIS	Geographic Information System
GLAAS	UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water
HH	Household
HPI	Hygiene Poverty Index
HW	Handwashing
IWP	Improved waterpoint
IWRM	Integrated water resources management
JMP	WHO / UNICEF Joint Monitoring Programme for Water Supply and Sanitation
LQAS	Lot quality assurance sampling
M&E	Monitoring and Evaluation
MDGs	Millennium Development Goals
MICS	Multiple Indicator Cluster Survey
MIS	Management Information System
NGO	Non-Governmental Organisation
O&M	Operation and Maintenance
OD	Open defecation
ODF	Open-defecation Free
oobn	Object-Oriented Bayesian Networks
PCA	Principal Component Analysis

PSR	Pressure-State-Response
R,A,C,U,E	Resources, Access, Capacity, Use and Environment
RADWQ	Rapid Assessment of Drinking Water Quality
SDGs	Sustainable Development Goals
SPI	Sanitation Poverty Index
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UN Habitat	UN-Habitat - United Nations Human Settlements Programme
UWP	Unimproved waterpoint
WaSH	Water, Sanitation and Hygiene
WASH PI	WASH Poverty Index
WB	The World Bank Group
WHO	World Health Organization
WP	Waterpoint (Distribution Point)
WPI	Water Poverty Index
WPM	Water Point Mapping
WRMA	Water Resources Management Authority
WSP	Water safety plans
WSB	Water Services Boards
WSS	Water Supply and Sanitation

FOREWORD

Margaret is from Koguta, a rural community in Homa Bay district, Western Kenya. It is 6 am, and the sun has yet to rise. Today, Margaret will spend around half an hour to reach the only spring that produces good tasting water nearby. There used to be a spring nearer to her home but it dried up in the midst of the dry season. Soon after the spring dried up, Margaret learned that the fuel needed to pump water from the active tubewell into the distribution tank had also run out. Margaret is carrying the only jerry can that her family owns to collect drinking-water for her family of six. In addition, Margaret is considering whether to send her eldest daughter Joyce to fetch water from an unprotected shallow well, whose water is typically used for bathing and for washing clothes. There is no need to pay for water from this well, making it a popular place to fetch water. This means that Joyce may spend up to one hour queuing. Despite all the difficulties and inconveniences faced by Margaret's household every day, they are well aware that the situation may worsen. The neighbouring community for example has no longer access to safe water, as the local fundi moved into town and the water committee continuously fails to properly operate the water scheme. Margaret considers that active involvement of the community members, especially women, in the water committee is essential to guarantee sustainable management of the water supplies. Although she dreams about piped water into the house, she would happily accept a nearby community waterpoint that delivers safe and affordable water without interruption.

Margaret is not the name of a real woman, and I have adopted it to present a story that too often repeats itself in the rural context of many low income countries. Unfortunately, official data do not capture this reality, as they often only report on accessibility to improved water and sanitation infrastructure, regardless of functionality, safety or affordability issues. While there have been recent efforts to implement harmonised monitoring systems for the water sector in Africa, this monitoring and reporting architecture is still generally weak and poorly adapted to implement the new post-2015 development agenda. Further improvements are necessary in many areas, including methods and approaches to data collection and acquisition, analysis, management and dissemination. This thesis aims make contribution in all these topics.

INTRODUCTION

This introductory chapter is divided into two parts. This first part presents the theoretical framework. It begins by briefly describing the context. It then provides a short history of development of monitoring frameworks for water and sanitation services, and introduces the indicators and indices most frequently employed in global monitoring. The chapter also describes the international context in which these services are delivered, and highlights the increasing role of local stakeholders in decision-making. It finally outlines the rationale for improved monitoring and reporting to inform decision-making. The second part describes the research problem in more detail, introducing the aim, objectives and research questions, and outlining the structure of the remainder of the thesis.

1. Setting the scene

Diseases related to unsafe water, poor sanitation, and lack of hygiene are common causes of illness and death (Cairncross et al., 2010b; Esrey et al., 1991). The health benefits are an outcome that partially arises from people drinking safe water (Fewtrell et al., 2005). Health implications are also evident when the quantity of water available is enough to promote adequate personal and domestic hygiene (Cairncross, 1990; Feachem, 1984), particularly the practice of washing the hands with soap (Curtis and Cairncross, 2003). And health outcomes are also improved if people use the improved sanitation facilities at their disposal(Clasen et al., 2010; Esrey and Habicht, 1986), especially where sanitation is community-wide and prevents environmental pollution (Kar and Milward, 2011). The impacts of improved services provision are, however, broad in scope, and their interconnections with education, livelihoods and well-being make water, sanitation and hygiene (WaSH) initiatives a cornerstone of development (Briscoe and de Ferranti, 1988; Cairncross and Valdmanis, 2006; Carter et al., 1990).

Recent estimates show that universal access to drinking-water and the use of improved sanitation still remains elusive, especially in rural areas of low-income countries, where vast numbers of people do not have access to these basic services: one in every three individuals in the world do not have access to even a simple pit latrine; and nearly one in ten have no available source of safe drinking water (Joint Monitoring Programme, 2014; World Health Organization, 2012). The provision of water and sanitation has therefore emerged as a top priority on the development agenda, and specifically to help end this appalling state of affairs, the Millennium Development Goals (MDGs) include a specific target (number 10 of Goal 7) to cut in half, by 2015, the proportion of people with no sustainable access to these basic services. This international target and the forthcoming Sustainable Development Goals[1] (SDGs) are instrumental in driving the sector forward, but they require reliable and up-to-date information to measure progress.

In the last decades, the sector has been experiencing a decentralization of responsibilities, where decision-making moves to local administrative units and decentralized bodies assume some

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[1] UNGA "Report of the Open Working Group of the General Assembly on Sustainable Development Goals" Resolution A/68/970. New York. August 2014

political autonomy. This process is built on the assumption that decentralized governments are more knowledgeable about and responsive to the needs of the poor (Steiner, 2007). For decentralization to work effectively there is a need of self-governments that are accountable for the performance of service delivery (Blair, 2000; Devas and Grant, 2003). This requires, amongst others, evidences for bringing about a more equitable allocation of resources and for measuring progress.

In poverty alleviation strategies, monitoring and reporting are therefore fundamental processes, since donors, governments and civil society need objective data in which to base sound planning, targeting and decision-making. Accessible data and information may for instance be employed to assess performance, to track national and local progress, to highlight gaps and opportunities for accelerating that progress, to influence resource allocation, to advocate for financing, to improve transparency in budgetary procedures, and to increase downward accountability to local citizens, among others (Cotton and Bartram, 2008; Joint Monitoring Programme, 2011a).

Today, reliable information on services at the local level is often missing. Even when information is available, it is rarely accessible to all different stakeholders, and the adoption of such data by policymakers is, at best, challenging. In consequence, decision-making is typically done without the use of information (Schouten and Smits, 2015; WaterAid, 2010).

2. A short history of global monitoring of Water Supply and Sanitation

The first international initiative that monitored the status and trends in water supply and sanitation can be traced back to 1977. The United Nations Water Conference held that year at Mar del Plata, Argentina, established an International Drinking Water Supply and Sanitation Decade to run from 1981–1990, with the aim to deliver safe water and sanitation for all by 1990. During this period, progress was reported by national governments through self-estimations. In reviewing the progress achieved during the decade, the reliability of the data used to assess progress was seriously questioned (Cotton and Bartram, 2008). The need for estimates based on representative population samples was highlighted. Another lesson learned pointed to the importance of defining a common monitoring framework, since "you can't manage what you can't measure" (Creech et al., 2002). In response, WHO and the United Nations Children's Fund (UNICEF) combined monitoring efforts into a Joint Monitoring Programme for Water Supply and Sanitation (JMP), whose main objective was to monitor national progress toward universal access to safe drinking water and sanitation.

Since then, the sector has undergone a transition from hardware-based indicators to monitoring frameworks that assess the quality of service provided across a number of indicators. They encompass the hardware, i.e. the infrastructure, but also the quantity of water of a given quality accessible by users (Moriarty et al., 2011), or the safety of a facility that is easily accessible and sustainably operated at the household level (Potter et al., 2011). Indeed, taking as a point of reference these definitions of "service", the term "service level" has been widely discussed and used to categorize and differentiate between qualities of service.

One of the earliest approaches to water service monitoring was introduced by Lloyd and Bartram (1991), who stated that "the focus on increased coverage needs to be amplified to include improvement of the quality of service". They proposed a strategy to survey progressive

improvement of service quality in terms of health risk reduction, and the surveillance framework included a short list of indicators: 1) coverage, measured by the type of supply; 2) continuity, measured by hours per day and days per year that water is supplied; 3) quantity, measured by volume supplied per capita; 4) sanitary risk, measured by an E. coli count scale combined with sanitary inspection, and 5) cost, measured by the regular tariff paid per household (Lloyd and Bartram, 1991).

In 2003, Howard and Bartram reviewed the requirements for water from a health perspective, and derived a figure of an acceptable minimum to meet the needs for consumption and basic hygiene (Howard and Bartram, 2003). Different levels of service were summarized along a scale of linked indicators that included distance and time to the waterpoint and source reliability. On this basis, they defined the basic requirements that any water service should met in order to sustain good health, and linked each increase in level (from no access to optimal access) to a decrease in associated health risk. This study confirmed a rapid decrease in water consumption as fetching time increases, and a poor hygiene behaviour in households with diminished water quantity available (Cairncross and Feachem, 1993).

As previously mentioned, the UNICEF / WHO Joint Monitoring Programme for Water Supply and Sanitation (JMP) has taken over the role of reporting on the status of drinking-water supply and sanitation since the beginning of the nineties, and it currently is by far the most well-accepted monitoring strategy. The coverage figures in assessments prior to 2000 referred to "safe" water supply and "adequate" sanitation, but consistent definition of "safety" and "adequacy" remained elusive (Joint Monitoring Programme, 2000). To improve on the comparability of data, the JMP formulated a set of core questions (Joint Monitoring Programme, 2006) with the hope that its expanded use worldwide in regularly conducted household-based surveys would produce more accurate estimates at country and regional levels. The surveys did not, however, provide specific information on the quality of the drinking-water, or precise information on the adequacy of sanitation facilities. The harmonized definitions of coverage were technology-based. More specifically, the JMP assumed that certain types of technology were safer or more adequate than others; and consequently the terms "safe" and "adequate" were replaced with "improved". The following water technologies were treated as improved: piped water to the dwelling, plot or yard, public standpipe, borehole with hand pumps, protected (lined) dug well, protected spring and rainwater collection. A water service ladder with three different rungs was proposed to describe the incremental progress in service delivery: "unimproved", "improved" and "piped" (Joint Monitoring Programme, 2008). With regard to sanitation, a wide range of technologies might be in place, particularly for settings where low-cost solutions were required. Instead of distinguishing between technologies, the excreta disposal system was considered adequate as long as it was private (but not shared / public) and hygienically separated human excreta from human contact (Joint Monitoring Programme, 2008). As a result, "improved" sanitation was defined to include a house connection to a sewer or septic tank, a pour-flush latrine, a simple pit latrine and a ventilated improved pit latrine. In much the same way as with water supply, sanitation coverage was ultimately presented as a four-step ladder that distinguished between "open defecation" on the bottom rung, "unimproved", "shared" and "improved sanitation", on the top rung. Only people with access to improved water supply and sanitation were considered to be "covered".

In addition to these regular coverage reports, and in response to the call for water quality measurements, the JMP piloted the introduction of quality tests in monitoring programmes through

the Rapid Assessment of Drinking Water Quality (RADWQ) protocol (Howard et al., 2012). The RADWQ initiative demonstrated the technical feasibility of water quality surveillance, but it also showed that such monitoring at large scale was economically not viable. Alternatively, Water Safety Plans were promoted as a standard method for assessing sustainable access to safe drinking-water (Joint Monitoring Programme, 2010a).

One further monitoring initiative complements the information supplied by the JMP: the UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS). Initially launched in 2008, GLAAS analyses progress and obstacles to that progress in the sector (a task performed by JMP prior to the switch to household data), and exploits for this purpose existing high-quality sources of consolidated data, supplemented by ad hoc questionnaire surveys for other data (World Health Organization and UN-Water, 2014; World Health Organization, 2008).

In 2010, the UN General Assembly and the UN Human Rights Council recognized water and sanitation as a human right (United Nations General Assembly, 2010a, 2010b). These human rights, as described in the respective General Assembly resolutions, are met through progressive realization of universal access to sufficient, safe, physically accessible, and affordable services (United Nations General Assembly, 2010a, 2010b). This recognition clarified the parameters by which adequacy of drinking water and sanitation was to be judged. It also increased demand for analytical approaches capable of measuring the issues of equity and non-discrimination (Bartram et al., 2014). JMP responded in part with wealth quintile analysis and analysis of urban-rural disparities, but to assess water and sanitation as rights-related outcomes, monitoring initiatives should be broader in scope and strengthen the focus on spatial (e.g. urban, rural and peri-urban), group-related (e.g. race, nationality, religion, etc.) and individual-related (e.g. gender, age, disability, etc.) inequalities (Joint Monitoring Programme, 2012a).

Today, an ongoing consultative process is debating a consolidated proposal of targets and indicators for the post-2015 global monitoring of drinking-water, sanitation and hygiene (Joint Monitoring Programme, 2012b, 2011a) and their integration in the global SDG framework. This consultation aims to review the strengths and weaknesses of the MDG strategy in current use, and then propose a new battery of targets and indicators for the period post-2015. As opposed to the MDGs framework, the human rights perspective has strongly influenced this emerging monitoring initiative, and particularly, it has been guided by four fundamental considerations (Joint Monitoring Programme, 2012b): i) a definition of acceptable levels of service, ii) the inclusion of other settings beyond the household (i.e. schools and health centres), iii) a focus on reducing inequalities, and iv) the integration in the monitoring framework of sustainability issues.

3. The international context: a process of ownership and decentralization

The delivery of water and sanitation services in developing countries has undergone significant changes during the last decades. In 1977, the United Nations Water Conference (Mar del Plata, Argentina) proposed the target of universal coverage of clean water and basic sanitation by the end of the International Water Supply and Sanitation Decade (1981-90). Targets were not achieved, particularly due to low sustainability of the implemented infrastructure (Carter et al., 1993). However, access to these basic services was set as a top priority for the first time on the development agenda. In September 2000, the member states of the United Nations unanimously

adopted the International Development Goals as the Millennium Declaration (United Nations General Assembly, 2000), and included one specific target to "halve, by the year 2015, the proportion of people who are unable to reach or to afford safe drinking water" (United Nations General Assembly, 2000). There was no mention of sanitation or hygiene behaviour in the declaration. A year later, as a follow-up on the Millennium Declaration, the United Nations agreed on the Millennium Development Goals or MDG (United Nations, 2001a) as part of the road map for implementing the Millennium Declaration. At the 2002 World Summit on Sustainable Development in Johannesburg (United Nations, 2002), a clear commitment was finally made towards sanitation, and the MGG target was reformulated accordingly. In 2004, the UN General Assembly declared the period from 2005 to 2015 as the "International Decade for Action: Water for Life", with the aim of renewing attention in the MDGs.

Despite this political commitment, progress on the ground has been uneven and often limited, and growing concern to make aid more effective led in 2005 to the Paris Declaration on Aid Effectiveness. The Declaration is grounded on five mutually reinforcing principles: i) aid recipients exercise effective leadership over their development policies and strategies (ownership); ii) donors base their overall support on partner countries' national development strategies (alignment); iii) donors' actions are more coordinated, transparent, and collectively effective (harmonisation); iv) development policies are directed to achieving clear goals (managing for results); and v) donors and recipients are jointly responsible for achieving these goals (mutual accountability).

In the rural water and sanitation sector, greater community involvement was increasingly accepted as key aspect to improve sustainability (Mukherjee and van Wijk, 2003; Narayan, 1995). This led to what is known as the demand-response approach (DRA), which received considerable support during the nineties (Katz and Sara, 1998). The underlying idea was that supply-led approaches were financially unsustainable. In response, DRA primarily revolves around the principles of community participation and community management, i.e. users have to be brought into the process of selecting, implementing, and ultimately financing the long-term delivery of water services (Katz and Sara, 1998). While this approach significantly engaged end users in the design and management of their services, it also made them liable for the responsibilities and costs related to the full operation and maintenance (O&M) of schemes, which proved to have important limitations from a sustainability viewpoint (Harvey and Reed, 2007).

The DRA approach has been widely accepted together with a decentralization process of responsibilities on services' delivery. The rationale for this process is that decentralized governments have an informational advantage over the central government with regard to local needs and priorities, for which reason they are assumed to supply services in accordance with demand, allocate resources more equitably, and ultimately conceive and implement policies with a focus on poverty reduction (Crook, 2003; Devas and Grant, 2003; Steiner, 2007). Decentralization is also supposed to decrease corruption, as well as increase public participation and the accountability of public officials (Steiner, 2007). These beliefs are, however, naïve, and effective implementation of these processes remains elusive. The links between decentralization and pro-poor planning are at best ambiguous, and achieved outputs vary across countries (Blair, 2000; Crook, 2003; Devas and Grant, 2003; Jiménez and Pérez Foguet, 2011; Steiner, 2007). In most of the cases, central governments are reluctant to decentralize resources, and despite the official line of thought, different mechanisms are in place to retain control (Ribot et al., 2006). In other cases,

decentralization has not empowered challenges to local elites, who may be even more resistant than national elites to pro-poor policies (Blair, 2000; Crook, 2003). And the willingness of decentralized governments to become financially autonomous through the collection of local taxes may eventually exclude the poor from the benefit of improved services delivery (Ellis and Mdoe, 2003). This problem is aggravated in rural settings, where the lack of reliable information systems at the grassroots level hinders an efficient pro-poor targeting and an equitable allocation of resources.

Despite these challenges, many Sub-Saharan African countries, such as Kenya, Tanzania, Ethiopia, or Mozambique, and most countries in Latin America, such as Peru and Bolivia, have adopted the policy principles cited above as cornerstones of sector reform: i) the responsibility for the demand and management of rural supplies has shifted to communities, and ii) planning and monitoring activities have been delegated to different local government bodies (Federal Democratic Republic of Ethiopia, 1999; Gobierno de Bolivia, 2000; Gobierno del Perú, 2006; Government of Kenya, 2002; Government of Mozambique, 2007; Government of United Republic of Tanzania, 2002). Hence, there is an imperative need to assist decentralized governments in their role of policymakers.

4. The rationale for improving monitoring and reporting at the local level

Long-term plans and policies are likely to need fine-tuning as new insights on their implementation and impacts emerge (Hermans et al., 2012). Therefore, monitoring and reporting play a major role in improving planning and enhancing policymaking through the collection and presentation of evidences (Thomson et al., 2005). Monitoring extracts relevant information from past and ongoing activities, which then needs to be reported to inform decision-making and adjust, guide planning processes. Without effective monitoring and reporting, it would be difficult to assess progress and performance, direct efforts towards those sectors most in need, be transparent and accountable for the use of available public resources and, ultimately, contribute to sound and evidence-informed policies (Cundill and Fabricius, 2009; Harvey and Reed, 2004). In brief, planning, monitoring and reporting may come together as a cycle approach that builds on the process of defining, doing, learning and improving; i.e. planning should be an ongoing process that is continuously modified based on the inputs produced in monitoring processes and disseminated through regular reporting systems (Jiménez and Pérez Foguet, 2010a).

To be sustainable, however, the entire process of planning, monitoring and reporting should adopt some guiding principles (Giné Garriga and Pérez Foguet, 2008; Harvey and Reed, 2004; United Nations Development Programme, 2009):

- it should be a need-led process and respond to the ambitions and concerns of both policymakers and communities,

- it should seek to build on the capacity of stakeholders - the process should be sustainable in the long run, and thus be easily adaptable and transferable to final users,

- it should be owned by all those with an interest in the desired change - findings, recommendations and lessons from ongoing monitoring should be fully owned by those

responsible for results and those who can make use of them,

- it should be change or outcome focused - it should be geared towards ensuring that results are achieved - not towards ensuring that all activities and outputs get produced as planned. The aim should be to achieve real and measurable changes that lead to improvements in people's lives,

- it should cover all levels of operation (from national governments to communities) and all aspects of water supply and sanitation interventions (e.g. policy, institutions, finances, technology and O&M),

- it should be participatory - it should engage as many stakeholders as possible, particularly communities and service users that are intended to benefit, as well as vulnerable groups -, promote buy-in and commitment, and motivate action, and

- it should be concerned with learning and continuous improvement - it should promote understanding of change and use the lessons learned to guide future action. It should however be implemented gradually, so that the knowledge required to plan is gained simultaneously with the capacity to implement plans.

The traditional approaches to monitoring and reporting have focused more on the implementation aspects – inputs, activities and outputs - than on improvements in the wellbeing of individuals (Schouten and Smits, 2015). In accordance with the principles underlying Aid Effectiveness, the focus has recently moved to demonstrating real and meaningful results (High Level Forum on Aid Effectiveness, 2005). More specifically, a shift towards performance-based monitoring is currently in place (Welle, 2010), which links financial inputs to results, mainly in the form of outputs (e.g. water schemes / latrines constructed), outcomes (e.g. access to water supply and sanitation) and impacts (e.g. improved hygiene behaviour). In principle, MDGs at the international level and equivalent national targets establish an entry point for performance-based monitoring, but its practical implementation remains elusive.

At the national level, the linkages between financial inputs and results are far from straightforward (Welle, 2010), which hampers an effective reallocation of resources within the sector (Shordt and Akanbang, 2005). Another weakness relates to the inconsistency of available information both within and across countries, largely due to two factors: the fact that there are multiple information sources producing different estimates (Thomson et al., 2005); and differences in definitions with respect to the types of water and sanitation facilities that count towards coverage (Bartram et al., 2014). In addition, monitoring and reporting processes typically involve a wide range of actors, and where the roles for data collection, analysis and reporting are not clearly defined, the problem of fragmentation and overlapping activities or duplication of efforts remains unsolved. By way of example, despite the progressive implementation of country owned monitoring systems, many aid agencies and NGOs often deploy their own monitoring systems for their own interventions, resulting in a multiplicity of project-monitoring systems which most of the times are not aligned with and do not support the development of country monitoring systems (Lockwood, 2014). On the operational side, a further issue to address is the lack of mechanisms to put lessons learnt - policy changes, resource reallocations, and operational improvements - into practice (Thomson et al., 2005). And financially, monitoring and reporting initiatives have often been poorly estimated (Harvey and Reed, 2007) and under-budgeted, receiving only a small fraction of available

resources (Giné Garriga and Pérez Foguet, 2008). In consequence, national monitoring and reporting systems are generally weak (Giné Garriga and Pérez Foguet, 2008), and it has been widely recognised as one of the critical constraints towards making informed decisions on the development and use of water and sanitation infrastructure.

The local level monitoring and reporting suffers from the same weaknesses and flaws, but with nuances. The data needed to inform policy and practice at national and sub-national level are different. For local decision-making, for instance, to report on schemes' functionality and use of facilities is important, while the focus of national stakeholders may be on the number of schemes constructed. Similarly, national estimates are stratified by geographic (e.g. urban / rural) and occasionally demographic (e.g. age, wealth) variables, while the local level will probably aim to report on the elimination of inequalities among disadvantaged groups. Greater harmonisation of monitoring and reporting across these levels would be desirable to increase efficiency, so that local stakeholders can make better use of national monitoring data, and vice versa (Bartram et al., 2014). The reliability and the representativity of the available data on which the performance indicators are based is another area of concern. The lack of a widely accepted clear definition for "served" and "unserved" populations and representativeness account for some inconsistencies, although other differences are likely due to bias and error in data sources, the data collection methods, the survey instruments, or a combination of these. Finally, inadequate mechanisms to identify the vulnerable segments of the population seriously hinders pro-poor planning, and Jiménez & Pérez Foguet (2010b) state that a mixture of policy incoherencies, technical shortcomings and political influence commonly results in an uneven allocation of resources: only a small proportion of funds reach the under-served areas. The failure to target the poor is in part due to the lack of reliable information systems that report on the service of level accessed by certain populations - such as those living in marginal or informal settlements -; and partly because of reduced information management and monitoring capacities of local decision-makers. The circumstances cited above severely limit the ability of planners and policymakers to use monitoring information to provide evidence for better decision-making, and specifically to link local government resource allocation to performance levels.

From the previous discussion, it is evident that monitoring and reporting are cornerstones to effective planning. Indeed, the ability of governments, multilateral agencies and donors to make effective progress towards achieving sector-related goals depends crucially on the quality and availability of reliable data, i.e. on the collection of evidence reported regularly. This first involves gathering observations and measurements that help assess what happened and what outcomes resulted from what interventions. Second, and equally important, this monitoring information needs to be reported regularly and on a timely basis to inform decision-making. It is often the case, however, that insufficient resources are allocated to the development of a monitoring and reporting framework, it is developed independently of broader policy-making and planning, and available data continues to be fragmented, inconsistent, poorly collected and not standardised (von Schirnding, 2002). Decentralization offers an opportunity to reverse this situation, through the adoption by local governments of a learning-by-doing approach that effectively links monitoring and reporting with ongoing planning (Harvey and Reed, 2004).

AIMS AND METHODS

This chapter first defines the research problem and then introduces the objectives, research questions and methodology. It then presents the case studies and describes the structure for the remaining chapters of dissertation.

1. Defining the research problem

The world over, the provision of water and sanitation services has become a global problem as decision-makers are faced with increasing and competing demands with limited resources. Ideally, resources should be allocated to those that need them the most, but these individuals (and geographical areas) may be hard to identify without proper data. Therefore, an essential prerequisite to evidence-based decision-making is access to reliable information through accurate monitoring and evaluation. Evidence supported by accurate field data can be used to determine how the sector is faring, whether it is on-track to meet its objectives and what decisions need to be made to maximize performance levels in the future (Thomson et al., 2005).

For a monitoring system to be effective, a harmonised definition of access to water and sanitation must be adopted. As yet, there is no clear consensus on what constitutes "adequate level of service". In recent years, the focus has been more often on accessibility to water and sanitation infrastructure. Greater emphasis should be placed, however, on enabling a more equitable delivery of these basic services as well as on promoting hygiene behaviour. To do this, the scope should be broadened to include the issues of affordability, acceptability, quality and safety (United Nations General Assembly, 2010b; United Nations Human Rights Council, 2011). Moreover, regardless of data accessibility, it is well known that the take-up of information by decision-makers is challenging, and they commonly do without them (WaterAid, 2010). Limited access to data, poor capacity of recipient institutional bodies to analyse the data and interpret the results, inadequate reporting systems, lack of data updating mechanisms, or poor interaction with end users during data collection and data analysis are common reasons that hamper an adequate appropriation and continued use of the information.

Against this background, the specific problems this research is trying to address range from improving the availability of reliable information, to improving access to information through data analysis, interpretation and dissemination, and to encouraging the use of this information in decision-making processes. They may be conceptualised as a stepped approach as displayed in Figure 1. The first step is to develop a survey methodology to collect and make available consistent field data. The second step is to produce statistically sound estimates of a range of indicators that are valid for decision-making support. Such estimates have to be easily computed, understandable and accessible to all relevant stakeholders. Finally, the third step is to promote the use of indicators for improving the processes of taking decisions and ultimately increase sector performance.

Figure 1 Thesis approach

In the WaSH sector, data are collected through different methods, which make data difficult to aggregate or compare. If the unit of analysis is the waterpoint[2], an approach that is being increasingly adopted by agencies and NGOs is to comprehensively map all waterpoints in the geographic area of interest – these mapping exercises are commonly referred to as Water Point Mapping (WaterAid and ODI, 2005). If the focus is on water quality, the WHO / UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) has piloted the Rapid Assessment of Drinking Water Quality (RADWQ) protocol, in which a sample of waterpoints are randomly selected for quality testing (Howard et al., 2012). At the household level, common practice is to conduct a household survey, e.g. the UNICEF-supported Multiple Indicator Cluster Survey - MICS - (United Nations Children's Fund, 2006a) or the USAID-funded Demographic and Health Survey - DHS - (ICF International, 2012). In these surveys, since populations tend to be large and often geographically scattered, there is little choice but to select a sample from the population, and infer from it the characteristics of the entire population. At a local level, however, the direct application of the approaches commonly employed in the nation-wide surveys produce samples that are too large and ultimately impracticable (Bennett et al., 1991). In addition, the types of data collected also presents substantial limitations. Monitoring and evaluation initiatives tend to limit its scope to outputs - water supply schemes or latrines constructed - and outcomes - people with access to improved water supplies and sanitation facilities -, while neglecting the impacts - people enjoying an improved health status, time savings, etc. - (Welle, 2010). And both outputs and outcomes are by and large narrowly defined: current surveys rarely address the issues of water quality, equity of access or sanitary conditions of sanitation facilities, among others (Bartram et al., 2014; Joint Monitoring Programme, 2011b).

A key challenge that must be taken into account when improving access to available information relates to problems of putting evidence in an operational framework. More specifically, data must be communicated in a way that enables end users to adequately interpret the problem in question (Grosh, 1997). As cited above, one constraint that hinders an effective use of the data is that information - where available – is too vague, generic and incomplete. Many relevant aspects of service delivery are typically not covered by current monitoring approaches. Moreover, data can seldom be broken down for analysis at the local level (Bostoen, 2002). At best, national data is disaggregated by region or district, which undermines their applicability for monitoring progress and allocating resources below the district level. Lastly, it is often the case that different agencies working in the sector (ministries, development partners and NGOs) often have different information needs. These diverse needs should be properly addressed in order for the various stakeholders to offer more effective feedback into planning.

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[2] A waterpoints is defined in this study as a place / facility where water is drawn for various domestic uses such as drinking, washing and cooking.

Other sector weaknesses are mainly related to the use of information for planning. It is remarkable that informed decision-making largely depends on the ability to both produce and use new and updated evidences. This, in turn, requires i) strengthening the information management and monitoring capacities of local governments on the one hand, and ii) developing methodologies for the regular update of primary data. In recent years, new technologies are leading to an exponential increase in the volume and types of data available, creating unprecedented possibilities for informing decision-making and improving service delivery. However, too many organisations and governments are excluded from this "data revolution", typically because of lack of knowledge or capacity (Independent Expert Advisory Group on a Data Revolution for Sustainable Development, 2014). Moreover, WaSH-related monitoring and reporting structures at the local level remain weak. The sector does not have - compared to other sectors such as health and education - dedicated extension workers who can regularly report on the status of water supply schemes and the use of sanitation facilities (Welle, 2010). In combination with the large number and geographical dispersion of water schemes and households - the two primary sources of information -, this poses a logistical challenge for water sector staff, who typically has access to very limited operational budgets and resources. Finally, different organizations often collect information on different indicators and use different methods to estimate the level of service. The lack of harmonisation of reporting may lead to notable information gaps.

Today, accurate and timely data on performance is rarely accessible let alone correctly exploited. The key problems within the planning, monitoring and evaluation cycle can be summarized as follows:

- Data collection methods are well defined, proven and documented for large-scale surveys. However, the direct application of these methods at the local level has proven impractical. Moreover, available data at national level show little possibility of disaggregating.

- Nation-wide surveys focus on other sectors (demography, health, wealth, etc.), so WaSH issues are rarely included in the questionnaires. Specifically, information on hygiene behaviour is seldom collected.

- Poor consensus on the definitions of "service level" - the standard indicators of the WHO / UNICEF Joint Monitoring Programme (Joint Monitoring Programme, 2006) are inappropriate to assess access to basic services and describe their linkages with poverty.

- Monitoring and reporting structures at the local level are by and large inadequate. Accordingly, accurate and timely data on service levels typically lack.

- There are huge and growing inequalities in access to open data and information and in the ability to use it, particularly at the local level. Decentralized governments often lack capacities to handle large volumes of data and information.

All these problems together seriously hinder evidence-based planning and decision-making, which in turn has an impact on sector progress and performance.

2. Hypothesis

The rationale underlying the study is that enabling decision-makers to measure access to water and sanitation as well as hygiene behaviour is a necessary condition for making progress towards the achievement of internationally agreed goals and targets, and for ultimately improving the standard of living of the poor. It is assumed that accurate and timely data on sector performance may be exploited by planners and decision-makers to target the neediest, allocate and distribute resources equitably and reveal where advocacy is required. Specifically, it is expected that data analysis will produce reliable outputs that may be employed to guide pro-poor policy-making and tailor sector programmes and strategies.

Testing this, however, would be far too ambitious for this thesis. In addition, the continued use of evidence in decision-making depends on numerous factors other than the accessibility of data, thus a narrower focus on the processes of data collection, data analysis and data dissemination has been opted for. The project will specifically test whether:

i) simple data collection methods can be developed to measure in a representative, consistent and affordable way the proportion of people that have access to "improved" water sources, "improved" sanitation, and to "improved" hygiene behaviour;

ii) timely and WaSH-specific information is useful to understand the main drivers and barriers in relation to the promotion of sustainable and equitable access to basic services;

iii) instead of single indicators - which do not adequately capture the complexity of services delivery -, multidimensional measures are robust, transparent and reliable to define WaSH-related poverty and characterize the poor; and

iv) systematic monitoring and in-depth analysis of poverty-related data are central to pro-poor planning.

These hypotheses are tested by improving existing survey methods, developing WaSH-specific indices and indicators, and mainly through observing their implementation in several case studies.

3. Aims of the research

This research is designed to study and improve the planning, monitoring and evaluation cycle in the WaSH sector at the local level. Specifically, the emphasis will be placed on the process of collecting, analysing and presenting information, whereas the challenge of transferring produced knowledge to local stakeholders and promoting continued use of accessible data in decision-making is only partially addressed.

Basically the overall aim of this research is to produce reliable information at the local level that can be directly employed in the processes of taking decisions to increase sector performance. More specifically, the objectives are i) to design a survey methodology that allows data collection at the local level in a representative way, and ii) to develop robust decision-making tools that are suitable for use in strategic planning.

Within the outlined aim and objectives, the study will examine the following research questions (RQs):

RQ1   How data related to "improved" hygiene practices, "improved" water supplies and "improved" sanitation can be collected at a local level in a consistent, representative way and at reasonable cost? This question is examined and responded to in Chapter 1.

RQ2   Are monitoring approaches in current use adequate to provide a complete picture of the underlying linkages between poverty and WaSH? This question is examined and responded to in Chapter 2.

RQ3   Do aggregated indicators and planning indices produce reliable outcomes that might be directly employed to support targeting and prioritization of resources? This question is examined and responded to in Chapter 3.

RQ4   Which data dissemination strategies make information more easily accessible and more readily understandable to decision-makers? This question is examined and responded to in Chapter 4.

4. Brief overview and topics addressed in the research

This research is three-fold, as visualized in Figure 1. The first part focuses on the production of reliable data. The initial aim is to develop a methodology for data collection that covers the needs of the sector at the local level (Chapter 1). The next step is to validate the core set of indicators that are currently used internationally (Chapter 2). In the second part of this research, a number of alternatives to promote easy access to information are presented. We highlight the role of aggregated indicators and simple planning indices as powerful tools to measure access to water, access to sanitation and hygiene behaviour (Chapter 3). Then, various mechanisms are proposed to analyse and interpret the collected data from different perspectives (Chapter 4). The third part introduces the main barriers to effective and continued use of generated information in decision-making, and to suggest various approaches to overcome these challenges (Conclusions and Ways Forward). In more detail:

Chapter 1 - *Methodologies for data collection* - presents an improved approach for WaSH data collection at a decentralized level. The survey design takes the Water Point Mapping (WPM) as a starting point to record all available water sources at a particular location. This information is then linked to data produced by a household survey, in which a representative sample of households is selected to assess sanitation and hygiene habits. Integral to this selection process there is the issue of the sample size, which is commonly determined through the formula of the simple random sampling. At a local level with reduced populations, however, such approach proves expensive and time consuming; or alternatively, precision of achieved results is sacrificed in the interests of lower costs and simplicity. In this study, a refined method to calculate the sample size is proposed. For a given precision, confidence level and population size, a simple formula implicitly determines the required sample size. It is shown that a reduced sample size is adequate to produce estimates with sufficient precision for use in targeting and prioritization initiatives. Specifically, a categorization

process is presented to group estimates in three or more different categories, which may be relevant for local level planning support.

Chapter 2 - *Review of indicators and aggregated indices in the WaSH sector* – reviews four different approaches that are commonly adopted for monitoring purposes: i) health impact indicators, ii) standard indicators of the WHO / UNICEF Joint Monitoring Programme (henceforth JMP), iii) one multidimensional, water-focused composite indicator, and iv) easy-to-use planning indices designed locally on an ad hoc basis. From a policy-making perspective, the usefulness of outcomes produced by each approach is discussed. The epidemiological study produces misleading results, which do not help draw relevant conclusions. JMP indicators provide reasonable quality basic estimates of coverage across different contexts, but are inappropriate to build up a complete picture of such context. The index approach takes into account a broader view of service level, and proves useful as a policy tool to guide action towards improved service delivery. There are problems with composite indices, however; and they have been criticized on several grounds. Finally, simple and thematically related planning indices might become effective in assisting local governments in decision-making processes.

Chapter 3 - *Development of tools to support local level planning* - introduces a variety of policy tools that may be used to promote decision-making in the WaSH sector. First, the chapter discusses the use of composite indices. It introduces the Water Poverty Index (WPI) and highlights its main conceptual weaknesses. Then, it proposes a suitable methodology to assess water poverty that overcomes these weaknesses and taking this method as starting point, two alternative composites are presented: i) an enhanced-Water Poverty Index (eWPI) to assess the diverse, interacting components at basin level of water-related processes, societal pressures, and policy actions, and ii) a WaSH-focused, thematic indicator: the WASH Poverty Index (WASH PI). Second, a small set of simple thematic indicators are defined as the basis to reveal which planning areas require policy attention. Finally, the chapter explores the use of object oriented Bayesian networks (ooBn) as a valid approach for supporting decision making in WaSH planning and management. On the basis of the WPI, a simple ooBn model is designed and applied to reflect the main issues that determine access to safe water and improved sanitation. Results indicate that accurate and comprehensive data, if adequately exploited through easy-to-use instruments, may be the basis of effective targeting and prioritization, which are central to sector planning.

Chapter 4 - *Mechanisms to exploit and disseminate data for planning purposes* - explores various approaches to enhance data interpretation and to promote data dissemination. The ultimate aim is to improve targeting and prioritization, these being central planning activities to guide appropriate action and policymaking towards improved service delivery. In terms of data analysis, a focus on poverty reduction in planning requires a selection of beneficiaries based on needs and real hardship. A simple classification process is first proposed to prioritize among various populations. Also, the regional and socio-economic disparities need to be adequately visualized. To do this, the chapter addresses equity issues and identifies population groups at risk. The goal is to assess the gaps in service provision between the poor and the better off. Finally, the issue of scale is discussed, and the challenges associated with the application of the tools developed in previous chapters at different scales are pointed out. As regards the dissemination of achieved results, two alternatives are proposed. First, poverty maps are developed to show at a glance the level of water poverty and its heterogeneous pattern within different geographic and administrative units. Second, a cluster analysis is performed to classify large amounts of information into manageable

sets. Specifically, it is used to group information on populations based on their similarity on different indicators. The chapter suggests that previous approaches are helpful to easily and meaningfully interpret data, and there is thus potential for wider implementation.

Chapter 5 - *Conclusions and Ways Forward* – presents main findings of this research study. Achieved results indicate that accurate and comprehensive data, if adequately collected, analysed and exploited through simple instruments, may be the basis of effective targeting and prioritization, which are central to sector planning. The application and implementation of the proposed monitoring and reporting tools and processes in the real world, however, is to a certain extent elusive; and this has been pointed out as a major weakness of this research. Two specific challenges that remain unaddressed, namely the upgrading of decision support systems, and the design of data updating mechanisms, suggest the way forward.

5. Methods

This thesis integrates three different research approaches to tackle the formulated research questions: review of the literature, implementation of case studies, and data analysis and interpretation. The literature review is intended to provide all critical elements needed to build the conceptual framework of the study. Case studies constitute the skeleton of the research, as they integrate, test and validate research hypothesis and research findings. The analysis of the information is essential to extract the key messages emerging from the data, which need to be correctly interpreted to draw conclusions. Furthermore, although dissemination is not in itself a research approach, efforts have been devoted to bringing back research findings to potential end users, such as technicians and decision-makers of local government authorities, officers and analysts from various UN and other cooperation agencies, and practitioners from sector-related NGOs. In parallel, major research findings have been published in books (2 chapters), in academic reports (2), in various technical reports and in scientific journals (7 published and 1 unpublished papers), as well as presented in national (5 papers) and international congresses (10 papers).

The literature review aims to identify the relevant theoretical and methodological debates and approaches in the area of the proposed research topic. To do this, a wide and diverse array of information sources has been consulted, encompassing scientific papers, handbooks, guidelines and manuals, published reports by UN agencies and NGOs, and other grey literature as project reports, technical materials and unpublished academic papers. The broad themes addressed included, but were not limited to international monitoring strategies of drinking water and sanitation, the human right to water and sanitation, methodologies for data collection, health impact measures of water and sanitation, sector-related indices and indicators, and decentralization processes and local decision-making. The insights from the literature review have informed the theoretical framework upon which this study is based.

The implementation of the case studies has comprised different methods and techniques. In total, this thesis includes eight different studies, which are briefly introduced in following section. They all contain field work for primary data collection and the transfer of newly produced knowledge to those who can apply it to address WaSH-related problems. In brief, data have been gathered through both qualitative and quantitative methods. As regards qualitative approaches, interviews and focus group discussions with an identified set of actors representing different interests groups

have been conducted where appropriate. However, data have been mainly provided by means of quantitative methodologies, namely water point mapping exercises and household-based surveys. In terms of results dissemination and knowledge transfer, the commonly adopted approach has been to organize thematic workshops, seminars and short courses. It is noteworthy, however, that all case studies have endeavoured to engage those stakeholders with competences in WaSH – specifically the local authority - in various stages of the process, thus promoting capacity building and the transfer of knowledge as an ongoing and continuous activity.

Table 1 Type of research conducted per thesis' topic and summary of published works

Chapter	Type of Study	Published works
Methodologies for data collection	Desk review (scientific papers, UNICEF manual on MICS, WaterAid reports on WPM, JMP reports, etc.)	1 published papers (Science of Total Environment), and 1 unpublished paper
	Field work, in Bolivia (one stay of 12 weeks) and East Africa (Ethiopia -1 stay of 4 weeks-; Kenya -5 stays of 2 to 4 weeks; and Mozambique -3 stays of 2 to 3 weeks-)	Proceedings of 1 international congress (36th WEDC Conf, Nakuru)
	Data analysis and interpretation (categorization processes, validity of reduced sample sizes, etc.)	Proceedings of 2 national congresses (2nd IWA YWP, Madrid; 5th CUD, Cádiz)
Indicators and Indices	Desk review (scientific papers, JMP reports, WHO reports on service level, UN resolutions on the human right to water and sanitation etc.)	1 published papers (IWA Water Policy), and 1 unpublished paper (submitted to Social Indicators Research). In addition, 2 academic reports
	Field work, in Kenya (5 stays of 2 to 4 weeks)	Proceedings of 6 international congresses (35th WEDC Conf, Loughborough; 2nd IWA Development Cong, Kuala Lumpur; IRC WaSH Symposium, Addis Ababa; 36th WEDC Conf, Nakuru; 2013 Water Week Latinoamérica, Viña del Mar; 2013 World Water Week, Stockholm)
	Data analysis and interpretation (health impact assessment, correlation among WaSH indicators, etc.)	
Tools to support local level planning	Desk review (scientific papers, OECD handbook on composite indicators, etc.)	3 published papers (ASCE Journal of Environmental Engineering , and Water Resources Management -2-); and 1 unpublished paper (submitted to Social Indicators Research)
	Field work, in Peru (two stays of 4 to 6 weeks) and East Africa (Kenya -5 stays of 2 to 4 weeks-; and Mozambique -3 stays of 2 to 3 weeks-)	Proceedings of 5 international congresses (34th WEDC Conf, Addis Ababa; WISA 2010 Conf, Durban; 1st IWA Development Cong, México; 2nd IWA Development Cong, Kuala Lumpur; IRC WaSH Symposium, Addis Ababa)
	Data analysis and interpretation (construction of aggregated indicators, weighting and aggregation methods, correlation among WaSH variables and indices, etc.)	Proceedings of 2 national congresses (4th CUD, Bellaterra; 5th CUD, Cádiz)
Data exploitation and dissemination	Desk review (scientific papers, etc.)	2 published papers (IWA Water Science and Technology and Science of Total Environment)
	Field work, in East Africa (Kenya -5 stays of 2 to 4 weeks-; and Mozambique -3 stays of 2 to 3 weeks-)	Proceedings of 2 international congresses (2nd IWA Development Cong, Kuala Lumpur; IRC WaSH Symposium, Addis Ababa)
	Data analysis and interpretation (correlation issues, prioritization processes, equity issues, scale issues, poverty maps, cluster analysis, etc.)	Proceedings of 1 national congress (II Congrés UPC Sostenible, Barcelona)

All case studies have produced large amounts of primary information, which has to be post-processed, analysed, interpreted and disseminated effectively to avoid data misreading or misuse.

Typically in this thesis, the analysis of the data has been conducted through the development of indices and indicators that describe the status of water and sanitation infrastructure and the level of service delivered. More specifically, the statistical analysis has employed tools such as the Pearson's chi-square test and the Principal Component Analysis (PCA), using in both cases a standard statistical package (SPSS 15.0, 2006). The Pearson's chi-square test is performed to assess relationship between survey variables. PCA is used in index construction to create and validate the composite. Main goal of this analytical approach is to explore how variables are correlated with each other, and how they can be summarized to avoid any risk of repetition prior to their aggregation. Likewise, to support data interpretation and data dissemination, poverty maps have been developed to spatially display WaSH-related information. Spatial analysis has been performed using geographic information system software (ArcGis 9.3, ESRI).

6. Case studies

Integral to the thesis has been the implementation of various case studies in the context of low-income countries through partnerships with bi-lateral agencies such as the Spanish Agency for International Development Cooperation (AECID), multi-lateral agencies as the United Nations Agencies, universities and research centres, and non-profit organisations. In Latin America, one case study was implemented in the upper part of the Jequetepeque basin, Peru, during two different periods, from July to September 2008 and from July to August 2009. This case study was partially funded by the Catalan Agency for Development Cooperation (ACCD, call reference U2008) and the Center of Cooperation for Development of UPC (CCD, references O021-2008 and O048-2009). Another case study was carried out in the municipality of Tiraque in Cochabamba, Bolivia, during summer 2009 (July to September; AECID - PCIIC, references D/018825/08 and D/023916/09, and CCD, references O048-2009 and O011-2010). In East Africa, the Turkana District was selected as initial case study, though it did not include field work as we made use of a database developed by UNICEF. Also in Kenya, another case study included 21 rural districts, namely those districts where the national WaSH program is being implemented (January to July 2010; UNICEF, Agreement No. SSA/KENA/2009/00002642-0, and CCD, references O032-2009 and O024-2010). A third study in Kenya was conducted in the districts of Homa Bay and Suba, in Nyanza Province, in 2011 (from November 2010 to October 2011; UNICEF, Agreement No. SSA/KENA/2010/00003470-1, and CCD, reference O010-2011). In Tanzania, research was carried out in collaboration with the Spanish NGO ONGAWA. Kibondo District in Kigoma Region was selected as case study (2010; CCD, reference O024-2010). And in Ethiopia, we undertook the study in Bora district, in the Central Rift Valley, during 2010 (May to August; AECID - PCIIC, reference A/022983/09, and CCD, references O032-2009 and O024-2010). One final case was documented in the Municipality of Manhiça - Maputo Province, Mozambique in 2012 (November 2011 to April 2012; AECID - CAP, reference 11-CAP2-1562, and CCD, reference O010-2011).

It is observed in Table 2 that each case study addresses some but not all topics included in the thesis. Therefore, the intention was not to make a concrete comparison between all the case studies, but rather to make a soft comparison of aspects of the study whenever possible, without reducing the wider picture.

The regional setting of the different case studies is briefly described below.

Table 2 Summary of case studies

Topic	Case Studies – Scope of study
Methodologies for data collection	***Bolivia, Municipality of Tiraque***
	Field work for data collection (239 WPs and 1,530 HHs), in collaboration with Centro AGUA (Universidad Mayor San Simon)
	Ethiopia, Bora District
	Field work for data collection (3,756 HHs), in collaboration with INGO Intermon Oxfam
	Tanzania, District of Kibondo
	Field work for data collection (986 improved WPs and 3,656 HH), carried out by the Spanish NGO ONGAWA
	Kenya, 21 rural districts
	Field work for household data collection (407 WPs and 5,050 HHs across 317 rural clusters to cover 21 targeted districts), in collaboration with UNICEF
	Kenya, Districts of Homa Bay and Suba
	Field work for data collection (254 WPs and 1,157 HHs in Homa Bay, and 240 WPs and 1,215 HHs in Suba), in collaboration with UNICEF
	Mozambique, Municipality of Manhiça
	Field work for data collection (5 piped schemes, 228 WPs and 1,229 HHs), in collaboration with UN Habitat
Indicators and Indices	***Kenya, 21 rural districts***
	Health impact assessment, review of JMP indicators, and development of a WaSH-related composite
Tools to support local level planning	***Peru, Jequetepeque Basin***
	Development of an enhanced - Water Poverty Index
	Kenya, District of Turkana
	Development of a Water Poverty Index (improved methodology)
	Kenya, 21 rural districts
	Development of a WaSH Poverty Index
	Tanzania, District of Kibondo / Kenya, Districts of Homa Bay and Suba / Mozambique, Municipality of Manhiça
	Development of simple indices to support local level planning
Data exploitation and dissemination	***Peru, Jequetepeque Basin***
	Development of an enhanced - Water Poverty Index at basin scale; results dissemination through poverty maps
	Bolivia, Municipality of Tiraque
	Development of an enhanced - Water Poverty Index at community level
	Kenya, 21 rural districts
	Analysis of equity issues to identify vulnerable populations; cluster analysis to group districts based on their similarity on WaSH issues; results dissemination through poverty maps
	Tanzania, District of Kibondo / Kenya, Districts of Homa Bay and Suba / Mozambique, Municipality of Manhiça
	Analysis of equity issues to identify vulnerable populations; definition of priorities to support decision-making; results dissemination through poverty maps

Jequetepeque Watershed, Peru (Figure 2). The Jequetepeque river basin is a 4,372.5 km^2 catchment located in the north part of Peru that flows into the Pacific. It contributes significantly to

the livelihoods of 389,859 people, according to 2005 official data. The "Gallito Ciego" reservoir separates the upper-middle part from the lower part of the watershed. This study focuses on the upper-middle part, which is made up of 41 sub-basins, covering 3,564.8 km^2.
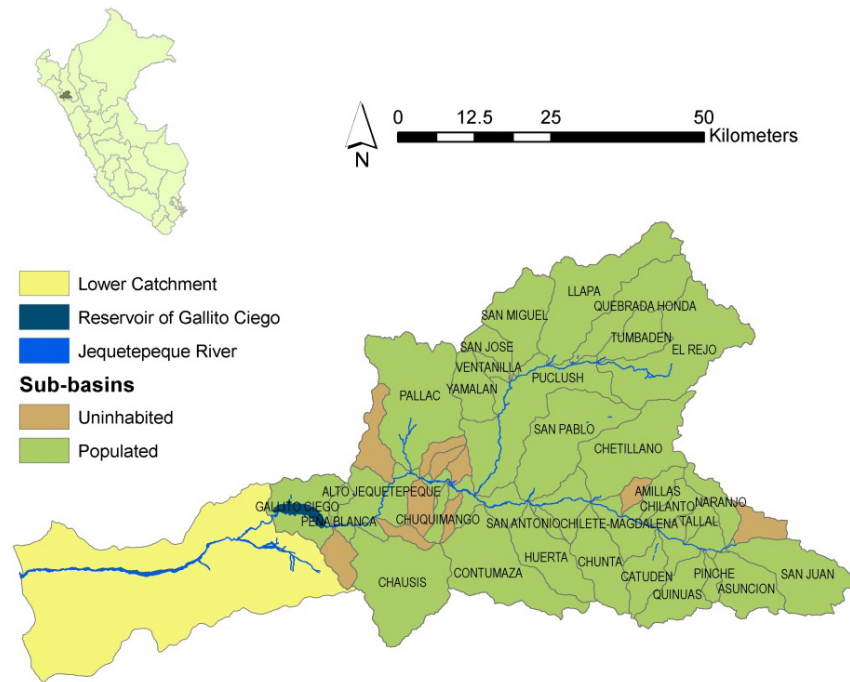
Figure 2 The Jequetepeque River Basin and its sub-basins

Municipality of Tiraque, Bolivia. The municipality is located in the Cohabamba Department, Bolivia. Administratively, it is divided into 10 districts, and includes 141 rural communities. According to the 2001 census, total population is roughly estimated at 21,000 people, and population density stands at 30 persons per km^2.

The WaSH National Programme, Kenya (Figure 3). The Government, in collaboration with UNICEF, identified through a consultative process the vulnerable populations living in rural areas with low access to safe drinking water and/or sanitation, thus representing highest risk areas of WaSH related diseases. The national Program targeted these populations, which are found in the pastoral arid and semi-arid districts of Isiolo, Wajir, Garissa, Mandera, West Pokot, and Turkana, in the Lake Basin Districts of Busia, Kisumu, Siaya, Bondo, Rachuonyo and Nyando; in the Coastal district of Kwale and Tana River; in the Eastern province districts of Mwingi, Marsabit and Kitui; in the Rift Valley province districts of Kajiado, Uasin Gishu and Molo; and in the Kieni district of Central province.
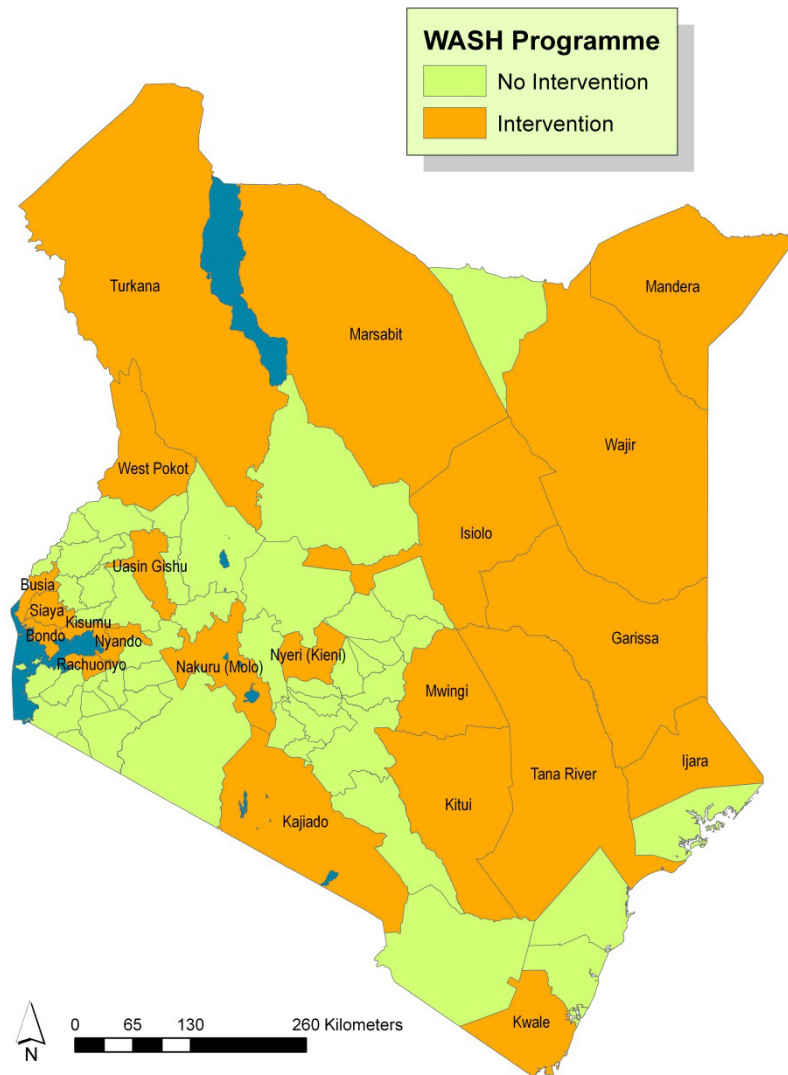
Figure 3 Map of Kenya with WaSH Programme Districts

Homa Bay and Suba Districts, Kenya (Figure 4). The rural Districts of Suba and Homa Bay are administratively located in Nyanza Province, in western Kenya, along the shores of Lake Victoria. Homa Bay is bordered by Rachuonyo District to the north, Suba District to the west, Kisii Central District to the east and Migori District to the south. The total area is 1,169.9 Km², out of which 30 Km² is surface water. Administratively, the district is divided into five divisions, namely Rangwe, Ndhiwa, Riana, Asego and Nyarongi. The divisions are further sub-divided into 25 locations and 63 sub-locations. According to the 2009 census, the population is estimated at 366,620, and the district's density averages 313 persons per km². Suba District borders Bondo District to the north across the lake, Homa Bay and Rachuonyo Districts to the east, Migori District to the south and Lake Victoria to the west. The district comprises sixteen islands, the biggest in size being Mfangano and Rusinga. The district's mainland and islands cover an area of 1,062.7 km², with the surface water accounting for 11.3% of the total district area. Administratively, the district is divided into five divisions, i.e. Mbita, Lambwe, Central, Gwassi and Mfangano, which, in turn, are sub-divided into 20 locations and 52 sub-locations. The total population is about 214,463, and the district's density stands at 202 persons per km².
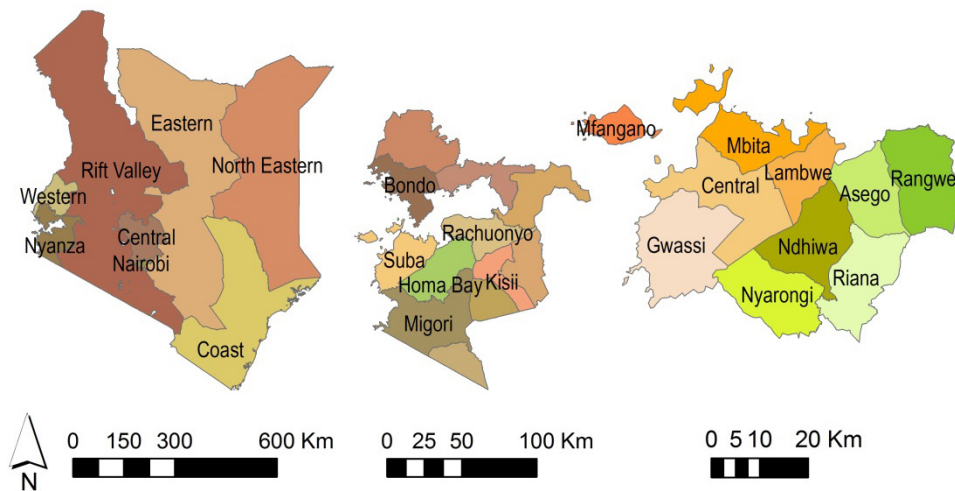
Figure 4 Administrative Units of Kenya, Nyanza Province, and Suba and Homa Bay Districts

Kibondo District, Tanzania. Kibondo is one of the 4 districts of Kigoma Region of Tanzania, and borders on Kagera Region to the North, Shinyanga and Tabora Regions to the East, Kigoma Urban District to the South, Kasulu District to the West and on Burundi to the Northwest. The district is administratively divided into 20 wards, and covers an area of 16,058 km^2. According to the 2002 Tanzania National Census, the population is estimated at 414,764; though due to closing of refugee camps, current estimation of population is 261,120.

Turkana district, Kenya. Turkana district is the largest district in Kenya, covering 70.720 km^2 of some of the most arid parts of the country. It is also one of the poorest, with frequent droughts and famines. Turkana is located in Rift Valley Province, and borders Uganda to the west, Sudan to the northwest, and Ethiopia to the northeast. The district, whose administrative headquarters is at Lodwar town, is divided into 17 administrative divisions, 58 locations and 158 sub-locations. The population density in the district is low, the total population being estimated at 450,860 (1999 National Census).

Bora District, Ethiopia. Bora District is located in the Ethiopian Central Rift Valley. Administratively, the district is situated in Oromiya region, and is made up of 18 kebeles and 305 villages, covering a total area of 738 km^2. The region largely suffers from food insecurity and poverty, and some of the factors that contribute to this perennial state are rain-based agriculture, lack of alternative source of income, backward technologies, population pressure and low land productivity. The total population is roughly about 53,452, according to 2005 national estimates.

Manhiça Village, Mozambique (Figure 5). The Municipality of Manhiça is located in Manhiça District, Maputo Province, in southern Mozambique. Administratively, the municipality of Manhiça has 18 bairros, and covers a rough area of 250 km^2. According to the local estimates, the population roughly totals 61,000 distributed in peri-urban and rural contexts.
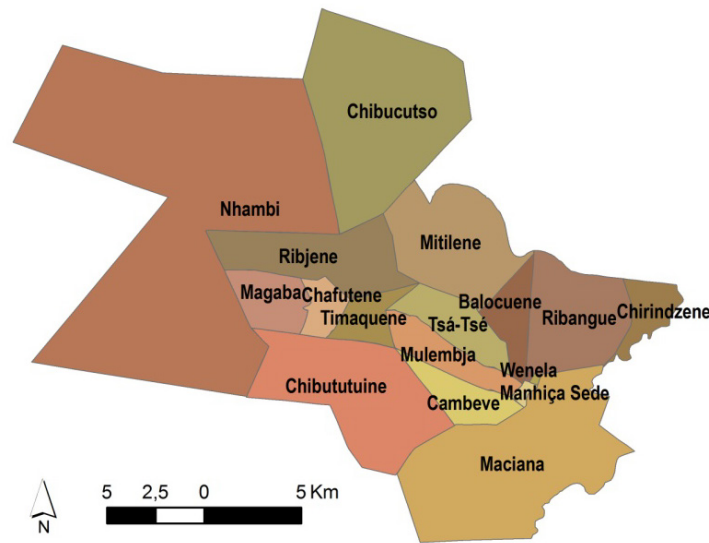
Figure 5 Bairros of the Municipality of Manhiça

7. Structure of the thesis

The remainder of the thesis is composed of four different chapters. Being part of a common sector-related challenge, i.e. development of improved frameworks for local decision-making, each chapter may be seen or used in isolation as a constituent part of an overall problem. Therefore, all chapters include an outline of the research method, present achieved results, and discuss related research findings. The analyses and conclusions of all the chapters provide a separate basis for the understanding of specific aspects within the planning, monitoring and evaluation cycle. Chapter 1 discusses key problems relating to data collection at the local level, and proposes an improved survey methodology that combines the water point and the household as key information sources. Chapter 2 reviews monitoring approaches that are in current use internationally: i) health impact indicators, ii) the JMP indicators, iii) one multidimensional, water-focused composite indicator, and iv) simple planning indices designed locally on an ad hoc basis. Chapter 3 introduces a variety of decision-making tools that may be used to promote planning, targeting and prioritization in the WaSH sector. Chapter 4 presents various approaches to enhance data interpretation and to promote data dissemination. In last chapter, the main research findings are analysed and interpreted in relation to the hypothesis and research aims that were initially formulated, and conclusions are drawn from them. Also based on these findings, two specific challenges that remain unaddressed are presented as the way forward.

CHAPTER 1

METHODOLOGIES FOR DATA COLLECTION

Abstract

In order to make decisions efficiently and equitably, accurate and up-to-date information is required. A variety of methods and techniques are in place to collect such information, specifically in the WaSH sector. With increasing decentralization, where the emphasis moves to the local level, it is imperative that such information is provided by means of cost-effective methodologies. However, some weaknesses arise when developing an instrument for routine data collection, particularly at a local level: i) comparability problems due to heterogeneity of indicators, ii) poor reliability of collected data, iii) inadequate combination of different information sources, and iv) statistical validity of produced estimates when disaggregated into small geographic subareas.

This chapter presents an improved approach for WaSH data collection at a decentralized level of government in low income settings, as an attempt to overcome previous shortcomings. The ultimate aim is to provide local policymakers with strong evidences to inform their planning decisions. The survey design takes the Water Point Mapping (WPM) as a starting point to record all available water sources at a particular location. This information is then linked to data produced by a household survey, in which a representative sample of households is selected to assess sanitation and hygiene habits. Integral to this selection process there is the issue of the sample size, which is commonly determined through the formula of the simple random sampling. At a local level with reduced populations, however, such approach proves expensive and time consuming; or alternatively, precision of achieved results is sacrificed in the interests of lower costs and simplicity. In this study, a refined method to calculate the sample size is proposed. It is based on exact confidence limits of binomial distribution, which are corrected for finite populations. For a given precision, confidence level and population size, a simple formula implicitly determines the required sample size. It is shown that a reduced sample size is adequate to produce estimates with sufficient precision for use in targeting and prioritization initiatives. Specifically, a categorization process is presented to group estimates in three or more different categories, which may be relevant for local level planning support. In order to demonstrate the applicability of the method, outcomes produced from four different case studies (Homa Bay District -Kenya-; Kibondo District -Tanzania-; Municipality of Manhiça –Mozambique-; and Municipality of Tiraque -Bolivia-) are presented.

Keywords: data collection, sample size; water point mapping; household survey; categorization; prioritization.

1. Introduction

Strategic planning and appropriate development and management of water and sanitation services are strongly supported by accurate and accessible data. If adequately exploited, these data might assist planners and managers with performance monitoring, benchmarking comparisons, resources allocation and decision making. In order to produce such data for the WaSH sector, a variety of tools and techniques have been developed in recent years. Amongst others, the Water Point Mapping -WPM- (WaterAid and ODI, 2005), the UNICEF-supported Multiple Indicator Cluster Survey -MICS- (United Nations Children's Fund, 2006a), the Rapid Assessment of Drinking Water Quality -RADWQ- (Howard and Bartram, 2003), and the Water Safety Plans (Bartram et al., 2009). However, methodological problems arise when they are implemented at the local scale.

First critical shortcoming is related to the type of data required to monitor the sector, since different information sources may be required (Joint Monitoring Programme, 2012b). Household surveys are by large the most commonly used tools for collecting WaSH data (Joint Monitoring Programme, 2006; Macro International Inc, 1996; United Nations Children's Fund, 2006a). But a focus on households is not sufficient to answer many relevant questions, and hence needs to be supplemented with data from other sources (Cronk et al., 2015). For instance, an audit at the water point might provide insight into operational and management-related aspects of the service. A methodology to efficiently combine these two types of information sources should have potential for wider implementation.

Another key limitation is that of comparability (Joint Monitoring Programme, 2006), since a variety of indicators are being simultaneously employed to measure different aspects of the level of service. More often than not, to assess trends over periods of time or to compare indicators regionally has therefore remained challenging. As a first step against this comparability problem, the Joint Monitoring Programme for Water Supply and Sanitation (JMP) formulated a set of harmonized survey questions (Joint Monitoring Programme, 2006) to provide worldwide reliable estimates of drinking-water and sanitation coverage at national level (Joint Monitoring Programme, 2014, 2012c). In so doing, JMP has improved the processes and approaches to monitoring the sector, though the definitions employed have been criticised as being too infrastructure-based (Giné Garriga and Pérez Foguet, 2013a; Giné Garriga et al., 2011; Hunt, 2001; Jiménez and Pérez Foguet, 2012). Today, an ongoing consultative process is debating a consolidated proposal of targets and indicators for the post-2015 monitoring framework (Joint Monitoring Programme, 2012b, 2011a).

The techniques employed for data acquisition also play a key role in terms of data reliability and validity (United Nations Children's Fund, 2006a). A well-designed questionnaire helps elicit a response that is accurate and measures the things one seeks to measure. On the other hand, interviews with predetermined and closed-end questions are not conducive to study respondent's perceptions or motivations (Grosh, 1997), thus pointing out the need for employing alternative survey instruments to avoid bias in survey's outcomes. For instance, water quality should be bacteriologically tested (Howard et al., 2012; Jiménez and Pérez Foguet, 2012; Joint Monitoring Programme, 2011b); while study of handwashing through structured observation may help avoid over-reporting of "desirable" hygiene behaviours (Manun'Ebo et al., 1997).

Finally, there is an issue with the statistical precision of the estimates, since to influence decentralized decision-making, performance statistics at the lowest administrative subunits (e.g. communities, villages, etc.) are required. However, it is not usually possible to survey each family comprising a population or waterpoint in the study area, and there is little choice but to select a sample and infer from it the estimates back to the entire population. In order for such estimates to be produced, it is necessary that the size of the sample be adequately determined and a valid sampling methodology be employed. The level in which information needs to be disaggregated at the local level is often high, since the number of administrative units in decentralized contexts tend to be large (Grosh, 1997). In addition, the population size in each administrative unit is reduced, since the number of households, i.e. the basic sampling unit where WaSH indicators are usually assessed (Bostoen, 2002; Joint Monitoring Programme, 2006), typically ranges from 20 to 500. With these figures, one is faced with the need to balance precision against cost when deciding the size of the sample, since the direct application of the standards and guidelines commonly employed in large scale-surveys would produce too large samples (Bennett et al., 1991; Grosh, 1997; Lwanga and Lemeshow, 1991; United Nations Children's Fund, 2006a). A scientifically sound sampling methodology is also necessary to achieve reliable estimates. Several sampling methods are currently in use, including among others simple random sampling, stratified sampling, cluster sampling and lot quality assurance sampling (LQAS). Despite the importance of these methodologies in national or regional surveys (Macro International Inc, 1996; United Nations Children's Fund, 2006a; Valadez, 1991), where populations are large and covering the overall study area would be practically impossible, they present significant flaws if applied at lower administrative scales.

A need for further research into feasible alternatives for data collection to the currently used strategies has been highlighted (Joint Monitoring Programme, 2011a). There is also growing interest among development stakeholders in harmonizing sector monitoring (Joint Monitoring Programme, 2012d). In line with these goals, the purpose of this chapter is to adopt a new specific approach to collect domestic WaSH data at the local level. Taking advantage of the current momentum of WPM as field data collection method in the water sector (Government of Liberia, 2011; Government of Sierra Leone, 2012; Jiménez and Perez-Foguet, 2011a; Pearce and Howman, 2012; WaterAid, 2010), this study presents a cost-efficient alternative to simultaneously perform a WPM together with a household survey. Specifically, a mapping exercise is taken as a starting point to record all available water sources at a particular location, which results in the need of covering the whole study area. This information is then combined with data provided from a household-based survey, in which a representative sample of households is selected to assess sanitation and hygiene habits. The size of the sample is determined based on exact confidence intervals; and although the expected errors of the estimates produced are large, it is shown that achieved results may be used to classify and prioritize among groups of households. Such prioritization is valuable for local decision-making processes. To test the applicability and validity of the proposed approach, three different case studies in East Africa and an additional one from Latin America are presented.

In Section 2, basic concepts of the evaluation framework adopted in this study are outlined, and commonly employed sampling strategies are briefly introduced. Integral to this frame is the description of the theoretical basis of sample size determination. The methodology proposed to collect WaSH primary data is described in Section 3. It presents the four case studies and highlights key features of the approaches adopted in each one of them. The categorization of the

data is carried out in Section 4, basing the priorities on a process performed in terms of the precision of the survey (a priori), and not in terms of the estimates produced (after survey completion). For illustrative purposes and to provide useful guidelines on data exploitation, Section 5 presents different examples from the case studies outlined before. The chapter concludes that efficient data collection mechanisms can be designed to produce reliable estimates with sufficient precision for use in local planning processes.

2. Evaluation framework

This section introduces core aspects of the evaluation frame proposed to locally assess the WaSH status. First, the two methodologies for data collection in which we base our approach are presented, i.e. the Water Point Mapping (WPM) and the Multiple Indicator Cluster Survey (MICS). Second, it discusses the issue of the sample size, as the survey design has to enable the compilation of accurate primary data to produce statistically representative estimates.

2.1. The Water Point Mapping

Mapping of water points has been in use by NGOs and agencies worldwide for over a decade, particularly in sub-Saharan Africa (e.g. Malawi, Tanzania, Ghana, Ethiopia, Zambia, Liberia, Sierra Leone, etc.). This methodology, largely promoted by the NGO WaterAid, can be defined as an 'exercise whereby the geographical positions of all improved water points[3] in an area are gathered in addition to management, technical and demographical information' (WaterAid and ODI, 2005). It involves the presentation of these data in a spatial context, which enables a rapid visualization of the distribution and status of water supplies. A major advantage is that water point maps provide a clear message on who is and is not served; and particularly in rural areas, they are being used to highlight equity issues and schemes' functionality levels at and below the district level. This information can be therefore employed to inform decentralized governments about the planning of investments to increase water coverage (Jiménez and Pérez Foguet, 2010a; WaterAid, 2010).

Specifically, the mapping does not refer to a fixed set of indicators, and two different actions are suggested in this regard: i) biological testing to ensure water quality; and ii) the inclusion of unimproved sources. First, water quality analysis has long been nearly absent from water coverage assessments because of affordability issues (Howard et al., 2012; Joint Monitoring Programme, 2010a). In the absence of such information, it is assumed that certain types of water supplies categorized as 'improved' are likely to provide water of better quality than traditional unimproved sources (Joint Monitoring Programme, 2000, 2012a). This assumption, though, appears over-optimistic, and improved technologies do not always deliver safe water (Bain et al., 2014; Giné Garriga and Pérez Foguet, 2013a; Jiménez and Pérez Foguet, 2012). Contrary to what might be expected, and particularly in comparison with overall investments projected for new infrastructure or with ad hoc quality testing campaigns, water quality surveillance does not significantly impact

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[3] The types of water points considered as improved are consistent with those accepted internationally by the WHO/UNICEF Joint Monitoring Programme (Joint Monitoring Programme, 2006). More specifically, an improved water point is a place with some improved facilities where water is drawn for various uses such as drinking, washing and cooking (Stoupy and Sugden, 2003).

on the overall cost of the mapping exercise: from USD 12 to 15 dollars/waterpoint in standard WPM (Stoupy and Sugden, 2003) up to USD 20 when quality testing is included (Jiménez and Pérez Foguet, 2012). Second, being the original focus of WPM on improved waterpoints, unimproved sources may be also mapped if they are accessed for domestic purposes. A thorough analysis of collected data would shed light on the suitability of the improved / unimproved classification proposed by the JMP, but more importantly, this would help understand equity issues in service delivery (Giné Garriga and Pérez Foguet, 2013a; Jiménez and Perez-Foguet, 2011b; Joint Monitoring Programme, 2012b).

2.2. Household Surveys

A major strength of WPM is, per definition, comprehensiveness with respect to the sample of water points audited, which entails complete geographic representation of all strata in the study area (i.e. all enumeration areas as communities, villages, etc.). Taking advantage of this logistic arrangement, and in addition to the mapping, a household-based survey may be thus designed to evaluate sanitation and hygienic practices at the dwelling. As it may be assumed that all households are located within walking distance of one water source (either improved or unimproved), the approach adopted practically ensures full inclusion of families in the sampling frame.

In terms of sampling technique, the simplest method to conceptualize a survey is the simple random sampling, in which each basic sampling unit (i.e. the household) has an equal probability of inclusion in the sample. Its direct application, however, presents numerous drawbacks, and for household surveys it often becomes unrealistic to implement in practice (Bennett et al., 1991; Bostoen and Chalabi, 2006; Lemeshow and Stroh, 1988). To be random, the sampling relies on the exhaustive identification of all households, and such identification might be too expensive in terms of time and resources, especially in rural contexts. Another flaw is that selected households may be highly dispersed, thus hampering the survey logistics. And individuals representing certain subgroups in the population may, by chance, be oversampled, undersampled or totally overlooked in the sample. An alternative approach to ensure sampling of all population groups related to the variable of interest is the stratified random sampling, in which mutually exclusive and exhaustive strata of non-overlapping subpopulations are created (e.g. rural / urban). Simple random samples are, however, selected from each stratum, and major disadvantages of this approach thus still relate to the need of requiring a comprehensive list of individuals. One practical solution to overcome the need of basing the sampling frame on an exhaustive list of enumeration units is to use a cluster sampling strategy (Bennett et al., 1991; Bostoen, 2002; Lemeshow and Stroh, 1988). The term "cluster" is herein defined as a natural grouping within the population, such as village or community, from which a subsample may be selected; and cluster sampling therefore entails that selected individuals are located geographically close to one another. The goal is to improve the efficiency of the assessment by facilitating access to the selected individuals and by reducing costs (Howard et al., 2012). When sampling, a set of clusters is identified, and from each cluster, a sample of individuals is selected through random techniques. The process of clustering, however, increases the risk of homogeneity within the clusters, i.e. there is a loss of sensitivity in detecting the true proportion of individuals in the cluster with a particular feature. In consequence, this

technique needs an adjustment to mitigate this risk, i.e. the sample design effect, *deff*[4]. This statistical measure varies from region to region, from survey to survey, and from variable to variable (Kish, 1980), but literature suggests that the design effect of most water and sanitation variables may range from 2 to 10 (Bostoen, 2002; Howard et al., 2012; United Nations Children's Fund, 2006a). More precisely, the value 4 seems to be widely accepted by experts (United Nations Children's Fund, 2009), though it is noted that ten-fold or even higher variations are not uncommon values in WaSH studies (Bostoen, 2002; Giné Garriga et al., 2013a; Kish, 1980; United Nations Children's Fund, 2006a). The cluster sampling approach is commonly adopted for surveys where the interest is in one single value for the entire study area (e.g. nation, district, municipality, etc.). However, since obtained values at cluster level are not sufficiently precise for comparative purposes, the validity of this technique is doubtful when applied locally for targeting and prioritization purposes.

As opposed to cluster-sampling, LQAS produces some basic information from each stratum in the study area (i.e. lot), namely whether the performance of a particular lot is likely to be above or below a given threshold (Singh et al., 1996), and therefore provides local managers with valuable inputs that enable informed decision-making (Robertson et al., 1997). In terms of method, LQAS approach is similar to stratified sampling, but the samples are too small to obtain meaningful confidence intervals for estimates for a specific lot. Rather, it performs a one-sided hypothesis test to decide about the acceptability or unacceptability of the lot on the basis of a particular characteristic. The benefits of adopting an LQAS approach need to be weighed against the loss of precision in each lot, since acceptably narrow confidence intervals provide much more information for decision-makers than a simple binary decision (Lemeshow and Stroh, 1988).

In this study, the design and selection of the sample draw on the MICS, i.e. a cluster survey methodology developed by UNICEF (United Nations Children's Fund, 2006a) to collect social data, which is ultimately required amongst others for monitoring the goals and targets of the Millennium Declaration or producing core United Nations' development indices. Main difference from the MICS's sampling approach is, however, that a sample of households is selected in this study from each population stratum (stratified sampling), rather than selecting a reduced number of strata, from which a subsample of households is identified (cluster sampling). In so doing, the risk of homogeneity within the strata remains relatively low, thus reducing the need for applying large design effects.

2.3. The sample size

In local decision-making, there is concern for estimating the performance of administrative subunits (e.g. communities, villages, etc.) to identify the most vulnerable areas. In contrast to the viewpoint of central governments, where one regional coverage value might be sufficient; estimates at the lowest administrative scale are required for decentralized planning, since overall values say nothing about local variations. The goal of WPM is to develop a comprehensive record of all water points available in the area of study. There is no need of sampling in data collection.

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[4] The "design effect" is an adjustment that measures the efficiency of the sample design, and is calculated by the ratio of the variance of an estimator to the variance of the same estimator computed under the assumption of simple random sampling.

For the household survey, however, a statistically representative sample needs to be selected to achieve reliable estimates.

In stratified sampling, much like the random sampling and other sampling approaches, the standard representative sample of size *n*, for an estimated proportion *p*, is numerically the smallest integer verifying the following inequality (Cochran, n.d.):

$$n \geq \max_{0<p<1} \left(\frac{z_{\alpha/2}}{d}\right)^2 p(1-p) = \left(\frac{z_{\alpha/2}}{2\,d}\right)^2 \tag{1}$$

where α is the confidence level, z is a constant which relates to the normally distributed estimator of the confidence level ($z_{\alpha/2} = 1.96$, $\alpha = 0.05$; $z_{\alpha/2} = 1.64$, $\alpha = 0.1$; $z_{\alpha/2} = 1.28$, $\alpha = 0.2$), *d* is the required precision on either side of the proportion, and a figure of 0.5 is chosen for *p* to maximize $p(1-p)$. Equation (1) provides a simple and explicit expression[5] for *n* in terms of *d* and α, and it is obtained by imposing:

$$2d \geq max_{0<p<1}\, p_u - p_l \tag{2}$$

where p_u and p_l are the upper and lower limits of the confidence interval with the approximation to the binomial distribution by the normal one.

When estimates at local scale are required, though, major shortcoming is that if (1) is applied repeatedly at all administrative sub-units of interest, the overall sample size, $n = \sum n_i$ being n_i the sample size of the sub-unit *i*, turns out too large in comparison with overall population, $N = \sum N_i$ being N_i the population of sub-unit *i*. Since large sample sizes hinders in practice the implementation of local surveys, relative large lengths of confidence intervals are typically obtained. This presents a drawback from the viewpoint of interpretability. Small area estimates (Elbers et al., 2003; Ghosh and Rao, 1994; Rao, 2003) may be used to improve precision, and the Small Area analysis has been extensively applied, for instance, for developing poverty maps (Benson, 2002; Davis, 2003; Henninger and Snel, 2002; Hentschel et al., 2000). This technique combines information from different administrative scales or relates to auxiliary data (e.g. census data) in order to improve the estimates for small populations, but only to a limited extent and under specific circumstances (Tarozzi and Deaton, 2009). Alternatively, sample size may be computed from exact confidence limits for *p* (Equations 2.1 and 2.2), rather than employing Equation (1). Numerically, these equations are based on the F distribution (Leemis and Trivedi, 1996), the so called Clooper-Pearson interval (Reiczigel, 2003):

$$p_L^{EXA} = \left(1 + \frac{n-y+1}{y\,F_{2y,2(n-y+1),1-\frac{\alpha}{2}}}\right)^{-1} \tag{2.1}$$

$$p_U^{EXA} = \left(1 + \frac{n-y}{(y+1)\,F_{2(y+1),2(n-y),\frac{\alpha}{2}}}\right)^{-1} \tag{2.2}$$

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[5] There is conflicting advice concerning which values of *n* and *p* are appropriate for using the approximation of Eq. 1, since they have been widely estimated for different purposes. A standard recommendation is when *np* and *n(1-p)* are both greater than 5 (Leemis and Trivedi, 1996). A minimum *n* of 10 would be then required when *p* = 0,5, and higher sample sizes would be needed for limit values of *p*.

being y the number of observed events. The maximum length of the confidence interval is found at $y = n/2$, which leads to:

$$2d^{EXA} = \max_{0<y<n}\left(p_U^{EXA} - p_L^{EXA}\right) = \left(1 + \frac{n}{(n+2)\,F_{(n+2),n,\frac{\alpha}{2}}}\right)^{-1} - \left(1 + \frac{n+2}{n\,F_{n,(n+2),1-\frac{\alpha}{2}}}\right)^{-1} \quad (3)$$

To obtain accurate confidence limits for reduced finite populations, the finite population correction ordinarily applied are employed (Anderson and Burstein, 1968, 1967), but with minor fine-tuning (Burstein, 1975):

$$p_L^{FPC} = \frac{2\,y-1}{2\,n} - \left(\frac{2\,y-1}{2\,n} - p_L^{exa}\right)\left(\frac{N-n}{N-1}\right)^{1/2} \quad (4.1)$$

$$p_U^{FPC} = \frac{(n+1)\,y}{n^2} + \left(p_U^{exa} - \frac{(n-1)\,y}{n^2}\right)\left(\frac{N-n}{N-1}\right)^{1/2} \quad (4.2)$$

where p_L^{FPC} and p_U^{FPC} are the confidence limits for a finite population, FPC. Equations 4.1 and 4.2 are only valid for $y/n \leq 0.5$, and the limits for $(n-y)/n$ can be computed as complements of those for y/n (Anderson and Burstein, 1968; Newcombe, 1998). The maximum length of the confidence interval is:

$$2d^{FPC} = \max_{0<y<n}\left(p_U^{FPC} - p_L^{FPC}\right) = \left(\frac{N-n}{N-1}\right)^{1/2}2d^{EXA} \quad (5)$$

which is smaller than the uncorrected interval for N and n greater than 1. The sample size for a given set of N, α and d is given by the lower value of $n \in (1, N)$:

$$F^{EXA,FPC}[n; N, \alpha, d] = d - d^{EXA,FPC}[n; N, \alpha] \geq 0 \quad (6)$$

It is worthwhile noting that Equation (6) can be easily computed in any standard spread-sheet, as both d^{EXA} and d^{FPC} monotonously decrease with n, and Table 3 shows by way of example a range of sample sizes n for different values of N, α and d.

It is observed that sampling for a population size N lower than 8 may be to certain extent meaningless, since either the confidence level α or the precision d have to be significantly sacrificed. Specifically, a sample size n of 6 in a population N of 8 would produce estimates within 40% ($\pm$ 20%) of the true proportion with 80% confidence. And estimates with 95% confidence in abovementioned sampling design (n:N of 6:8) would fall within 25 percentage points of the true proportion. In contrast, a sample size of 17 from a population of size N lower than 100 guarantees estimates with 90% confidence within 20% points of precision. For higher precision, e.g. $\pm$ 15% or $\pm$ 10%, the sample size increases significantly up to 27 and 46 respectively; and with 95% confidence, the required size of the sample would be 22, 33 and 53. Simple tables as Table 3 help select an optimal sampling plan (minimum sample size) on the basis of available resources, desired precision and the maximum permissible sampling error. Since the table also presents the values for n suggested by Equation (1), one can easily infer the validity of the final selection.

Table 3 Sample size *n* for different values of *N*, α and *d*. *Source*: Pérez Foguet and Giné Garriga (2014)

N	$\alpha = 0,05$				$\alpha = 0,1$				$\alpha = 0,2$			
	d < 0,1	d < 0,15	d < 0,20	d < 0,25	d < 0,1	d < 0,15	d < 0,20	d < 0,25	d < 0,1	d < 0,15	d < 0,20	d < 0,25
8	---	---	7	6	---	---	7	6	---	7	6	5
10	---	9	8	7	---	9	8	7	---	9	7	6
12	---	11	9	8	---	10	9	7	11	10	8	6
15	14	13	11	9	14	12	10	8	14	11	9	7
20	18	16	13	10	18	14	11	9	17	13	10	7
25	22	18	14	11	21	16	12	9	19	14	10	
30	26	20	15	12	24	18	13	10	21	15		
40	31	24	17	13	29	20	14	10	25	16		
50	36	26	18	13	33	22	15	11	28	18		
75	46	30	21	14	40	25	17		32			
100	53	33	22	15	46	27	17		35			
150	64	37	23		53	29			39			
250	75	40	24		60							
500	87	43			67							
Eq. 1	96	43	24	15	67	30	17	11	41	18	10	7

From the point of view of the practitioner, the question then reduces to how large might *d* be in order to achieve estimates sufficiently precise for decision-making support. And though the answer will clearly depend on the nature and scope of the study, and on the expected results, the approach described in Section 4 suggests that the acceptance or rejection of *d* may be based on a categorization process.

3. Improved methodology for data collection

Section 3 describes the approach adopted for data collection which, as mentioned above, combines a mapping of water sources with a stratified survey of households. Different methodologies already employ the waterpoint and the household as key information sources, but they commonly differ from the method proposed herein in i) the focus -national rather than local-, and in ii) the statistical precision of the estimates -inadequate to support local level decision-making-. Key features of the proposed methodology include i) an exhaustive identification of enumeration areas (administrative subunits as communities, villages, etc.); ii) audit in each enumeration area of all improved and unimproved water points accessed for domestic purposes; and iii) random selection of a sample size of households that is representative at the local administrative level (e.g. district, municipality, etc.) and below.

The mapping of waterpoints is exhaustive regardless functionality issues, though the inclusion of unimproved sources in the analysis will be dependent on the scope of the exercise and available resources. The need to tackle equity and non-discrimination issues has been highlighted from the viewpoint of human rights (United Nations General Assembly, 2012), and any exercise covering unimproved waterpoints would provide inputs to elucidate the access pattern of the population. In rural contexts, however, this type of water source may be common, thus increasing significantly the budget and resources devoted to data collection in case of inclusion. Similarly, where main water technology is piped systems with household connections, the idea of a comprehensive audit of all these private points-of-use is practically impossible. A more convenient solution would be to visit the distribution tank and a reduced number of domestic taps, which are taken as representative of the overall system.

The household survey is conducted in parallel with the mapping. Ideally, a defined number of households will be selected in a statistically random manner from a comprehensive list of all households in the subunit of study. However, such a list does often lack. Then, if the population size is small, the optimum alternative may be to create a list by carrying out a quick census. In those cases where enumerating all households is impracticable, literature suggests different sampling techniques to achieve a random or near-random selection (Bennett et al., 1991; Frerichs and Tar, 1989; Lemeshow and Stroh, 1988). They usually involve two stages: the identification of one or various households to be the starting point, and a method for selecting "n" successive households, preferably spread widely over the community. In the end, where a complete random exercise is not achievable, any methodology during the sampling process which promotes that the sample is as representative as possible would be acceptable, as long as it is clear and unambiguous, and does not give the enumerator the opportunity to make personal choices which may introduce bias. In these cases, however, and to ensure data validity, to apply a correction factor in sample size determination ($deff = 2$) is recommended.

In terms of technique, the method relies on a variety of mechanisms to assure quality of produced outcomes. Among the most important are:

- *Territorial delimitation of study area.* As an exercise to support planning, administrative subunits in which base data collection should play a relevant administrative role in decentralized service delivery. Thus, they should be adequately delimited, unambiguous and well-known by both decision-makers and local population.

- *Design of survey instruments.* On the basis of a reduced set of reliable and objective indicators, appropriate survey tools should be developed for an accurate assessment of the WaSH status. This study is reliant on a combination of quantitative and qualitative study tools, which are specially designed to collect data from the water point and the household. Field inspections at the source employ a standardized checklist to evaluate the existence, quality and functionality of the facility; and a water sample is also collected for on-site bacteriological testing. At the dwelling, information related to service level is captured through a structured interview administered to primary care-givers. In addition, direct observation enables a complementary evaluation of domestic hygiene habits that may not be otherwise assessed, as sanitary conditions of the latrine, existence and adequacy of the handwashing facility, etc..

- *Involvement and participation of local authorities.* This study engages in various stages of the

process with those government bodies with competences in WaSH. Specifically in data collection, the commitment of officers belonging to the local government i) helps ensure a link between field workers and the local structures at community level, and ii) promotes sense of ownership over the process, as prerequisite for incorporating the data into decision-making. As important of promoting collaborative data collection methods is to foresee the viability of future data update activities, and accessibility and reliability of information have been two core criteria when preparing the survey instruments. Moreover, a consultative approach has been adopted for indicators' definition to tailor the survey to each particular context. Finally, data collection focuses on the administrative scale in which decisions are based, thus producing relevant information for local policy-makers.

- *Pilot study*. A pilot run helps explore the suitability of the approach adopted, i.e. methodology and study instruments. Further fine-tuning (question wording and ordering, filtered questions, deletion of pointless questions, etc.) follows the pilot.

- *Data processing*: The data entry process needs to be supervised, and the produced datasets need to be validated on a regular basis. Various quality control procedures must be in place to ensure that the data reflects the true position as accurately as possible, and routine analysis of database or random checks of a reduced number of questionnaires may help detect data inconsistencies and improve database robustness.

3.1. Study Area

Three different East African settings and an additional one from Latin America have been selected as initial case studies to test the applicability and validity of the proposed methodology, namely the municipality of Tiraque (Bolivia, in 2009), the district of Kibondo (Tanzania, in 2010), the district of Homa Bay (Kenya, in 2011) and the municipality of Manhiça (Mozambique, in 2012). The implementation of each case study has adopted particular features, which are briefly summarized in Table 5, and scope of work has been designed on the basis of local needs (e.g. inclusion / exclusion of unimproved waterpoints, inclusion of non-household settings - schools and health centres -, the focus and level of detail required in survey questionnaires, etc.). However, they have all shared same approach, method and goals: i) they have been formulated against specific call from a development-related institution to support local level decision-making (in Tanzania, a Spanish NGO; in Kenya, UNICEF; and in Bolivia and Mozambique, the Spanish Agency for International Development Cooperation); ii) researchers from the Technical University of Catalunya have undertaken overall coordination of the study; iii) the local authority has been engaged as principal stakeholder throughout the process; and iv) a consultancy firm has been contracted for field work support (except in Bolivia, where students from the local university actively participated in the data collection exercise).

Table 4 Key features of the approach adopted for data collection in each case study. *Source*: Adapted from Giné Garriga et al (2013b)

Case Study	Adm. Division	Cost, in USD[a,b]	Data collection		Key features
	Unit (Subunits)		*No. WPs[c]*	*No. HH*	
Tiraque, Bolivia	Municipality (10 Districts)	---[d]	239 145 IWPs and 94 UWPs	1.530	- The total population is roughly about 21,000 (INE, 2001), with an estimated density of 31 persons per km^2. - Sampling Plan (at district level): $\alpha = 0.05$; $D = 2$; $d = \pm 0.15$; n (min) = 86. - Audit of improved and unimproved WPs. The WP audit included 67 questions (35 minutes per WP) + 1 water quality test - HH checklist included 24 questions related to water, sanitation and domestic hygiene issues (15 minutes per HH) - The field team included two staff from GRECDH - UPC (1 fully involved), 1 staff from the local university (fully involved), 1 technician from the municipality (partially involved), and 7 students split into two data collection groups. Field work was completed in 39 days.
Kibondo, Tanzania	District (20 Wards)	13.578 P (42%), T (45%) and OC (13%)	986 IWPs	3.656	- The total area is 16,058 km^2 and the population is estimated at 414,764 (2002 Tanzania National Census). - Sampling Plan (at ward level): $\alpha = 0.05$; $D = 2$; $d = \pm 0.10$; n (min) = 192. - Unimproved WPs were not audited. The WP audit included 38 questions (30 minutes per WP) + 1 water quality test.. - HH checklist included 18 questions related to sanitation and domestic hygiene issues (10 minutes per HH). - The field team included one staff from Spanish NGO, 1 technician from District Water Department, two staff from a consultancy firm and two people from each visited village. Field work was completed in 42 days.
Homa Bay, Kenya	District (5 divisions)	32.389 P (74%), T (17%) and OC (9%)	255 187 IWPs and 68 UWPs	1.157	- The total area is 1,169.9 km^2, and the total population is about 366,620 (2009 National Census). - Sampling Plan (at division level): $\alpha = 0.05$; $D = 2$; $d = \pm 0.10$; n (min) = 192. - Unimproved WPs were audited in only 3 out of 5 divisions. The WP audit included 38 questions (30 minutes per WP) + 1 water quality test. - HH checklist included 65 questions related to water, sanitation and domestic hygiene issues (35 minutes per HH). - Data collection did not include urban areas. It included schools (85) and health centres (37). - The field team included tree staff from GRECDH - UPC (1 fully involved), 1 technician from the District Water Department (partially involved), 1 technician from the District Public Health Department (partially involved), 8 staff from a consultancy firm, and one people from each visited community. Field work was completed in 33 days.

Case Study	Adm. Division	Cost, in USD[a,b]	Data collection		Key features
	Unit (Subunits)		*No. WPs[c]*	*No. HH*	
Manhiça, Mozambique	Municipality	23.719	228	1.229	- The total area is 250 km^2 and the population is estimated at 57,512 (2007 national estimates)
	(18 bairros)	P (41%), T (42%) and OC (17%)	224 IWPs and 4 UWPs		- Sampling Plan (at bairro level): $\alpha = 0.05$; D = 2; d = ± 0.15; n (min) = 86.
					- Audit of improved and unimproved WPs. The WP audit included 41 questions (30 minutes per WP) + 1 water quality test
					- HH checklist included 82 questions related to water, sanitation and domestic hygiene issues (45 minutes per HH)
					- Data collection included schools (16) and health centres (2)
					- The field team included three staff from GRECDH - UPC (1 fully involved), 3 technicians from the Vereação para Urbanização, Construção, Água e Saneamento (partially involved), 14 staff from a consultancy firm and 1 people from each visited village. Field work was completed in 29 days.

Note: a) Includes data collection and data entry into the database. It does not include the cost of the portable kit for water quality analysis and consumables. b) In percentage, overall budget broken down into personnel (P), transport (T), and other costs (OC). c) Type of waterpoints includes IWP for Improved waterpoint and UWP for unimproved waterpoint. d) Data collection in Tiraque was performed by students from the local university.

4. The categorization of estimates in prioritization processes

For targeting and prioritization purposes, the standard way of analysing the results is to consider p with its respective confidence interval (p_L, p_U), or in the limit of the normal approximation, $p \pm d$. In this regard, top positions would denote highest priority in which thus focus policy attention. Based on the data from the Kenyan case study, for instance, and as observed in Table 4, Rangwe may be easily identified as the most water poor division in Homa Bay ($p_{i, \text{access}} = 0,355$; $p_{i, \text{time}} = 0,753$). When relative large values of d are expected, however, this presents a drawback from the viewpoint of interpretability, since understanding the relative importance of differences between estimated proportions p_i may be challenging. In these conditions, this categorization criterion is often underused or misused.

Table 5 Estimated proportion and Confidence Interval of water indicators in Homa Bay

	Access to improved waterpoints		Time to fetch water[a]	
	p_i	$\alpha = 0,2$ $p_{L,i} - p_{U,i}$	p_i	$\alpha = 0,2$ $p_{L,i} - p_{U,i}$
Asego	0,510	0,462 - 0,556	0,807	0,766 - 0,842
Rangwe	0,355	0,310 - 0,401	0,753	0,708 - 0,792
Ndhiwa	0,521	0,472 - 0,569	0,968	0,944 - 0,983
Nyarongi	0,663	0,625 - 0,699	0,936	0,913 - 0,953
Riana	0,441	0,399 - 0,482	0,910	0,882 - 0,932

Note: a) Households spending less than 30 minutes for one round-trip to collect water.

Against this background, this section justifies the validity of the estimates produced with reduced sample sizes from the viewpoint of prioritization and decision-making, and this is done through the definition of a non-overlapping criterion between the confidence interval (C.I.) of the estimates. Specifically, we interpret the C.I. in terms of a hypothesis test, which provides an alternative way to analyse the results. Given the estimation of a proportion p and its C.I. (p_L, p_U), we reject the hypothesis test[6] $H_0: p = q$ with a given level of significance α for all values of q not in the C.I., i.e. q in $[0, p_L)$ or $(p_U, 1]$. Alternatively, we may compare two different proportions p_1 and p_2 and their respective C.I. $(p_{L,i}, p_{U,i})_{i=1,2}$. Both of them being considered normally distributed and independent, we reject the hypothesis test[1] $H_0: p_1 - p_2 = 0$ with a given level of significance α when the following interval does not contain the value zero (Krishnamoorthy and Thomson, 2002; Taillard et al., 2008).

$$(p_1 - p_2) \pm z_{\alpha/2} \sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}} \,. \tag{7}$$

---

[6] The power of the test can be computed with respect to an alternative hypothesis. It can be included as design criteria for sample size determination in case its value is of concern.

Remarkably, it is easy to check that the sum of the lengths of both C.I. is larger (or equal in limit cases) than the interval of non-rejection given by (Krishnamoorthy and Peng, 2008; Takahashi et al., 2006):

$$(p_{U1} - p_1) + (p_2 - p_{L2}) \geq z_{\alpha/2} \sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}, \tag{8.1}$$

which may be verified thanks to the inequality $(a + b)^2 \geq a^2 + b^2$ for non negative a and b, given by:

$$\sqrt{\frac{p_1(1-p_1)}{n_1}} + \sqrt{\frac{p_2(1-p_2)}{n_2}} \geq \sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}. \tag{8.2}$$

Based on this property and with the goal of overcoming the issue of interpretability for large values of d, we assign the estimate p, i.e. any real value between [0,1], to a specific category. A set of sorted categories are defined as $C = [0,1] = \cup_{i=1,...,m} C_i$, with, for instance $C_i = [l_i, u_i)$, except the last one which includes the boundary $C_n = [l_{n-1}, 1]$. Each category is characterized by its limit values l_i and u_i.

For the assignment process, we analyse the potential overlapping between the C.I. of estimates from one category with the C.I. of the limit values of the other categories. The idea is that if a given estimate p is categorized in a certain category C_i, there will be reasonable doubts about the exact location of the real value of p in C_i or in the surrounding C_{i-1} or C_{i+1}. Particularly, when the estimate is close to the limits of C_i, since the corresponding C.I. of p will overlap C_{i-1} or C_{i+1}. In contrast, the assumption that there will be no overlapping of the C.I. with the rest of the categories located further away (i.e. $C_{i\pm k}$, with $k \leq -2$ and $k \geq 2$) seems more realistic. We therefore impose the criterion that if the estimate lies in C_i, there is no chance for it to belong neither to C_{i-2} nor to C_{i+2}. This may be checked by comparing the C.I. of C_i limits with those of C_{i-2} and C_{i+2}; specifically, whether p_U^{FPC} for u_i is lower than p_L^{FPC} for l_{i+2}, and whether p_L^{FPC} for l_i is larger than p_U^{FPC} for u_{i-2}. If both conditions are confirmed for all i, the set of categories C_i may be considered adequate to discriminate proportions. This approach is simpler and more conservative than the hypothesis test for difference of proportions, though the latter may be preferred in those cases where a more precise measurement is required to justify a specific categorization

The simplest categorization, the "uniform" one with interval lengths $h_i = u_i - l_i = h = 2/int(1/d)$, verifies the previous criterion. Following Equation (5), it can be seen that h is larger (or equal in the limit $p = 0.5$) than the maximum expected C.I.. Therefore, no overlapping of the C.I. is observed with the interval defined by C_{i-2} and C_{i+2}, which also applies in the limit values $p = 0$ or $p = 1$ (where the unilateral C.I. with confidence level $\alpha/2$ is considered instead of α as it is more conservative). From a practical perspective, the uniform categorization entails that for a given $d = 0.05$ ($h = 0.1$), ten categories of p are justified, and three categories are defined for $d = 0.16$ ($h = 0.33$). Larger values of d would result in only two categories, which become useless on the basis of the categorization criterion mentioned above.

Taking into account that these examples correspond to limit scenarios for low values of n, in next step we validate this approach on the basis of the C.I. of discrete values of a dichotomous variable

y, which varies from 0 to *n*. It is therefore noted that the resulting categories are not based on survey's outcomes but on theoretical estimates, i.e. "a priori categorization".

Table 6 Approximate Confidence Limits for a reduced population of size N = 12

N	n	y	p	α = 0,05			α = 0,1			α = 0,2		
				p_L	p_U	$p_U - p_L$	p_L	p_U	$p_U - p_L$	p_L	p_U	$p_U - p_L$
12	8	0	0[a]	,000	,223	(b)	,000	,188	(b)	,000	,151	(b)
12	8	1	0,125	,027	,373	,173	,029	,340	,155	,033	,301	,134
12	8	2	0,250	,094	,504	,205	,102	,473	,185	,116	,436	,160
12	8	3	0,375	,175	,623	,224	,191	,596	,203	,213	,563	,175
12	8	4	0,500	,268	,732	,232	,290	,710	,210	,318	,682	,182
12	8	5	0,625	,377	,825	,224	,404	,809	,203	,437	,787	,175
12	8	6	0,750	,496	,906	,205	,527	,898	,185	,564	,884	,160
12	8	7	0,875	,627	,973	,173	,660	,971	,155	,699	,967	,134
12	8	8	1	,777	1,000	(b)	,812	1,000	(b)	,849	1,000	(b)
12	6	0	0[a]	,000	,339	(b)	,000	,290	(b)	,000	,235	(b)
12	6	1	0,167	,025	,524	,250	,028	,481	,226	,035	,428	,197
12	6	2	0,333	,097	,676	,289	,112	,640	,264	,134	,594	,230
12	6	3	0,500	,196	,804	,304	,222	,778	,278	,257	,743	,243
12	6	4	0,667	,324	,903	,289	,360	,888	,264	,406	,866	,230
12	6	5	0,833	,476	,975	,250	,519	,972	,226	,572	,965	,197
12	6	6	1	,661	1,000	(b)	,710	1,000	(b)	,765	1,000	(b)

Notes: (a) For simplicity, we have computed p_L, p_U [n, N, α/2] for p = 0, which is more conservative than p_L, p_U [n, N, α]; (b) The parameter "d" is not specified, as this is approximated to the one-side interval

Table 6 shows, for given sampling designs *n:N* of 8:12 and 6:12, the observed number of events *y*, the probabilities *p*, their approximated lower and upper confidence limits (Equations 4.1 and 4.2) and the precision *d* for particular confidence levels *α*. When categorization only considers the value of *d*, two categories could be set for the three *α* (*d* > 0,16 in all cases), while 3 categories could be justified with 70% confidence (*α* = 0,3, not shown here). On the other hand, for *n:N* of 8:12 the set of categories $A = \{0, 1, 2\}$, $B = \{3, 4, 5\}$, and $C = \{6, 7, 8\}$ verifies the criterion of non-overlapping of C.I. for both *α* = 0.1 and 0.2. Five categories are also possible, e.g. $A = \{0\}$; $B = \{1, 2\}$; $C = \{3, 4, 5\}$; $D = \{6, 7\}$, and $E = \{8\}$. With 95% confidence, an acceptable solution is given by the following three categories: $A = \{0, 1\}$, $B = \{2, ..., 6\}$ and $C = \{7, 8\}$. A more appropriate solution would be given by equally sized categories -as shown for both *α* = 0.1 and 0.2-, but in this case, limits do not strictly verify the proposed criterion, since $p_{U, y=2} = 0.504 > p_{L, y=6} = 0.496$. The hypothesis test for difference of proportions would be used in this case to

justify that these limits of categories are considered different. For *n:N* equal to 6:12, the categorization in three different levels: $A = \{0, 1\}$, $B = \{2, 3, 4\}$, and $C = \{5, 6\}$ is valid for both $\alpha = 0.1$ and 0.2, while categories A and C overlap with 95% confidence ($p_{U,y=1} = 0.524 > p_{L,y=5} = 0.476$). Other sampling plans with a larger sample size *n* show increased categorization possibilities.

In next section, a practical application is presented, where the "a priori categorization" is applied to prioritize the communities of one municipality on the basis of the estimates produced for two WaSH variables.

5. Discussion

The discussion makes use of a selection of different case studies with a two-fold aim: i) to show the gain obtained through the approach presented herein with respect to other standard sampling strategies in relation to sample size, and ii) to present two categorization approaches which, based on the same statistical principles, allow decision-makers to group estimates in three or more different categories. The case studies help show that despite lower precision of estimates, they are still valid for use in targeting and prioritization processes.

5.1. The issue of the sample size with reduced populations

In this section, three different case studies are presented. Municipality A has administratively 47 communities; and the population roughly totals 13,000 families. Municipality B covers 15 communities, and total population is estimated at 650 households. Municipality C has 25 communities with total population of 950 households. Table 7 shows the population distribution among the communities. All of them correspond to real study areas located in rural Mozambique, Bolivia and Nicaragua, where WaSH surveys have been already conducted.

Table 7 Population distribution among communities in Municipality A, B and C

Municipality A			Municipality B			Municipality C		
No. HH	No. Comm.	Pop. (in HH)	No. HH	No. Comm.	Pop. (in HH)	No. HH	No. Comm.	Pop. (in HH)
< 50	6	250	< 15	1	12	< 15	7	85
51 − 100	6	470	16 − 25	4	86	16 − 25	5	100
101 − 250	13	1,975	26 − 50	5	210	26 − 50	6	225
251 − 500	15	5,125	51 − 75	3	173	51 − 75	4	245
> 501	7	5,140	> 75	2	169	> 75	3	295
In total	**47**	**12,952**	**In total**	**15**	**650**	**In total**	**25**	**950**

In Table 8, overall sample sizes for different levels of precision required by different sampling methodologies are summarized. For a confidence level of 90% ($\square$= 0.1), the estimated sample size if required precision is 10 percentage points of the true value would be 68 households in each community for simple random sampling. This would mean for instance that in those less populated communities all households would be surveyed. At upper administrative scale, the total sample

size in Municipality A would be 3,196; while in Municipality B and C the required sample to cover all 15 or 25 communities would include all the population. Instead, if sample sizes are determined with the figures proposed above (see Table 3), for a confidence level of 90% and for estimates to fall within 10% points of the true proportion in each community, 2,524 households should be surveyed in Municipality A, 423 in Municipality B and 615 in Municipality C. With 80% confidence, the minimum sample sizes would be 1,850, 361 and 533 households respectively. If previous sample sizes are impractical with respect to time and money, the sample design should lower the requirements of precision to ± 20%. In this case, the required size of the samples would be reduced to 615, 165 and 255 for 80% of confidence in Municipality A, B and C respectively. Moreover, when disaggregated data is combined to obtain estimates for the overall study area, the sample size is large enough to provide acceptably narrow confidence intervals, in which may draw complementary conclusions at other scale of analysis. At the municipality level, the required sample size for estimates to fall within 10% (± 5%) of the true proportion with 90% / 95% / 99% confidence would be 270, 384, and 666 respectively. Therefore, despite low precision of local direct estimates, results at higher / aggregated levels show improved statistical soundness.

Table 8 Sample size based on different sampling methodologies

		Pop (in HH)	Random Sampling	Random Sampling (FPC)			
			d = 0.1; α = 0,1	d = 0.1 α = 0.1	d = 0.2 α = 0.1	d = 0.1 α = 0.2	d = 0.2 α = 0.2
A	Community	30 - 992	68	24 - 68 [a]	13 - 20 [a]	21 - 48 [a]	11 - 14 [a]
	Municipality	12,952	3,196 (68*47)	2,524	847	1,850	615
B	Community	12 - 90	68	12 - 44 [a]	9 - 17 [a]	11 - 34 [a]	8 - 13 [a]
	Municipality	650	1,020 (68*15)	423	209	361	165
C	Community	10 - 100	68	10 - 46 [a]	8 - 17 [a]	10 - 36 [a]	7 - 13 [a]
	Municipality	950	1,700 (68*25)	615	321	533	255

Notes: [a] The simple size depends on the population of the community

5.2. *The categorization processes*

From the viewpoint of decision-making, one could employ the categorization approach described in previous section to classify the local administrative subunits for a given WaSH variable in terms of performance. By way of example, we rank the communities of Municipality B in relation to two different indicators: i) access to improved sanitation, and ii) point-of-use water treatment. It is seen in Table 9 that most problematic sampling plans correspond to Community 15 and to Community 6, where $n{:}N$ is 7:12 -lowest population size N- and 11:49 -lowest $n{:}N$ ratio- respectively. In these two communities, three different categories may be defined for the first case with 90% confidence to avoid overlapping: $A_{Com\_15} = \{0,1\}$, $B_{Com\_15} = \{2,\dots,5\}$, and $C_{Com\_15} = \{6,\ 7\}$.Three other subgroups may be identified for the second one: $A_{Com\_6} = \{0,1,2\}$, $B_{Com\_6} = \{3,\dots,8\}$, and $C_{Com\_6} = \{9,10,11\}$. We then translate the previous categories into an expression in terms of p to define a set of categories that are valid for both communities: $A = [0,0.25]$, $B = (0.25,0.75)$, and $C = [0.75,1]$. Although further refinements of the limits between categories are possible, we apply

this categorization to rest of communities, and the estimates of proportions p_i are employed to categorize and classify all the administrative subunits, as shown in Table 9[7]. This categorization provides a relevant input for decision-makers, which is simpler and more rigorous than quantitative direct and interval estimates. At the municipality level, as initially expected, confidence intervals show improved levels of precision: for sanitation coverage, $p_{SAN} = 0,32$ $(0.269 - 0.375)$, and as regards household water treatment, $p_{HWT} = 0.719$ $(0.666 - 0.768)$.

Table 9 Categorization of communities from Municipality B for two different WaSH variables

Community	N	n	Improved sanitation					Point-of-use water treatment				
			yi	pi	pLi	pUi	Category	yi	pi	pLi	pUi	Category
Community_1	57	13	3	0.231	0.066	0.495	A	13	1.000	0.794		C
Community_2	40	18	11	0.611	0.392	0.801	B	13	0.722	0.502	0.884	B
Community_3	20	13	0	0.000	0.000	0.206	A	13	1.000	0.794		C
Community_4	55	20	1	0.050	0.003	0.216	A	13	0.650	0.442	0.823	B
Community_5	61	25	1	0.040	0.002	0.176	A	14	0.560	0.379	0.730	B
Community_6	49	11	0	0.000	0.000	0.238	A	9	0.818	0.530	0.967	C
Community_7	18	14	0	0.000	0.000	0.193	A	14	1.000	0.807		C
Community_8	90	23	6	0.261	0.120	0.451	B	14	0.609	0.417	0.778	B
Community_9	23	11	0	0.000	0.000	0.238	A	8	0.727	0.436	0.921	B
Community_10	49	16	13	0.813	0.583	0.947	C	11	0.688	0.452	0.868	B
Community_11	79	22	19	0.864	0.684	0.962	C	16	0.727	0.532	0.874	B
Community_12	25	13	8	0.615	0.355	0.834	B	10	0.769	0.505	0.934	C
Community_13	35	10	1	0.100	0.005	0.394	A	6	0.600	0.304	0.850	B
Community_14	37	12	9	0.750	0.473	0.928	C	7	0.583	0.315	0.819	B
Community_15	12	7	1	0.143	0.007	0.521	A	3	0.429	0.129	0.775	B

It is highlighted that, after survey completion, a variety of alternative categories may be defined for different purposes on the basis of the achieved results (see Chapter 4). The example provided herein, on the other hand, only aims to show the validity of the estimates produced with a reduced sample size for prioritization support.

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[7] Alternatively, it is noted that five categories could be established based on *n:N* equal to 11:49, since there is only one community where $n < 11$.

6. Conclusion

In an era of increasing decentralization of basic services, the need for reliable performance estimates at the local level is emerging. These data are required to identify the neediest areas in which policymakers may allot resources on the basis of efficiency, equity and transparency criteria. Many field data collection methodologies with different sampling strategies have been developed in recent years for the WaSH sector, but when applied in decentralized contexts with reduced populations, they present significant shortcomings. The aim of this chapter is to develop a method for local data collection which improves on other existing methodologies and ultimately produces estimates accurate enough to feed into decision-making processes.

The approach adopted combines data from two different information sources: the water point and the household. It takes the WPM as starting point, as a method with increasing acceptance amongst governments and practitioners to inform the planning of investments when improving water supply coverage. Since mapping entails a complete geographic representation of the study area, a stratified household-based survey is undertaken in parallel, in which a sample of households is selected from each stratum. An issue of concern with reduced populations is how large should the sample be in order to produce precise confidence intervals for the estimates obtained. This study adopts a simplified approach to sample size determination for local surveys. Specifically, it provides the formulas to select the minimum sample size on the basis of desired precision and the maximum permissible sampling error. The data analysis presents a practical method to categorize the survey estimates based on the criterion of non-overlapping between the C.I. of the estimates. The outputs produced, despite the low precision of estimates, may be used in categorization processes. Therefore, they could be further exploited for local level policymaking support. For illustrative purposes, four different case studies help demonstrate the applicability of the method.

CHAPTER 2

REVIEW OF INDICATORS AND AGGREGATED INDICES IN THE WASH SECTOR

Abstract

The importance of indicators and indices as decision-making tools has long been recognized. In consequence, much effort has gone in recent years into the development of alternatives to assess water, sanitation and hygiene issues from many disciplinary perspectives. In this chapter we compare four of these alternatives: i) health impact indicators, ii) standard indicators of the WHO / UNICEF Joint Monitoring Programme, iii) one multidimensional, water-focused composite indicator, and iv) easy-to-use planning indices designed locally on an ad hoc basis. From a policy-making perspective, the usefulness of outcomes produced by each approach is discussed. The epidemiological study produces misleading results, which do not help draw relevant conclusions. JMP indicators provide reasonable quality basic estimates of coverage across different contexts, but are inappropriate to build up a complete picture of such context. The index approach takes into account a broader view of service level, and proves useful as a policy tool to guide action towards improved service delivery. There are problems with composite indices, however; and they have been criticized on several grounds. Finally, simple and thematically related planning indices might become effective in assisting local governments in decision-making processes.

Keywords: health impact; joint monitoring programme; aggregated indicators; planning indices.

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1. Introduction

The issues of targeting and prioritization in policymaking are crucial to determine what gets done, and where. Ideally, the allocation process should be transparent and focus on the neediest. If the final decision is made purely on the basis of where water and sanitation infrastructure is accessible, this is unlikely to be successful. If on the other hand, there is emphasis on enabling a more equitable delivery of these basic services, then decisions need to be made on a much wider basis. In this case, an essential prerequisite would be to access consistent information through accurate monitoring backed up by rigorous interdisciplinary science, which is mainly dependent on a set of reliable and objective indicators. At the same time, reporting on performance is essential for the sake of efficiency and sound decision-making. Again, good and updated information supported by appropriate indicators is required to determine how the sector is faring, whether it is on-track to meet its objectives and what decisions need to be made to maximize performance levels in the future.

Against the need for providing policymakers with adequate evidence to support strategic and operational planning, the sector has witnessed the development of different approaches to monitor and evaluate drinking water supply and sanitation services. This chapter discusses four approaches which are being extensively used for the purposes cited above; that is, health impact indicators; standard indicators currently employed by the WHO / UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP); aggregated indices, specifically one water-focused composite of community poverty; and simple thematic indices purposively designed as tools for local planning support.

Over the past decades, the idea of evaluating water and sanitation on the basis of health has tempted both researchers and decision-makers, but the challenges are many and of different nature. Among others, epidemiological studies present methodological shortcomings in their ability to achieve reliable results (Blum and Feachem, 1983), which clearly reduce their validity as policy tools (Cairncross, 1990). A further problem is that health-based assessments do not attempt to measure use of infrastructure or behavioural changes, which are in fact main drivers for health improvement (Cairncross and Feachem, 1993; Hunt, 2001). Against these flaws, the JMP employs a technology-based definition to assess water supply and sanitation coverage, and this is done through household-based national surveys (Joint Monitoring Programme, 2006). The JMP reports provide an internationally comparable dataset which determine progress and trends at national, regional and global scale. Despite its evident value, more precise and complete measurements are required to drive the sector forward (Joint Monitoring Programme, 2011a). In particular, the recent recognition of access to safe water and basic sanitation as a human right (United Nations General Assembly, 2010b; United Nations Human Rights Council, 2011) highlights the need for improved evaluation mechanisms that address the issues of affordability, quality, reliability and non-discrimination, among others. Also inherent in the human rights framework is the willingness to operate at the appropriate level. Accurate information should thus be available for decentralized decision-making, to gain better understanding of local needs and priorities. In all, there is a call for interdisciplinary approaches to monitoring and evaluation, in which WaSH issues are blended with socio-economic and environmental dimensions. They should not only provide information on the progress of specific outputs (e.g. construction of water supply schemes), but also inform about the outcomes (number of people with access to safe water and improved sanitation) and indicate if the progress actually contributes to poverty alleviation (impacts). The index approach attempts to

simplify the complexity inherent in rural services delivery. In so doing, it provides a powerful tool for supporting decisions about planning and prioritization of poverty reduction initiatives. From the viewpoint of practitioners at a local level, however, aggregated indicators also present some limitations. Large amounts of data are required in the development of the composite, and data collection routines should therefore be in place to produce valuable information at the local level at a reasonable cost. In addition, statistics are required in index construction to avoid inaccurate outcomes. And for the purpose of policy-making, the practical usefulness of the index may not lie in its final values but in the sub-indices themselves. In consequence, an alternative approach may be to guide sector improvement through the exploitation of simple and thematic planning indices. The planning criteria in which base the indices should encompass sector priorities; and end users (e.g. technicians of local authorities) should be therefore engaged throughout the definition process. More specifically, each index would reflect a local need (e.g. extended practice of open defecation) and should be easily linked to an efficient remedial action (e.g. construction of basic sanitation infrastructure).

This chapter assesses the adequacy of these four planning instruments from a policymaking point of view, and specifically spotlights the potential and limitations of each approach to produce reliable estimates that might be used for targeting and prioritization support. They are all reviewed with reference to experience in Kenya, where the Government launched a countrywide initiative to accelerate the achievement of sector-related national targets. Integral to this process was a comprehensive baseline survey of households in relation to the use of safe water, adequate sanitation and hygiene education, in which this research draws on. The case study is introduced in the next section, followed by a detailed account of the survey framework developed for data collection. Then, the four approaches are analysed separately, and their strengths and weaknesses are underlined. The chapter closes with a discussion of adequacy of each policy tool to influence decision-making and ultimately improve strategic and operational planning.

2. The study area

In Kenya, a large proportion of population does not have access to safe water and sanitation facilities. According to the last national official statistics (Kenya National Bureau of Statistics (KNBS) and ORC Macro, 2010), about two-thirds of the people (60.2%) use improved sources of drinking water, and only 24.3% of the population have access to adequate sanitation facilities. Overall, the situation in rural areas is below the national average (53.1% and 21.8% respectively), and regional disparities are remarkable, a large number of rural districts do not even reach these coverage ratios. Water and sanitation-related diseases arising from lack of access to water, poor drinking water quality, inadequate sanitation facilities and poor hygiene practices are contributing to high mortality of children under five. This stands at 74 per 1,000 children, of which diarrhoeal diseases might cause about 20% of the deaths in high-risk areas (Kenya National Bureau of Statistics (KNBS) and ORC Macro, 2010).

Within this high-risk environment, in 2010, the Government, in collaboration with UNICEF, launched an initiative to increase the access to safe drinking water and sanitation: the most vulnerable rural populations were targeted. This study focuses on these populations (Table 10 and Figure 6), which are found in the pastoral arid and semi-arid districts of Isiolo, Wajir, Garissa, Mandera, West Pokot, and Turkana, in the Lake Basin Districts of Busia, Kisumu, Siaya, Bondo,

Rachuonyo and Nyando; in the Coastal district of Kwale and Tana River; in the Eastern province districts of Mwingi, Marsabit and Kitui; in the Rift Valley province districts of Kajiado, Uasin Gishu and Molo; and in the Kieni district of Central province (United Nations Children's Fund and Government of Kenya, 2006).

Table 10 Population, area, and density of WASH Programme recipient districts

District	Population	Area (Km²)	Density	District	Population	Area (Km²)	Density
Bondo	157,522	593.0	265.6	Molo	542,103	2,371.9	228.6
Busia	327,852	681.0	481.4	Mwingi	244,981	5,224.3	46.9
Garissa	190,062	5,589	34.0	Nyando	350,353	1,168.0	300.0
Isiolo	100,176	15,517	6.5	Rachuonyo	382,711	950.7	402.5
Kajiado	549,816	15,490	35.5	Siaya	550,224	1,534.0	358.7
Kieni	693,558	3,337	207.8	Tana River	143,411	22,822.9	6.3
Kisumu	618,556	918	673.9	Turkana	855,399	68,680	12.5
Kitui	447,613	7,616.0	58.8	Uasin Gishu	894,179	3,345	267.3
Kwale	151,978	1,031.2	147.4	Wajir	661,941	56,686	11.7
Mandera	1,025,756	25,991	39.5	West Pokot	512,690	9,169	55.9
Marsabit	46,502	2,052.0	22.7				
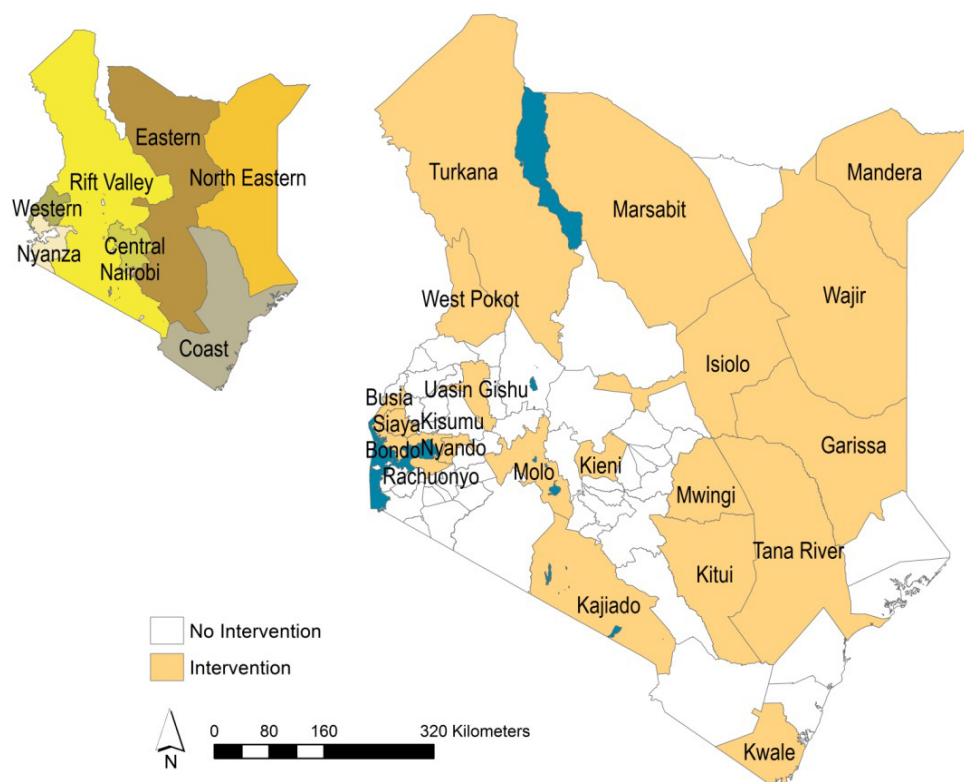
Figure 6 Map of Kenya with WaSH Programme Districts

3. The survey framework

It is well known that to produce inputs for evidence-based targeting and prioritization processes, decision-makers require a comprehensive survey framework. The first step is to identify pertinent and measurable indicators in which base the assessment. The second step is to develop appropriate survey instruments. Third, the sampling design has to enable the compilation of accurate primary data to produce statistically representative estimates. Finally, information has to be adequately examined to ensure its validity in decision-making.

3.1. Survey indicators and assessment tools

The framework proposed relies on a specific compilation of indicators as a starting point. From a WaSH perspective, it is evident that a wide range of variables exists to assess coverage or service level. Of particular interest is the recently adopted human rights framework, which reflects the concept of progressive realization in the level of service and requires the definition of specific indicators to deal with the issues of affordability, quality, reliability and non-discrimination, amongst others (United Nations General Assembly, 2012, 2010a); or the debate guided by WHO and UNICEF about the post-2015 WaSH targets and indicators (Joint Monitoring Programme, 2012b, 2011a).

To exactly identify *what* should be measured remains challenging, though, and rules of thumb for the selection process include the following criteria. First, the number of indicators should be as reduced as possible but sufficient to ensure a thorough description of the context in which the service is delivered, that is to keep a balance between avoidance of redundancy and comprehensiveness with respect to the survey's goals (Joint Monitoring Programme, 2011a; United Nations Children's Fund, 2006a). Second, in terms of cost-effectiveness, indicators should rely where possible on readily available information, rather than requiring additional data collection efforts. Third, to resolve the comparability problems, survey questions need to be harmonized with those internationally accepted (Joint Monitoring Programme, 2012d, 2006). Finally, indicators should be *EASSY* (Jiménez et al., 2009): *E*asily measurable at the local level, *A*ccurately defined, *S*tandardized and compatible with data collected elsewhere, *S*calable at different administrative levels, and *Y*early updatable.

In this study, a WaSH approach was adopted for indicator definition, and a set of relevant variables were formulated to cover all areas of study, that is, health issues, access to water supplies, use of sanitation facilities, and hygiene behaviour. In order to acquire the information needed for each indicator's assessment, the survey employed a combination of quantitative and qualitative instruments, and field inspections of the water points and household interviews were used as study tools. First, service level was captured through a structured household-based questionnaire and direct observation. In every visited household, the questionnaire was administered to primary caregivers, as they are largely responsible for WaSH-related issues at the dwelling. Issues covered included, among others: i) type of main drinking water source, ii) distance from dwellings to the source, iii) domestic water consumption, iv) household water treatment, v) access to and proper use of sanitation facilities, vi) disposal of children's stools, vii) hand-washing behaviour, and viii) key socio-economic aspects. Second, relevant data for all drinking water sources identified at households were collected using a standardized checklist of key criteria. Water point audits focused on issues of i) technology, ii) operational status, iii) seasonality, iv) construction quality,

v) existence of water point committees, and vi) operation and maintenance. Furthermore, all sources were sampled for on-site water quality surveillance, and a complementary sanitary inspection was performed as a form of risk assessment to evaluate the likelihood of contamination occurring (Howard, 2002). The water analysis was carried out with a portable kit and included bacteriological testing (thermotolerant coliforms) as well as other critical parameters: i) pH; ii) conductivity; iii) turbidity; v) free chlorine (where water was disinfected using chlorine); and v) nitrates. From each water point, one household accessing the source was also selected and one additional water sample was collected and analysed at household level.

All assessment tools were elaborated in a participatory manner through consultation with primary stakeholders. Care was taken to tailor the questions to represent the rural situation in Kenya. Likewise, questionnaires were reviewed and issues of question order, wording and intention were systematically checked in such a way as to minimize misleading outcomes. They all were piloted in three villages, and the outcomes were useful to spotlight challenges both in the field and with the instruments. Following the pilot, further fine-tuning was required. The questionnaires were then translated into local dialects (e.g., Kiswahili, Kikuyu, Kamba, Luo, Turkana, Somali, etc.). Finally, training sessions were held with project staff that would administer the survey. The enumerators were taken through the questionnaires and various other issues concerning the fieldwork, such as making GPS coordinate readings, water quality testing, etc.

3.2. The sampling method

The survey was mainly household-based, and the sample design was in line with methodological principles implemented in other major data collection exercises on water, sanitation and health (Bennett et al., 1991; Howard et al., 2012; United Nations Children's Fund, 2006a). Key features of the sampling frame included: i) selection of a sample size that allowed for separate estimates for each of the recipient districts, ii) cluster-sample design instead of simple random sample, iii) self-weighting sampling procedure for selection of clusters, and iv) a random probabilistic technique for household selection at cluster level. This was done based on the Kenya National Bureau of Statistics (KNBS) fourth National Sample Survey and Evaluation Program (NASSEP IV), which was developed on the platform of a two-stage sampling design. The first stage involves selection of clusters from the national master sample frame. In Kenya, 1,800 clusters (1,260 are rural and 540 are urban) have been identified by sampling with probability proportional to size (pps) from an initial list of 62,000 enumeration areas covered in the 1999 population and housing census. The second stage of selection involves the systematic sampling of households in each cluster from an updated list of households. In the NASSEP IV approach, the sample is stratified into urban and rural, and particularly urban estimates are oversampled. According to these differing sample proportions and since the focus of the study was on rural areas, a deliberate attempt was made to increase the size of selected clusters to get enough cases for the analysis.

In all, 5,050 households (HHs) were surveyed and 407 water points (WPs) were audited across 317 rural clusters to cover 21 targeted districts (Table 11). Data was collected from January 2010 to March 2010 (during the rainy season).

Table 11 List of districts, distribution of clusters and sample size

District	No. of clusters	No. of HHs	No. of WPs (Improved / Unimproved)	District	No. of clusters	No. of HHs	No. of WPs (Improved / Unimproved)
Bondo	18	252	6/13	Molo		200	19/14
Busia	15	240	24/5	Mwingi	15	240	2/14
Garissa	14	434	4/12	Nyando	18	252	13/5
Isiolo	13	234	8/7	Rachuonyo	18	252	5/13
Kajiado	18	252	25/1	Siaya	19	247	13/7
Kieni		200	1/23	Tana River	15	224	4/11
Kisumu	9	225	8/3	Turkana	15	128	4/5
Kitui	18	252	9/17	Uasin Gishu	17	238	8/12
Kwale	20	238	15/11	Wajir	14	238	6/8
Mandera	15	240	10/5	West Pokot	15	240	4/17
Marsabit	15	224	8/8				

3.3. Data analysis

Information has to be post-processed and analysed effectively to avoid data misinterpretation or misuse. Prior to data analysis, however, some quality control procedures should be in place. In this study, for instance, selected variables were assessed through more than one questionnaire to allow for triangulation and systematic checking of data consistency. Indicators were also reviewed for outliers, and frequency tables were produced to show the minimum and maximum values as well as some basic statistics (median, average, standard deviation, etc.). All suspicious values were checked and corrected where necessary, or removed as missing data in case correcting was not possible.

After data cleaning, the analysis focused on identification, from the viewpoint of planning and decision-making, of the strengths and limitations of four approaches that are being extensively used in the sector for planning and evaluation purposes:

- Health indicators to evaluate impact and performance of WaSH initiatives.
- International standard indicators defined in the JMP (Joint Monitoring Programme, 2006).
- A WaSH-focused, thematic indicator of rural poverty, the WaSH Poverty Index (Giné Garriga and Pérez Foguet, 2013b)
- Simple and thematic planning indices on WaSH (Giné Garriga et al., 2015)

To do this, the statistical analysis employed tools such as the Pearson's chi-square test and the Principal Component Analysis (PCA), using in both cases a standard statistical package (SPSS 15.0, 2006). The Pearson's chi-square test, specifically the SPSS Exact Tests v7.0 (Mehta and Patel, 1996), was performed to assess relationship between survey variables. In this test the null hypothesis is independence, and the value $P = 0.05$ is used as the cut-off for rejection or acceptance (meaning there is a 5% chance or less that the variables are actually independent, given the assumptions of the test are valid). PCA was used in index construction to create and validate the composite. Main goal of this analytical approach is to explore how variables are correlated

with each other, and how they can be summarized to avoid any risk of repetition prior to their aggregation.

4. Estimating the health impact of water and sanitation

The health benefits of improved water supply, household sanitation and hygiene behaviour are broad in scope (Cairncross and Valdmanis, 2006; Esrey et al., 1991; Fewtrell et al., 2005). Hence, there is a strong temptation to conduct health impact assessments of WaSH-related interventions. In practice nonetheless, there are many challenges and attempts to measure this impact have often produced meaningless results (Cairncross, 1990; Samanta and Van Wijk, 1998). One reason for this is that many different pathogens cause diarrhoea through various transmission routes; it is thus not easy to identify how people caught diarrhoea. In addition, incidence of diarrhoea may be influenced by a variety of other factors besides access to a water supply or sanitation, such as the socio-economic status of the household, education of the mother and access to health care (Cairncross and Feachem, 1993). Other problems are more related to methodological flaws of evaluation techniques employed to assess health benefits (Blum and Feachem, 1983). Against this background, one might conclude that health impact indicators are not easily defined and accurately measured, particularly in the short run (Samanta and Van Wijk, 1998).

4.1. Results

The survey results apparently support the previous hypothesis (Table 12). The number of diarrhoea episodes were recorded, where diarrhoea was defined as more than three loose stools passed in a 24 hour period (Baqui et al., 1991). Out of the sampled households; there were 1,647 households with children aged less than 36 months, and episodes of diarrhoea were only reported in 78 households (4.7%). Lower percentages were found in the rest of the age bands. In contrast, and according to the last '2008–09 Kenya Demographic and Health Survey', diarrhoea prevalence among children (less than 36 months old) in Kenya stands at 21.8% (Kenya National Bureau of Statistics (KNBS) and ORC Macro, 2010). There are different reasons which might partially justify such large disparities from baseline survey data; such as, i) Kenya Demographic and Health Survey estimates were collected at national level (including both urban and rural areas); and ii) seasonality issues (although it should be borne in mind that baseline data was collected during rainy season, which represents the peak season for diarrhoeal diseases). At best, the analysis confirms that health estimates need to be interpreted with caution when evaluating benefits of water and sanitation to health.

Table 12 Percentage of children with diarrhoea in the two weeks preceding the survey

		No episodes of diarrhoea	At least one episode of diarrhoea	Sample size (no. households)
< 36-months-old	Count (%)	1,569 (95.3)	78 (4.7)	1,647
36-months to 5-years- old	Count (%)	1,567 (97.0)	49 (3.0)	1,616
5–15-years-old	Count (%)	3,672 (98.1)	73 (1.9)	3,745

A closer look at the data (children aged less than 36 months) shows that six districts (i.e., Kieni, Molo, Garissa, Mandera, Kisumu and Turkana) recorded no cases of diarrhoea, while at the other end of the scale, Uasin Gishu (8 cases, 12.1%), Tana River (22 cases, 25.6%) and Kwale (27 cases, 24.3%) reported the highest number of cases. These estimates, however, do not help to reveal major causes that explain regional differences; and in those districts where the situation is more risky, the assessment does not itself shed light on how a health benefit may be materialized, or vice versa.

Table 13 Prevalence of diarrhoea by wealth and WaSH indicators

			Episodes of diarrhoea (children < 36 months old)		
			No episodes of diarrhoea	*At least one episode of diarrhoea*	*Pearson Chi-Square Exact Sig. (2-sided)*
Access to water	Improved	Count (%)	710 (96.60)	25 (3.40)	0.026[a]
	Unimproved	Count (%)	859 (94.19)	53 (5.81)	
Access to sanitation	Improved	Count (%)	279 (94.58)	16 (5.42)	0.545[a]
	Unimproved	Count (%)	1290 (95.41)	62 (4.59)	
Disposal of children's stools	Sanitary disposal	Count (%)	897 (94.03)	57 (5.97)	0.009[a]
	Unsanitary disposal	Count (%)	648 (96.86)	21 (3.14)	

Notes: a) 0 cells (0.0%) have expected count less than 5.

The health impact of key WaSH indicators may also be examined. It is gleaned from Table 13 that there is significant association between prevalence of diarrhoea and i) access to improved water supplies ($P = 0.026$), and ii) sanitary disposal of children's faeces ($P = 0.009$). In contrast, no significant reduction in diarrhoea is observed with access to basic sanitation. In brief, slight positive impacts are observed when an improved water supply is accessed by the household and when children's faeces are disposed of safely. But Table 13 also shows that using an improved sanitation facility would make no difference in relation to health.

On the basis of achieved results, it might be concluded that adequacy of health indicators to support operational and strategic decision-making should be at least questioned, which seriously diminishes the soundness of epidemiological studies as a tool to guide sector development. Instead of striving to measure the health impact, a more useful approach emerges from an understanding of the causal relations between the provision of water supply or sanitation and any improvement in hygiene which may result, such as washing of hands, use of a sanitary facility, or the safe disposal of children's stools (Cairncross and Feachem, 1993). For example, no potential benefits might stem from a water supply if it is not used. And it cannot be used if it is not functioning. Thus, one first should look at whether the water supplies are functioning and if they are being adequately used. If domestic water use increases, there is a good chance that most of the increase will be used for hygiene purposes, and then health benefits are likely to be materialized (Cairncross and Feachem, 1993). Similarly, a consistent use of a sanitation facility, not its mere existence, will probably result in health and environmental improvements; since use of sanitation isolates

contaminated faeces from the environment, thus breaking down the transmission route of disease (Hunt, 2001).

In terms of planning, the measurement of behavioural changes is likely to produce much more useful information for policymakers, since they are easily attributable to the sector strategy and related interventions. An input and behaviour oriented approach thus seems to be more feasible and practical, providing greater power to diagnose problems and indicate opportunities for improvement (Cairncross, 1990; Samanta and Van Wijk, 1998).

5. The Joint Monitoring Programme

An important first step toward shifting from monitoring infrastructure construction - e.g. number of water schemes constructed - to performance-based monitoring – e.g. access to water supply - is the implementation, at the international level, of the JMP. This initiative regularly reports on the coverage and status of drinking water and sanitation, and in so doing, the JMP helps countries in their efforts to monitor the sector. However, this monitoring has presented various challenges. The coverage figures in assessments prior to 2000 referred to 'safe' water supply and 'adequate' sanitation, but consistent definition of 'safety' and 'adequacy' remained elusive (Joint Monitoring Programme, 2000). Another key limitation was the variety of information sources and reporting formats employed for data collection. To improve on the comparability of data, the JMP formulated a set of core questions (Joint Monitoring Programme, 2006). Its expanded use worldwide in regularly conducted household-based surveys would produce more accurate estimates at country and regional levels.

In the end, the harmonized definitions of coverage are technology-based, since this is the data that can be consistently collected at a large scale. The JMP assumes that certain types of technology are safer or more adequate than others; and consequently the terms 'safe' and 'adequate' are replaced with 'improved'. The following water technologies are treated as improved: piped water to the dwelling, plot or yard, public standpipe, borehole with hand pumps, protected (lined) dug well, protected spring and rainwater collection; and a water service ladder with three different levels is proposed to describe the incremental progress in service delivery: 'unimproved', 'improved' and 'piped'. 'Reasonable access' is then defined as the availability of at least 20 litres per capita per day from an improved source within one kilometre of the user's dwelling (Joint Monitoring Programme, 2000). With regard to sanitation, a wide range of technologies might be in place, particularly for settings where low-cost solutions are required. Instead of distinguishing between technologies, the excreta disposal system is considered adequate as long as it is private (but not shared/public) and hygienically separates human excreta from human contact (Joint Monitoring Programme, 2010b). As a result, 'improved' sanitation is defined to include a house connection to a sewer or septic tank, a pour-flush latrine, a simple pit latrine and a ventilated improved pit latrine. In much the same way as with water supply, sanitation coverage is ultimately presented as a four-step ladder that distinguishes between 'open defecation', 'unimproved', 'shared' and 'improved sanitation'. Only population with access to improved water supply and sanitation is considered to be 'covered'.

This section presents the JMP indicators based on their nature: i) drinking water, ii) sanitation, and iii) hygiene; followed by an in-depth discussion of their adequacy from the viewpoint of decision-making.

5.1. Water Supply Indicators

The harmonized questions for drinking water assess the type of water source used, the time spent in fetching water, and the water-hauling burden. A separate indicator also evaluates the adequacy of the water treatment at the point of use.

The principal indicator provides information about the household's main source of drinking water, and, as above-mentioned, the type of technology is used as a proxy for a binary categorization of households. In the study area, the use of improved sources is by and large poor, with 43.5% of all households getting their drinking water from such sources (Figure 7). More specifically, 2.3% of households have piped water on the premises, while the predominant improved technology is the borehole (23.1%). On the other hand, more than half of surveyed households (56.5%) get their water from an unimproved source, mainly surface water from lakes, streams, and rivers (44.5%).
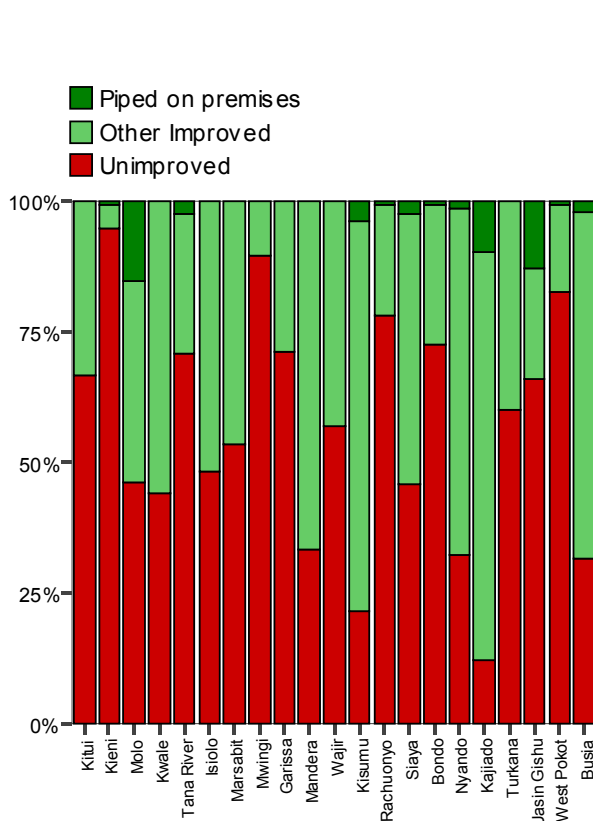
Figure 7 Access to improved drinking water sources (% of HH), at district level
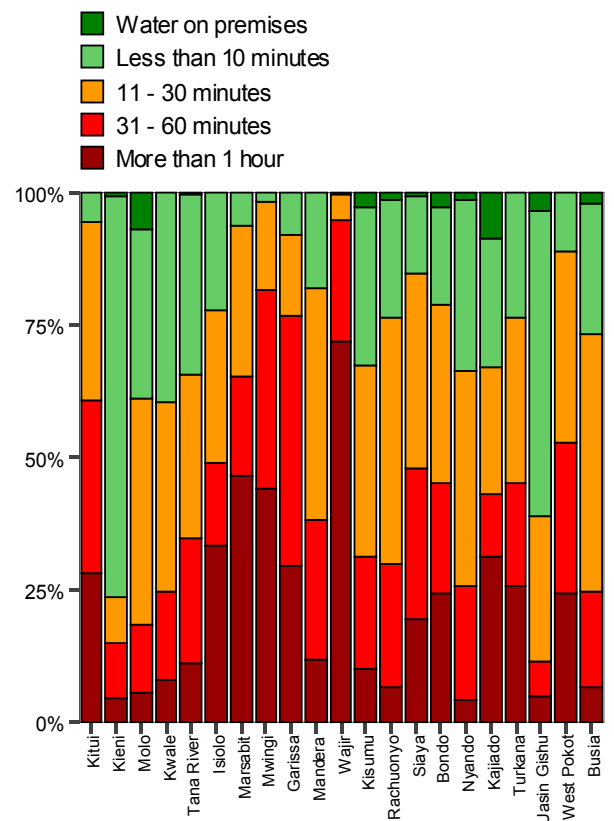
Figure 8 Time to fetch water (% of HH), at district level

A complementary indicator informs about the time spent in water fetching. Lack of ready access to a water source may limit the quantity of suitable water that is available to a household for domestic purposes. In particular, research has shown that those spending more than half an hour per round trip progressively collect less water (Cairncross and Feachem, 1993; Hutton and Haller, 2004;

Whittington et al., 1990), and this has been proposed by the JMP as the threshold distance. It is shown that a large percentage of households (45.4%) spend more than half an hour per round trip to collect water, despite significant regional differences (Figure 8). And interestingly, data indicate that households opt against spending 'extra time' to get an improved water source, that is distances from dwellings to improved and unimproved sources are basically the same (P > 0.05).

Another issue in evaluating the accessibility to water is gender disparities in water collection, since the burden of water-hauling responsibility often falls on female members of the household. The survey indicates that this is the case in 87.2% of households; while in 5% of households it is children who carry the main responsibility for collecting water, with girls under 15 years of age roughly being twice as likely to carry this responsibility as boys of the same age band (3.4% of households compared with 1.6% respectively).
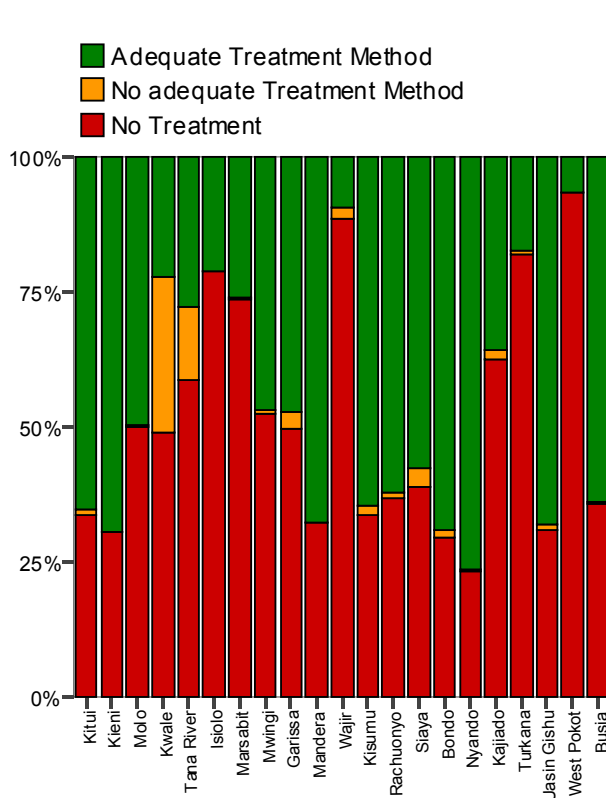
Figure 9 Adequacy of household water treatment (% of HH), at district level
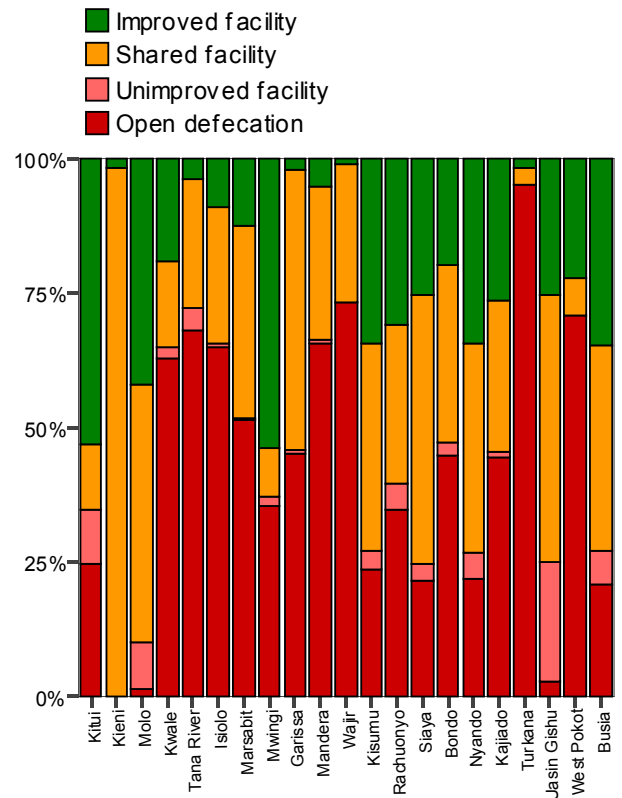
Figure 10 Access to improved sanitation (% of HH), at district level

Finally, it has been recently argued that the quality of the water delivered at the tap might not be an issue if users can treat water at their dwellings. Adequate household water treatment appears to be a cost-effective solution in the short-term, to complement the continuing expansion of coverage and upgrading of services (Fewtrell et al., 2005; Gundry et al., 2004; Haller et al., 2007). However, before widespread promotion of point-of-use water treatment, some related concerns should be better understood. The impact of household water treatment on health has not yet been sufficiently documented, and the acceptability, scalability and feasibility of this approach are still to some extent uncertain (Schmidt and Cairncross, 2009). It is gleaned from Figure 9 that household water treatment is common throughout the area of intervention. Half of households (50.1%) treat water

before consumption and the vast majority (94%) employ an adequate method (based on the categorization provided by the JMP). The main treatment practice is addition of bleach (24.9%), which is most likely related to campaigns that promote this method, while 20% of households boil water to make it safer for drinking.

5.2. Sanitation Indicators

The questions related to sanitation focus on access to and use of sanitation facilities, and determine the type of sanitation infrastructure used by the household and whether it is shared with others (Joint Monitoring Programme, 2006).

Based on the 'sanitation ladder' described before, the current coverage of improved sanitation is alarming, averaging only 21.6% for the whole survey. From Figure 10, it can be seen that sharing the facility is common (33.7%), although the largest percentage of households (41%) practise open defecation. Among the improved technologies, pit latrine with slab accounts for the highest proportion, while the most common unimproved toilet is an open pit or one without slab.

5.3. Hygiene Indicators

In terms of hygiene behaviour, the programme has failed to identify a robust indicator (Cotton and Bartram, 2008). The harmonized question deals with the disposal of children's stools as suitable proxy. When faeces are left uncontained, disease may spread by direct human contact. The safe disposal of children's faeces is extremely important in this regard, since they are the most likely cause of faecal contamination to the immediate household environment. The preferred disposal method is putting or rinsing stools into a sanitation facility, or burying waste if a toilet is not accessible.

On average, in 58.1% of households, the disposal of the stools of children under age three are disposed of safely. It is observed that the most commonly used method is rinsing stools into a toilet or latrine (43.6%), while unsanitary disposal methods include burying stools in the open (14.6%) or throwing them into the domestic refuse (23.6%).

5.4. Criticism of the JMP

At the global level, the JMP has considerably improved the processes and approaches to sector monitoring and reporting, strengthening the comparability of the WaSH outcomes over time and within countries. However, it has been criticized on several grounds, and an ongoing consultative process is currently debating a consolidated proposal of improved targets and indicators for the post-2015 monitoring framework (Joint Monitoring Programme, 2012b, 2011a). One shortcoming is related to the scale in which estimates are produced, as it is not adequate to assist decentralized governments with local planning (Hunt, 2001). A further issue concerns the definitions employed, which are too infrastructure-based. The human rights framework demands reinforced monitoring mechanisms to measure progress towards the realization of the right to water and sanitation (Flores Baquero et al., 2015; Roaf et al., 2005); and beyond coverage data, monitoring systems should provide a more complete picture of the context in which the service is delivered (Cotton and Bartram, 2008; Hunt, 2001; Jiménez and Pérez Foguet, 2012; Sutton, 2008). Issues such as physical accessibility, availability (quantity and reliability), safety, affordability, management,

accountability and non-discrimination should be effectively integrated. Finally, the JMP's methods to assess coverage have also been repeatedly criticised (Bartram et al., 2014). This section examines the main flaws of the JMP from the perspective of national and local actors with their different data requirements. In so doing, it makes a small contribution to frame a global post-2015 monitoring strategy for water and sanitation.

Drinking water

Access to water is primarily determined by distance to the source or time spent in fetching water, though the quantity of water that will be collected for domestic purposes may also reduce where supplies are not reliable, water quality is not adequate or tariffs are unaffordable (Howard and Bartram, 2003). Therefore, water coverage might be categorized in terms of service level and consider among other the above-mentioned requirements. The survey shows that water consumption for domestic purposes is by and large low, and specifically the average consumption in three-quarters of households (78.2%) is less than 20 litres per capita per day. There are regional disparities (Figure 11), despite the risky situation countrywide. And as expected, a clear correlation is observed between the per capita consumption with i) distance to the water point, shown in Figure 12 (P < 0.001); and ii) number of people in each household (P < 0.001). The further the source and the larger the household, the lower the consumption per member.
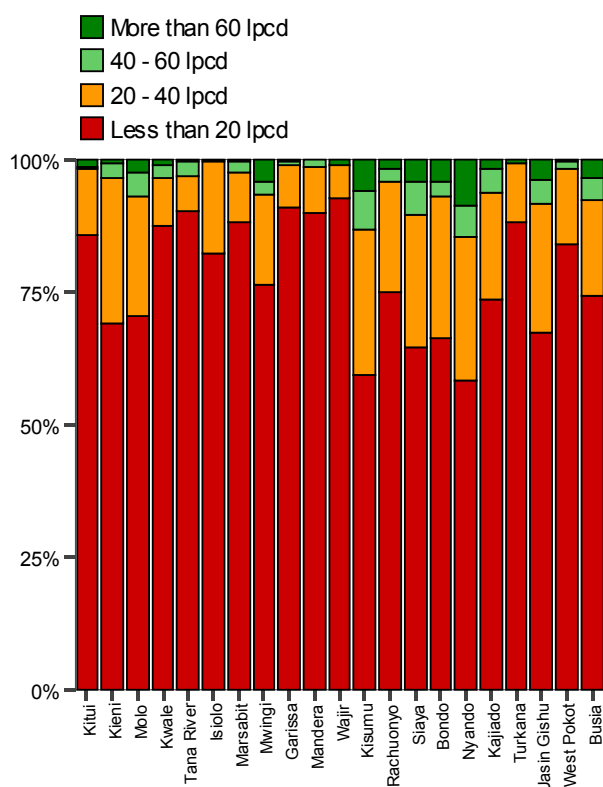
Figure 11 Water consumption in litres per capita per day (lpcd) at district level (% of HH)
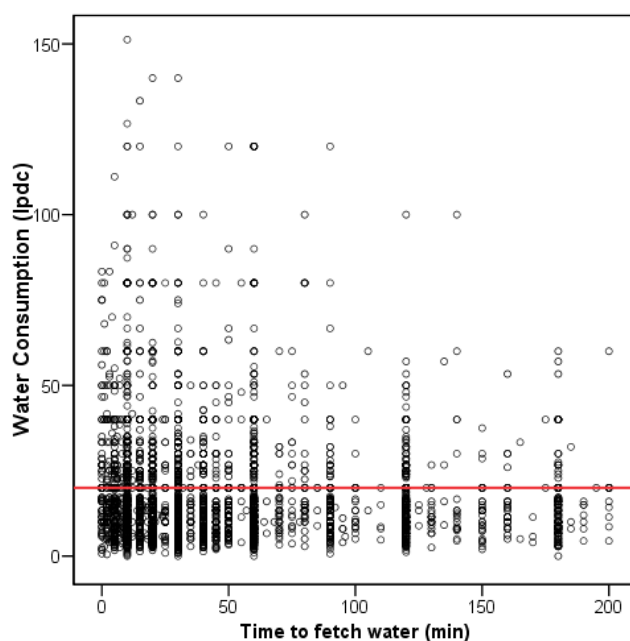
Figure 12 Water consumption with time to source

Moreover, there is weak evidence to establish the relationship between safe water and improved sources, and this has been acknowledged in literature elsewhere (Bain et al., 2014; Jiménez and

Pérez Foguet, 2012; Joint Monitoring Programme, 2011b; Onda et al., 2012; Sutton, 2008) and in a series of country reports which have been recently published by WHO and UNICEF (e.g. WHO/UNICEF, 2010a, 2010b). In the area of intervention, the assessment of drinking water quality at the source confirms this hypothesis, and bacteriological contamination is detected in almost half (47.9%) of sampled improved water points. Similarly, and although water safety plans are being promoted to ensure sustainable access to safe water (Bartram et al., 2009; Joint Monitoring Programme, 2010a), it is noted that 40% of improved sources in adequate sanitary conditions still show microbiological contamination.

Another flaw is related to the issue of service reliability, since the health benefits attributed to the consumption of safe water are almost entirely lost if raw water is consumed even once over the course of a few days (Hunter et al., 2009). A water service can be interrupted because of functionality/management reasons or seasonality issues. Regardless of the cause, lack of continuity may lead to prolonged periods without supply, which obliges households to search for alternative sources, often of inferior availability and poorer quality. The audit of water points reveals that functionality rates are surprisingly high in comparison with other sub-Saharan countries (Harvey and Reed, 2004; WaterAid, 2009a), and specifically, 94.6% of inspected sources were found operational at the time of the survey. One possible explanation could be that only main drinking water supplies identified at household level were audited, and interviewed households only provided information about operational sources. In terms of seasonality issues, roughly three-quarters of supplies (76.2%) are year-round (not seasonal), though this percentage varies across the districts. As expected, seasonality issues are of primary importance in those districts classified as arid (i.e., Wajir, Marsabit, Mandera, Tana River, Isiolo and Garissa) or semi-arid (i.e., Mwingi, West Pokot and Kwale), Turkana being the only exception (where the sample size of water points was not large enough to provide reliable estimates).

Sanitation

The definition of sanitation coverage also presents important drawbacks, as it does not adequately address the hygiene-behaviour change. First, the JMP indicator does not take into account sanitary conditions of the facility or safety issues, which not only might constrain a continued use of the infrastructure, but a lack of the latrine's maintenance may also result in a focus of disease transmission (Scott et al., 2003). Second, coverage figures do not distinguish between open defecation and latrine sharing, and both practices are categorized as unimproved. Open defecation contributes in various ways to a heavy disease burden (Kar and Milward, 2011; Musembi, 2010), while as sanitation practice, latrine sharing is markedly better in terms of environment protection (WaterAid, 2009b). Third, sanitation infrastructures should be available at a price that everyone can access them (COHRE et al., 2008), thus affordability issues should be properly dealt with in the sanitation definition. And finally, it should include the aspect of household hygiene promotion. It is therefore believed that sanitation needs to be defined in a broad and more holistic sense.

In those surveyed households where a latrine was used, its sanitary condition was visually evaluated, and particularly four different proxies were verified: i) inside cleanliness, ii) presence of insects, iii) smell, and iv) privacy. Data show that on average i) only two-fifths of observed latrines were found clean, ii) very few were fly-proof and insects were observed in 71% of the latrines, iii) an unpleasant smell was reported in almost three-quarters of inspected latrines, and iv) nearly half did not present adequate conditions of privacy. Based on these proxies, an aggregated indicator to

estimate the sanitary conditions of the latrine helps highlight that less than one-quarter of improved facilities (22%) present 'good' hygienic conditions, and that the conditions of shared latrines are not noticeably worse than those that are improved (Figure 13).

Affordability of sanitation services was also assessed, and those households without their own latrine were asked why did they not have one. On average, more than four-fifths cite cost as the reason; that is, no money (77.8%), or no adequate terrain on which to build the latrine (6.5%). In 3.3% of households the main reason is lack of habit to use the facility, and a further 3.9% report cultural-based obstacles.
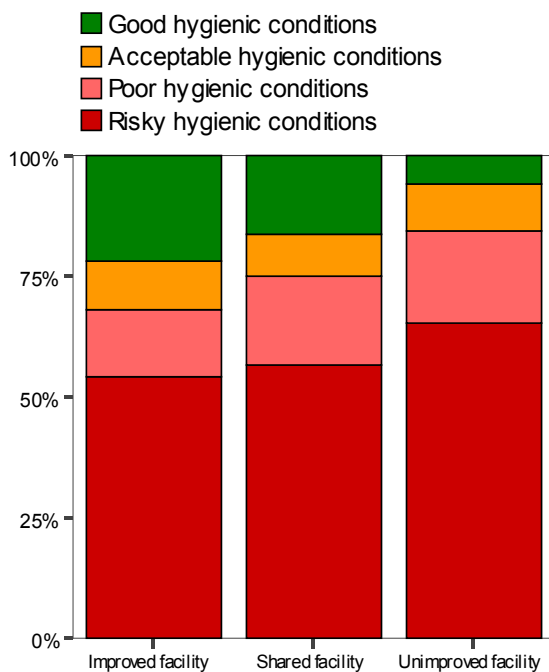
Figure 13 Sanitary conditions of latrines (% of latrines), based on type of sanitation
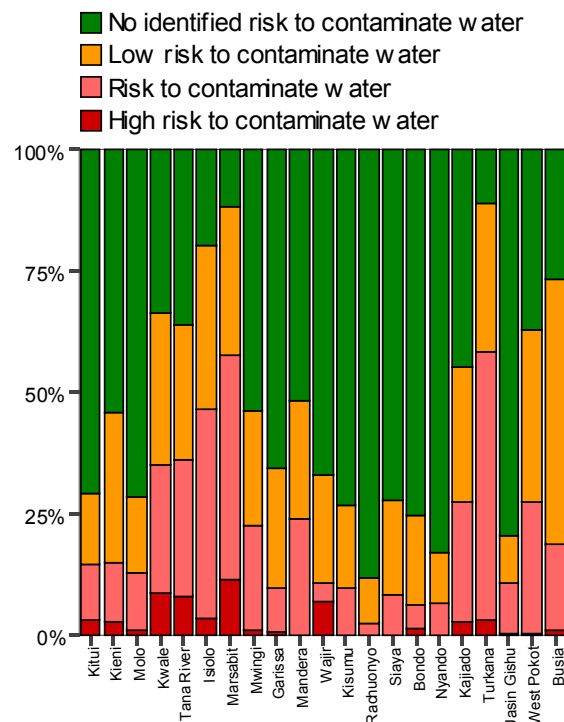
Figure 14 Household drinking water quality inspection (% of HH), at district level

Hygiene

The Global Water Supply and Sanitation Assessment 2000 Report (Joint Monitoring Programme, 2000) identifies, apart from the safe disposal of children's faeces, two further hygiene behaviours that are of greatest likely benefit to health, that is, i) safe water handling and storage, and ii) hand-washing with soap.

The survey therefore evaluated, where water was stored in a separate container within the home, whether the tank was covered and whether it was located away from potential sources of contamination. Such inspections prove useful to assess the hazards and contaminant pathways into the water tank that may cause contamination to occur (Howard, 2002). From Figure 14, it is observed that the majority of households (55.3%) store drinking water in a separate container that is correctly protected. However, regional disparities are remarkable; the districts of Turkana and Marsabit exhibit the riskiest practices.

Finally, simple hygiene behaviours, especially hand-washing with soap, have been suggested to break the faecal–oral route of disease transmission and reduce the occurrence of gastro-intestinal infections in poor settings (Cairncross and Feachem, 1993; Curtis and Cairncross, 2003). Billig et al. (1999) state that proper hand-washing behaviour includes two different dimensions: i) technique (use of water, use of soap or ash, washing of both hands, and hygienic drying), and ii) frequency (after defecation, after cleaning babies' bottoms, before food preparation, before eating, and before feeding children). In this study, data was obtained through a questionnaire interview conducted with the primary caregiver, and results show that the vast majority (97.2%) washes their hands. However, both the method employed and hand-washing frequency are by and large inadequate, and more specifically, of those caregivers who wash their hands, only 40.1% use an adequate technique and half of them (40.9%) fail to wash their hands at critical times. Another remarkable factor is that a complementary evaluation (not shown here) of hand-washing devices in the vicinity of latrines shows that, on average, a water point is only found in less than 10% of facilities; and soap is available in only 0.9% of inspected latrines. Since water and soap act as determinants of hand-washing (Schmidt and Cairncross, 2009), and as methodological problems of the evaluation technique might have biased achieved results (Billig et al., 1999), it may be concluded that while hand-washing knowledge is adequate, hand-washing behaviour is not.

6. Aggregated indicators to measure water and poverty linkages

There is evidence from the previous section that beyond data on infrastructure coverage and access, operational planning requires a broader view by which the reality on the ground is described. Information about institutional, financial, management and environmental issues would help gain an insight into sector performance, and further synthesis might guide the elaboration of development initiatives. However, while a number of selected individual fields can be assessed by separate single indicators, an assessment of the overall context also requires the integration of these individual fields with regard to their interlinking. In the WaSH sector, where decision-making feeds on information of different nature and from diverse sources, the search for new tools for monitoring, evaluation and planning purposes has prompted the development of a variety of composite indices (Cohen and Sullivan, 2010; Flores et al., 2013; Giné Garriga and Pérez Foguet, 2010; Pérez Foguet and Giné Garriga, 2011; Sullivan et al., 2003; Webb et al., 2006). They condense information from different disciplines, thus integrating in measurement the socio-economic, physical, environmental and institutional drivers which link drinking water, basic sanitation and household hygiene. Indices capture and simplify the complexity inherent in rural services delivery, and by doing so provide powerful tools for policy analysis.

In this section, an interdisciplinary, WaSH-focused approach is adopted through a multidimensional estimate, the WASH Poverty Index (WASH PI), which is proposed by Giné Garriga and Pérez Foguet (2013b) to support poverty-alleviation-oriented planning where delivery of water, sanitation and hygiene remains elusive. To do this, the index builds on a combination of three composites that are not aggregated to produce a single value. Rather, index components are presented individually as parts of a thematic indicator. The step-by-step procedure for index construction is described elsewhere (Giné Garriga and Pérez Foguet, 2013b), and a brief explanation of each composite's components follows (see Chapter 3 for a more detailed description):

- The water supply index is founded on the Water Poverty Index (WPI) framework from Sullivan (2002) and Sullivan *et al.* (2003). This composite combines a range of indicators that track the physical, economic and social issues which link water and poverty. It therefore distinguishes the broad themes that reflect major preoccupations and challenges in low-income regions related to the provision of water: physical availability of water (Resources, R_{WPI}), extent of access to water (Access, A_{WPI}), capacity for sustaining access (Capacity, C_{WPI}), ways in which water is used for different purposes (Use, U_{WPI}), and the environmental factors impacting on the ecology which water sustains (Environment, E_{WPI}). Environment-related aspects, though, are partially assessed by indicators included in the sanitation and hygiene indices; hence, this component has been removed from the WPI structure to avoid the inclusion of redundant information which might bias the final result.
- The Sanitation Poverty Index (SPI) considers whether or not people have access to improved sanitation. However, it is the consistent use of the facility, not its mere existence, which leads to health and environmental improvements. To this end, sanitation must be safe, physically accessible and affordable; and consequently SPI gauges the extent of access to sanitation, both in terms of accessibility and affordability (Access, A_{SPI}), assesses people's ability to construct and repair the latrine (Capacity, C_{SPI}), and includes those hygienic and safety issues that enable a continued usage of toilet facilities (Use, U_{SPI}).
- The hygiene sub-index (HPI) is measured by the aggregation of four different components (Webb et al., 2006), each one representing a different transmission route by which oral–faecal contamination may occur: drinking water (DW_{HPI}), food (F_{HPI}), personal hygiene (PH_{HPI}); and domestic household hygiene (DH_{HPI}).

6.1. Results and Discussion

WASH PI proves useful to unravel the linkages between poverty and access to basic services. It provides policymakers with clear messages, and allows them to identify more accurately the target groups and to allocate resources more equitably. The diagram in Figure 15, for instance, shows at a glance that all three sectors require urgent policy attention. It is observed that the water-related sub-index presents the lowest average (0.43), and although the two remaining sub-indices (SPI, 0.50; and HPI, 0.48) score higher, sanitation presents marked regional disparities (Std Dev. 0.14). The visualization of such heterogeneous pattern inherent in rural poverty is considerably improved through poverty maps (Figure 16), which identify the vulnerable areas in a spatial context and therefore allow for accurate geographic targeting (Cullis and O'Regan, 2004; Davis, 2002; Henninger and Snel, 2002). In terms of planning, each individual sub-index can be used as a performance indicator, and a straight comparison can be made when any district is compared for example to the leader, the laggard or the average performance.
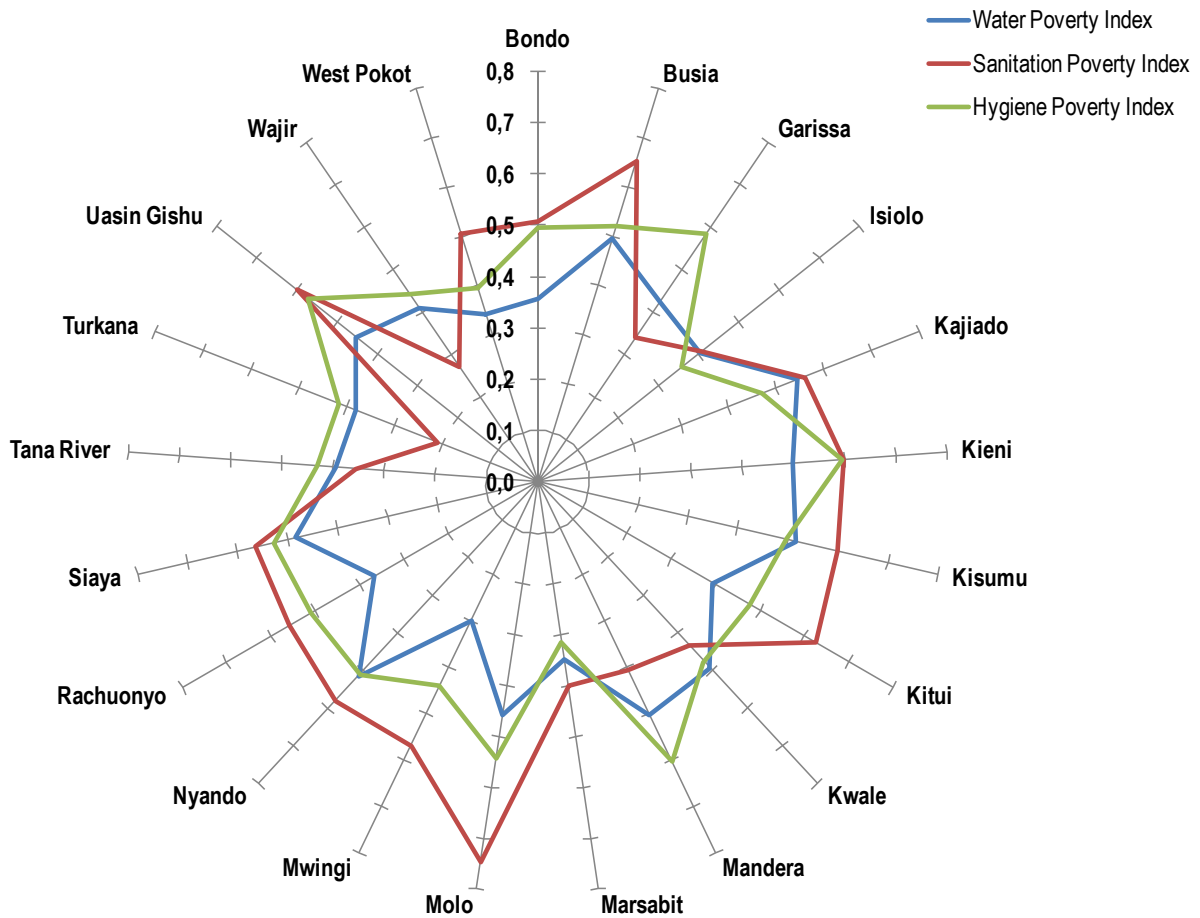
Figure 15 Spider diagram with WASH PI results for all 21 surveyed districts. Source: Giné Garriga and Pérez Foguet (2013b)

When each sub-index is studied separately, the analysis helps identify the root of the problem in each particular area and direct attention to those sector needs that require urgent intervention. As regards the WPI, regional disparities are observed in Figure 16a, although the level of water poverty is high throughout the study area. An accurate focus on a sub-index's components assists in capturing a more comprehensive picture of water-related challenges, and results from Table 14 suggest that areas for prioritization include those related to the 'Access' and 'Capacity' components, which average 0.25 and 0.21 respectively. A major sanitation challenge is undoubtedly related to the marked heterogeneous pattern, displayed in Figure 16b. The map shows that sanitation-related issues are particularly acute in the northern and eastern districts, in which SPI presents the lowest values (< 0.4). A closer look at the components, though, points out a clear distinction between access to (0.44) or use of (0.4) basic sanitation and abilities to construct/repair the facility, which scores noticeably higher (0.72). This difference highlights that to a large extent, the lack of access to sanitation services is not related to the inability of families to construct the latrine but to a lack of affordable sanitation technologies. Much like the WPI and SPI, a map is developed to visualize the level of household hygiene (Figure 16c), showing that geographic differences are not pronounced (Std. Dev. 0.07). The index can also be decomposed such that the contribution of each individual component is analysed, which shows that poor personal hygiene (0.36) represents the most likely pathway by which oral–faecal contamination may occur. In

contrast, handling practices and point-of use treatment of drinking water perform reasonably high (0.64).

(a)

(b)

(c)
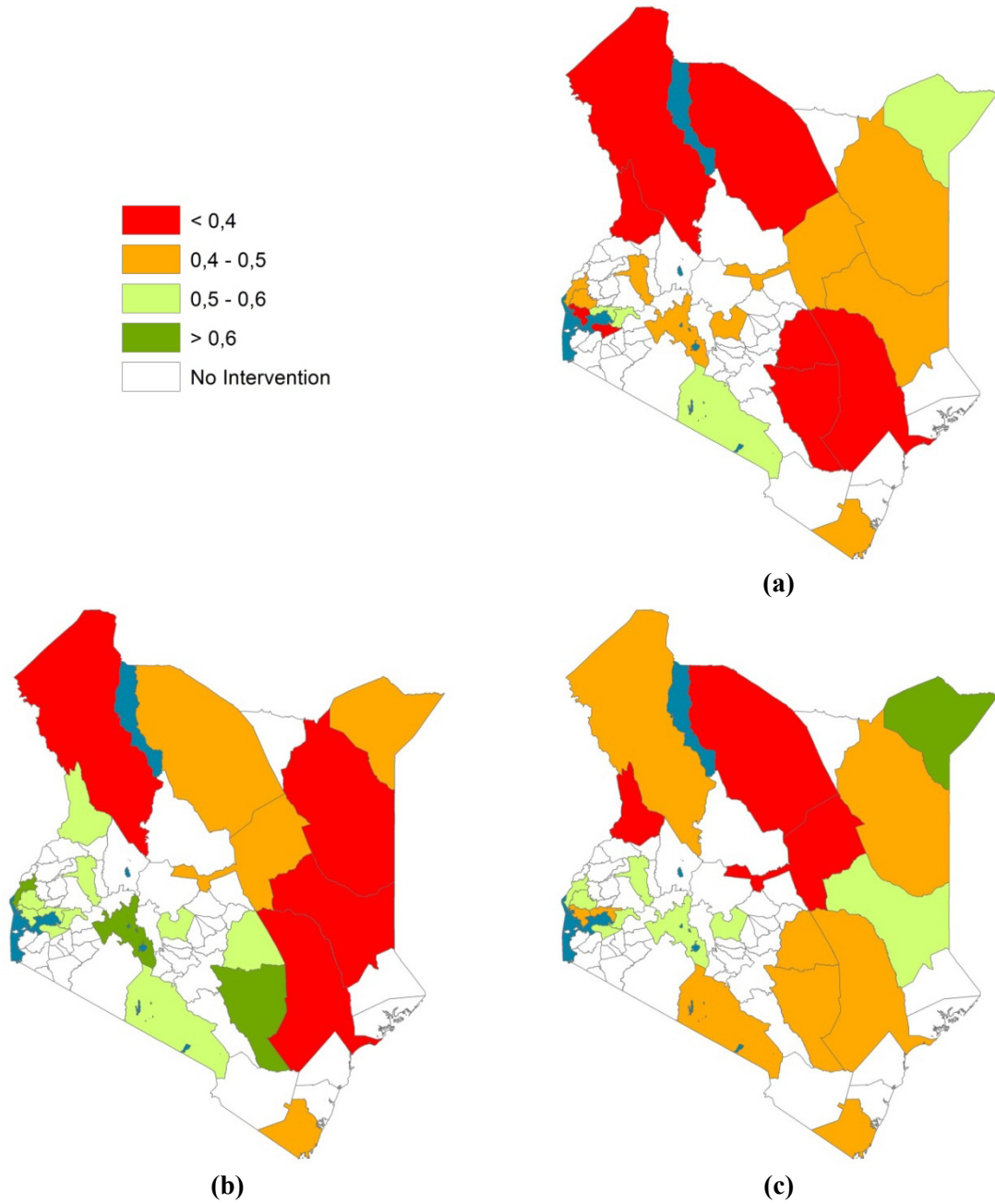
Figure 16 The WASH PI, at district level. a) The Water Poverty Index. b) The Sanitation Poverty Index. c) The Hygiene Poverty Index. Source: Giné Garriga and Pérez Foguet (2013b)

Table 14. Summary statistics of WPI, SPI, HPI and its components

	Water Poverty Index					Sanitation Poverty Index				Hygiene Poverty Index				
	R	A	C	U	WPI	A	U	C	SPI	DW	PH	F	DH	HPI
Min	0.48	0.09	0.09	0.54	0.30	0.12	0.03	0.49	0.21	0.37	0.27	0.18	0.29	0.31
Max	0.81	0.41	0.38	0.80	0.54	0.66	0.66	0.93	0.75	0.83	0.50	0.71	0.66	0.60
Mean	0.66	0.25	0.21	0.66	0.43	0.44	0.40	0.72	0.50	0.64	0.36	0.40	0.53	0.48
Std Dev.	0.09	0.09	0.08	0.06	0.07	0.19	0.17	0.14	0.14	0.15	0.06	0.17	0.09	0.08

Note: Water Poverty Index (WPI); Resources (R); Access (A); Capacity (C); Use (U); Sanitation Poverty Index (SPI); Access (A); Capacity (C); Use (U); Hygiene Poverty Index (HPI); Drinking water (DW); Food (F); Personal hygiene (PH); and Domestic household hygiene (DH)

In sum, the WASH PI eases the understanding of water, sanitation and hygiene linkages by making them intelligible in the form of maps, graphs and tables, so decision-makers can quickly identify which sectors may be most in need of assistance. The index approach therefore provides an adequate instrument for supporting decisions about sector planning, performance monitoring, and resource allocation.

Yet, if simplicity is its main appeal, it must be recalled that much like many other approaches that attempt to describe a complex reality, integrated indicators present some limitations. First weakness is related to the large amounts of data that are required in the development of the composite. In data-scarce contexts, data collection routines should be in place to produce valuable information at local level at a reasonable cost, which poses a serious challenge. Alternatively, there is the risk to oversimplify the measurement of some variables where data is unavailable or inaccurate. The method employed in index construction is also subject to criticism, and statistics are required at different stages of the process to avoid inaccurate results. However, capacities at the local level are often insufficient, thus hindering the use of appropriate techniques in the development of the composite. Last but not least, and with regard to the interpretability of the index, it has been acknowledged that the practical usefulness of the tool may not lie in the aggregated values but in the sub-indices themselves. This calls into question the soundness of the composite as a policymaking tool.

In consequence, significance at the local level of WASH PI and other composites tend to be spoilt by a variety of shortcomings including insufficiency of available data, poor capacities to produce meaningful indicators, and loss of information in the aggregation process. These weaknesses may challenge the validity of the index in decision-making processes from the practitioner viewpoint.

7. Simple thematic indices to support local level planning

In developing planning instruments at the local level, exhaustiveness in relation to the object of analyses needs to be balanced with simplicity. Otherwise the uptake and usage of such instruments by policymakers is at best, challenging (Schouten and Smits, 2015; WaterAid, 2010). With this in mind, planning criteria are defined herein in the form of simple indices (Jiménez and Pérez Foguet, 2010a). For each index, one ranking is produced and transposed into one league table to denote

priorities. A different threshold limit is set per list for this purpose. To show at a glance both index values and priorities, different maps are developed, which enable a quick identification of key focus areas. Finally, each priority list is related with specific remedial actions, ultimately translating development challenges into beneficial development activities.

As previously mentioned, these indices can be meaningfully assessed at the local level but not at national level, and thus a decentralized approach is adopted. The district of Homa Bay, in western Kenya, is selected as case study (Figure 17). For demonstration purposes, this section provides an in-depth explanation of one index as practical example, though a detailed description of different planning indices is given in Chapter 3.
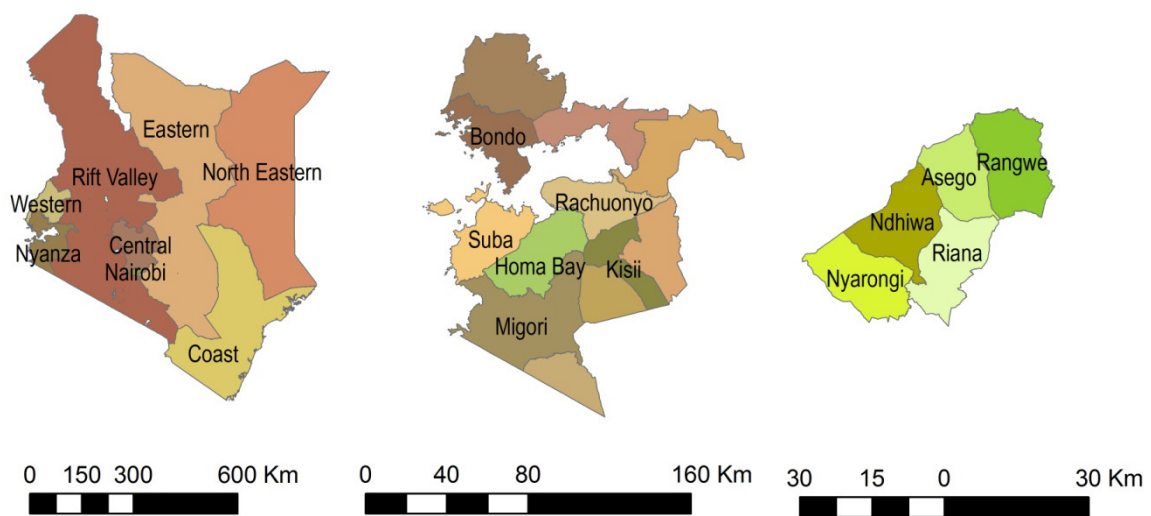
Figure 17 Location and Administrative Units of Kenya, Nyanza Province, and Homa Bay District

7.1. Results and Discussion

The selected index presents situational analysis of "water coverage", and highlights major constraints to accessibility issues. On the basis of the index results, it identifies those locations which require urgent policy attention and then suggests one alternative to mitigate this sector challenge.

To estimate water coverage, a common method is based on standard assumption on the number of users per improved water source, i.e. the source:man ratio, which in Kenya stands at 250 people per public tap. The index depicts the number and geographic distribution of waterpoints in terms of the population living in the area, and thus identifies those locations most in need of new waterpoints' construction. Numerically, the index can be calculated through a simple formula, which promotes its widespread application:

$$Water\ coverage\ = \frac{Number\ of\ waterpoints}{Population} \times 250$$

It is gleaned from the coverage map (Figure 18) that current availability of improved sources is not only low, i.e. 12.15% of population are properly covered by improved waterpoints, but marked regional disparities also hamper equity criterion. For instance, North Kabuoch and North Nanyamwa (0%) show the lowest coverage values, while West Kagan (56%) and North Kanyikela (69%) present the highest estimates.
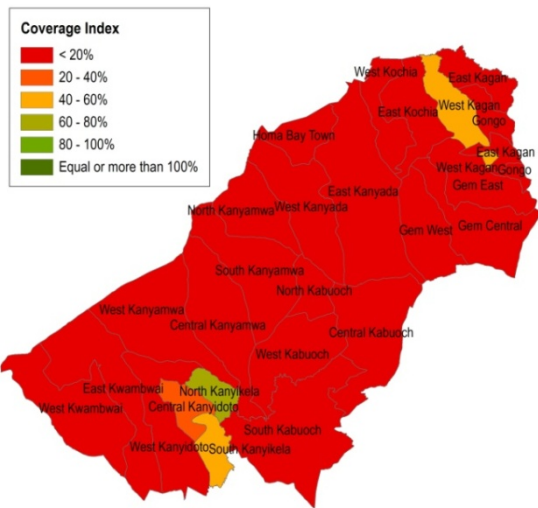
Figure 18 Coverage Index
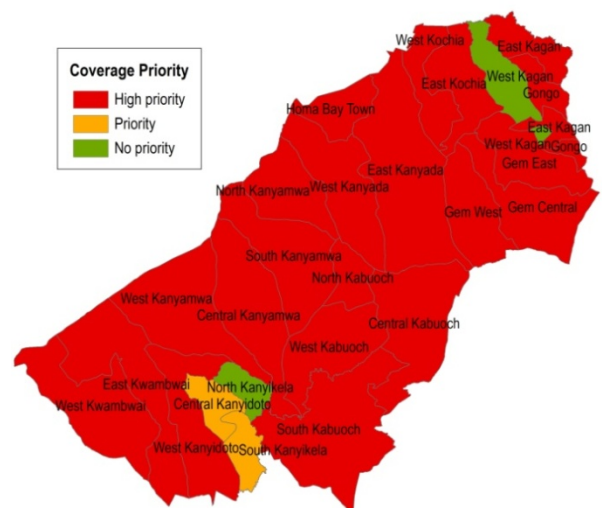
Figure 19 Coverage Priority Locations

To tackle water shortages, various approaches may be adopted when defining the list of priorities. In terms of regional equity, the goal would be to reach a minimum coverage threshold in every administrative unit, as commonly established in national policies. The focus in these cases should be on underserved areas, and for instance target in first place the locations included in the poorest and least-served quartile. Based on an efficiency criterion, however, those locations with the highest number of potential beneficiaries would be first targeted, regardless of coverage. A combination of both criteria is also feasible, but this would result in a complex indicator and has accordingly been dismissed. In this planning exercise, first approach has been opted for (Figure 19), since vulnerability is probably higher in total absence of improved sources (Jiménez and Pérez Foguet, 2010a).

It can be seen in Table 15 that one different ranking is produced depending on each abovementioned criteria, showing both ranks poor correlation (Figure 20). For example, it is observed that North Kabuoch has been prioritized as its coverage index stands at 0%, although in terms of potential beneficiaries, only roughly 5,000 people would beneficiate from the construction of new waterpoints. On the other hand, coverage index of East Kwambwai averages 19%, while beneficiaries from a hypothetical intervention would be raised up to 13,809. As mentioned, the territorial equity criterion has been employed for planning purposes, in order to emphasize those underserved locations with lowest source:man ratios.

Table 15 Priority List for Construction of New IWPs

Rank (equity)	Rank (efficiency)	Location	Estimated Population 2011	Coverage Index	Unserved Population	Required No. New IWP
1	19	North Kanyamwa	9.749	0%	9.749	39
2	21	North Kabuoch	5.342	0%	5.342	21
3	2	Homa Bay Town	37.601	5%	35.601	142
4	4	Gem Central	23.146	5%	21.896	88
5	7	Central Kanyamwa	16.004	5%	15.254	61
…						
18	10	West Kwambwai	16.112	16%	13.612	54
19	8	West Kanyada	17.560	17%	14.560	58
20	9	East Kwambwai	17.059	19%	13.809	55
21	13	South Kanyamwa	14.862	19%	12.112	48
22	22	Central Kanyidoto	6.407	27%	4.657	19
23	24	South Kanyikela	3.339	45%	1.839	7
24	23	West Kagan	9.419	56%	4.169	17
25	25	North Kanyikela	3.258	69%	1.008	4

Note: In red colour, locations with risky coverage (<25%). In orange, locations with poor coverage (25 – 50%). In green, locations with acceptable coverage (>50%)
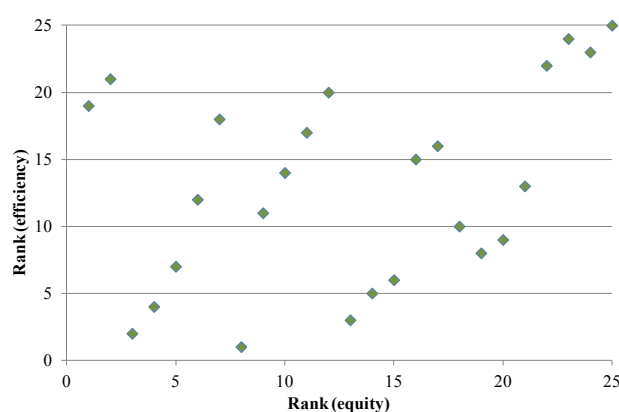
Figure 20 Coverage Ranks (equity versus efficiency)

In sum, a total number of 1,306 new waterpoints would be required to reach threshold coverage of 25% in all locations, which highlights the risky situation of Homa Bay District in terms of water accessibility.

This example shows that simple aggregated indicators may be useful tools to put planning criteria into practice. However, it is important to recall that such criteria should be objective and

transparent, while related indices need to be simple and easy-to-use. If adequately designed and visualized, the indices show areas for improvement and identify those locations in need of further investment. In doing so, they guide appropriate action and policy-making towards better service delivery

8. Conclusions

Despite the achievements in the approaches to monitoring the WaSH sector, there are certainly areas for improvement which demand the attention of both practitioners and academics. It is well recognized that monitoring and consistent reporting is essential to provide the evidence base for informed decision-making, and monitoring tools should be ultimately developed to respond to the informational needs of policymakers. This chapter aims to contribute to the existing debate about instruments for improved sector monitoring, and specifically assesses the utility of their respective outcomes to support planning. Different approaches that are widely promoted in the WaSH sector are compared. The first one describes the situation in terms of health impact. The other alternatives, in contrast, focus on inputs and behavioural changes, and thus encompass a variety of measures that not only influence health but consider many other aspects.

The results suggest that measuring the health impact of water and sanitation rarely produces reliable estimates, thus limiting the scope to drawing solid conclusions. Moreover, the interpretation of epidemiological studies is not straightforward; and in terms of policymaking, they hardly detect operational deficiencies or suggest improvements. Simply put, it appears that health impact evaluations are not useful tools for monitoring purposes. At the global level, the JMP has emerged as a consistent approach to report on WaSH sector status and trends. Its major strength, and the root of its success, is the simplicity of having a few relatively well-defined and easy-to-measure indicators, which produce reasonable estimates of coverage across different contexts. However, JMP assesses access through technology-based proxies, and it does not provide information on the quality of the water, the continuity of the water service, the sanitary conditions of the toilet facility, or whether economic, institutional, social or environmental reasons jeopardize the ability of households to access the services. Therefore, the simplicity of the monitoring framework is also its core limitation, and it is necessary to gain an insight into wider issues that relate to sector performance. For instance, the recognition as a human right of access to safe drinking water and sanitation spotlights new dimensions that monitoring initiatives should address. The index approach attempts to overcome this weakness. It combines data of different nature and then helps differentiate the multifaceted situation at the dwelling in relation to water, sanitation and hygiene. In doing so, indices appeal to policymakers as a tool for planning and monitoring support, as well as targeting and prioritizing of interventions. For decentralized decision-making, however, various factors jeopardize the practical utility of aggregated indicators, including inter alia the amount of data required in the assessment process, the techniques employed in index construction, and the validity of the composite itself to inform decisions. To balance simplicity and exhaustiveness, i.e. instruments that not only are easy to use but also provide a complete description of the context in which the service is supplied, the use of simple planning indices might be an in-between solution. In order to be effective, final users (technicians of local governments, practitioners, etc.) need to actively participate and be involved in various stages of the process leading to the design and implementation of such measures. In addition, indices should

be presented in a way (e.g. league tables, ranks, poverty maps, etc.) that provide clear messages and communicate a picture to decision-makers quickly and accurately.

In the end, these latter three monitoring approaches (i.e. JMP, composite indices and planning indices) are complementary to meet different needs at different levels. Consistent reporting of coverage is essential, and a more comprehensive monitoring system would probably be too difficult to implement and therefore counter-productive. The JMP's indicators are adequate to harmonize the monitoring mechanisms and produce quality basic estimates of the type of drinking water sources and sanitation infrastructure people use. In this regard, the ongoing consultation process guided by the JMP around the post-2015 sector-related goals, targets and indicators is of primary importance, as it should help produce a broader view of service level and take into account human rights criteria. The index approach proves especially useful for decision-makers and planners as a rapid appraisal instrument. It provides a better understanding of the interactions between WaSH and poverty. If routinely assessed, the composite sheds light on whether the intervention strategy needs fine-tuning and how it can be improved, which is precisely the aim of operational monitoring. Finally, simple and user-friendly (easy to assess, easy to use) planning indices are powerful tools for supporting decisions at the local level, where capacities of recipient institutional bodies are inadequate to correctly perform the information cycle, which includes data gathering, data processing, data analysis and data reporting.

CHAPTER 3

DEVELOPMENT OF TOOLS TO SUPPORT LOCAL LEVEL PLANNING

Abstract

In many parts of the world, inadequate provision of safe water and basic sanitation continues to undermine strategies for poverty alleviation. The root lies to a large extent in the inability of policy makers to tackle services development in a holistic and integrated manner. There is indeed a pressing need to provide policymakers with broad-based evidence for planning, targeting and prioritization support; mainly in the form of reliable and appropriate instruments.

It is with this in mind that this chapter introduces a variety of policy tools that may be used to promote decision-making in the WaSH sector. First, the use of composite indices is widely discussed. It introduces the Water Poverty Index (WPI) and highlights its main conceptual weaknesses. Then, it proposes a suitable methodology to assess water poverty that overcomes these weaknesses and taking this method as starting point, two alternative composites are presented: i) an enhanced-Water Poverty Index (eWPI) to assess the diverse, interacting components at basin level of water-related processes, societal pressures, and policy actions, and ii) a WaSH-focused, thematic indicator: the WASH Poverty Index (WASH PI). Second, a small set of simple thematic indicators are defined as the basis to reveal which planning areas require policy attention. Finally, the chapter explores the use of object oriented Bayesian networks (ooBn) as a valid approach for supporting decision making in WaSH planning and management. On the basis of the WPI, a simple ooBn model is designed and applied to reflect the main issues that determine access to safe water and improved sanitation. A variety of case studies from Latin America (Peru) and East Africa (Kenya, Tanzania and Mozambique) are presented to illustrate the application of the proposed tools. Results indicate that accurate and comprehensive data, if adequately exploited through easy-to-use instruments, may be the basis of effective targeting and prioritization, which are central to sector planning.

Keywords: aggregated indicators; planning indices; Bayesian network; local decision-making

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- Pérez Foguet, A., & **Giné Garriga, R.** (2011). Analyzing Water Poverty in Basins. *Water Resources Management*, 25(14), 3595-3612.
- **Giné Garriga, R.**, & Pérez Foguet, A. (2012). Unravelling the linkages between water, sanitation, hygiene and rural poverty: the WASH Poverty Index. *Water Resources Management*, 27(5), 1501-1515.
- **Giné Garriga R.**, Jiménez Fdez. de Palencia A., Pérez Foguet A. (2015). Improved monitoring framework for local planning in the water, sanitation and hygiene sector: From data to decision-making. *Sci. Total Environ*, 526, 204-214.
- **Giné Garriga R.**, Pérez Foguet A., Molina J.L., Bromley J., Sullivan C. (2009) Application of Bayesian Networks to assess water poverty. II International Conference on Sustainability Measurement and Modelling - ICSMM 09. Barcelona: CIMNE.

1. Introduction

In the context of decentralization, where decision-making moves to local administrative units and decentralized bodies assume some political autonomy, there is an increasing need for self-governments to be accountable for the performance of service delivery. This requires, amongst others, innovative tools for bringing about a more equitable allocation of resources (Jiménez and Pérez Foguet, 2010a); and specifically to assist decision-makers in i) identifying those regional areas and population groups most in need, ii) improving transparency in budgetary procedures, and iii) measuring progress. In recognition of this fact, the aim of this chapter is to introduce a variety of instruments that are developed for the improvement of WaSH sector planning at the local level.

First of all, the role of aggregated indicators is thoroughly analysed. It takes the Water Poverty Index (WPI) created by Sullivan (2002; Sullivan et al. 2003) as a remarkable example to advance the water-poverty interface and produce an interdisciplinary assessment of water scarcity. Yet, much like many other approaches which attempt to measure complexity, the WPI has been criticized on several grounds. In the light of those pitfalls that commonly arise when constructing the index, different methodologies for weighting and aggregating indicators into a composite are discussed. A step-by-step procedure for constructing the index is proposed. An example of the development of the revised WPI is given for the Turkana District, Kenya, as a baseline case to illustrate differences across different methods and to show up the impact on final outcomes of potential flaws (Giné Garriga and Pérez Foguet, 2010). In addition, taking the water poverty framework proposed by Sullivan (2002) as starting point, and the methodology for index construction cited above, two alternative composites to original WPI are presented, namely the enhanced Water Poverty Index (eWPI) and the WASH Poverty Index (WASH PI). The eWPI addresses water poverty in a more systemic way, and this is done by integrating the concept of causality through the Pressure-State-Response (PSR) model. To demonstrate the suitability of the index, the eWPI is piloted and implemented in the Jequetepeque basin, in Peru. The basic unit of analysis is the river basin, as it is the natural unit for territorial planning and management of water resources. This index ultimately allows a comprehensive understanding of the crosscutting nature of water issues and impacts. The rationale of the WASH PI is to produce an integrated assessment of the links between poverty and the delivery of WaSH services. The index, which is not presented as a single composite but as a thematic indicator, aims to support poverty alleviation while keeping water, sanitation and hygiene issues in focus. In this case, Kenya is selected as initial case study to illustrate the validity of the index.

Second, a set of simple planning indices are developed as policy tools for targeting and prioritization. They are defined to underline the emerging development challenges in relation to WaSH, and specifically they serve as the basis to rank population groups and reveal which areas may be most in need of further investment. To denote priorities, one ranking is produced per index, and results are disseminated through poverty maps and league tables, which help identify key focus areas. Finally, each priority list is linked to a remedial action, thus various approaches are suggested to mitigate WaSH-related emerging challenges. In doing so, the indices ultimately help define strategies and initiatives to steer regional development. The practical implementation of these tools is documented by three different case studies in East and Southern Africa, namely the district of Kibondo (Tanzania, 2010), the district of Homa Bay (Kenya, 2011) and the municipality of Manhiça (Mozambique, 2012).

Third, the flexibility of Bayesian networks (Bns) is exploited to model water poverty, as a type of Decision Support System (DSS) that is based on the concept of conditional probability (Bromley et al., 2005). Bns are techniques that have gained a reputation of being helpful for simulating complex problems which involve uncertain knowledge (Henriksen et al., 2007). In the water resource context, where many variables are highly interlinked and uncertainty plays a key role, they have been increasingly applied as an aid to decision-making (Bromley et al., 2005; Castelletti and Soncini-Sessa, 2007; Henriksen et al., 2007; Martín de Santa Olalla et al., 2007; Molina et al., 2009). This study particularly focuses on the construction of a model made up of traditional and object oriented Bayesian Networks (ooBn). Such approach allows complex domains to be described in terms of interlinked objects, and thus provides an appropriate framework to simultaneously deal with different water-related challenges. The case study is developed for the Turkana District, in Kenya, where the Government launched a programme to improve sustained access to safe drinking-water, sanitation infrastructure and hygiene (WaSH) for the rural population in 22 districts. Taking the original WPI definition and its five components as a starting point, the study demonstrates the usefulness of Bns to accommodate the complexities of water issues and to inform about the foreseen impact of the Kenyan Government's initiative.

Each of the tools cited above are thoroughly described herein in separate sections.

2. Aggregated Indicators

The increasing necessity of coming up with feasible tools to assess WaSH issues in a holistic way has led to the development of a variety of composite indices (Cohen and Sullivan, 2010; Feitelson and Chenoweth, 2002; Flores et al., 2013; Giné Garriga and Pérez Foguet, 2013b; Pérez Foguet and Giné Garriga, 2011; Sullivan et al., 2003; Webb et al., 2006). They are all aimed at condensing information of different nature, thus integrating various social, economic, and environmental aspects of the water sector. Such an index offers policy planners an appropriate tool for performance monitoring, benchmarking comparisons, policy progress evaluation, public information, and decision making.

The use of a numerical index as a management and planning tool, however, has a long and chequered history; and indices have been criticized on several grounds. Much like many other approaches which attempt to measure complexity, aggregated indicators are imperfect tools and caution is required when using them for supporting poverty alleviation. Specifically, soundness of composites depends on two aspects (Nardo et al., 2005): i) the quality of available data, and ii) the suitability of techniques employed in their construction. Both elements are equally important. If composite indicators are based on inaccurate information, they would easily be misinterpreted, regardless the adequacy of the method applied to their construction. Likewise, an aggregated index which feeds on comprehensive and coherent basic data but employs poor procedures would produce unreliable results. Development of composite indicators must consider all these aspects.

In Chapter 1, the importance of producing reliable data by means of efficient methodologies has been highlighted. The focus of this section is thus on developing a method that supports the aggregation of a variety of indicators to create a context-specific index of water poverty. In particular, it is an attempt to refine the Water Poverty Index (WPI) developed by Sullivan (2002). The theoretical basis of this index is first introduced, and its main strengths and limitations are highlighted. In the light of these shortcomings, different methodologies for weighting and

aggregating indicators into a composite are discussed. A step-by-step procedure for constructing a refined index is proposed, and different methods are tested to show up potential pitfalls. It is shown that a composite of water poverty may be developed which minimizes those shortcomings that commonly arise when constructing an aggregated index. To validate these findings, two alternative composites to original WPI are finally presented, namely the enhanced Water Poverty Index (eWPI) and the WASH Poverty Index (WASH PI).

2.1. Conceptual basis to construct the Water Poverty Index

The term water poverty has been amply discussed in recent years (Feitelson and Chenoweth, 2002; Jiménez et al., 2009; Shah and van Koppen, 2006; Sullivan, 2002), though its definition is still being disputed. This chapter looks into the concept of water poverty proposed by Lawrence et al. (2002), who state that people can be "water poor" because of two reasons: i) in the sense of not having sufficient water for their basic needs because it is not available, or ii) because they are "income poor"; and although water is available, they cannot afford to pay for it.

Based on this definition, and aimed at assessing the degree to which water scarcity impacts on human populations, the term water poverty was advanced as an indicator by Sullivan (2002) through the Water Poverty Index (WPI). The development of such an index should enable decision makers to identify and track the physical, economic and social drivers which link water and poverty (Sullivan, 2002) . Its theoretical framework integrates a number of aspects which reflect major preoccupations in developing countries related to the provision of safe water and improved sanitation: physical availability of water resources (R), extent of access to water and sanitation (A), people's ability and capacity for sustaining access (C), use of water for different purposes (U), and the environmental factors which impact on the water supply to ecosystems (E). Numerically, the WPI is given by the weighted arithmetic mean function of these five components. Different weighting systems could thus be employed to indicate the importance of each variable, though equal indicator weights are preferred since there is no evidence that it be otherwise (Sullivan et al., 2003). Likewise, use of an additive structure has been reported more transparent and acceptable to different stakeholders than other aggregation functions (e.g. geometric, multi-criteria ...).

Limitations of existing WPI

Recognizing the usefulness of the WPI and its spread application (Cullis and O'Regan, 2004; Giné Garriga and Pérez Foguet, 2011; Komnenic et al., 2009; Sullivan et al., 2003), the authors of the index and literature elsewhere have recognized different concerns that arise when constructing the index. In essence, two conceptual weaknesses have been identified, which this revision here attempts to overcome. One weakness involves how the basic input data are combined, and the other relates to the statistical properties of the index.

The ad hoc selection of indicators is subject to criticism. In data-scarce contexts nonetheless, availability and accuracy of data alone often drives the selection process (Booysen, 2002). It is recalled that the use of existing data is preferred where possible, rather than identifying data needs regardless availability (Sullivan and Meigh, 2003). To a certain extent, there is thus built-in flexibility in the choice of indicators, albeit at the cost of comparability. The weighting and aggregation technique is another major shortcoming, since this influences coherence and interpretability of final values (Nardo et al., 2005). The weights assigned to the components of the

WPI (which are undefined) are subject to individual judgments (Feitelson and Chenoweth, 2002), though an equal average weighting is not adequately justified either. Similarly, Molle and Mollinga (2003) criticize the index for conflating disparate and correlated pieces of information with arbitrary weights. In consequence, Heidecke (2006) points to the importance of transparent display of determined weights to avoid misinterpretation. Moreover, it is argued that additive aggregation implies full compensability among the various components of the index: the possibility of offsetting poor performance in some indicators by sufficiently high values of other indicators (Nardo et al., 2005). Such a complete compensability is often not desirable. The WPI has also proved to be inadequate for assessing the complexity of the water issues (Komnenic et al., 2009), and this is acknowledged by the authors (Lawrence et al., 2002) who note that "the information is in the components rather than in the final single number". Along the same line, the index has been criticized for being unable to reveal anything that a single variable alone cannot reveal. Shah and van Koppen (2006) state in this respect that the real indicator of water poverty is actually the "access" component of the WPI, not only suggesting that water resource endowment practically has no relationship with water poverty, but concluding that if a nation is poor, it has no means to exploit its resources. Last but not least, and with regard to the relationship between some of WPI components and other development indicators, Jiménez et al. (2009) show at international scale that WPI is highly correlated with the Gross Domestic Product (GDP) and Human Development Index (HDI). This reduces the usefulness of the index as a meaningful policy tool.

In sum, significance of WPI tend to be spoilt by a variety of shortcomings including inadequate quality of data, arbitrariness of weights, high correlation between WPI and its variables, and loss of information in the aggregation process. To improve the soundness of the index, major constraints are addressed in more detail below; and based on literature review, different alternatives to tackle these limitations are proposed.

The issue of weights

In composite indices, the choice of weights is aimed at reflecting the relative importance given to the variables comprising the index. For example in the WPI, greater weight would be placed beside the components which are considered to be more significant in the water poverty context.

To determine weights, different methods have been developed in recent years, including data-dependent statistical tools as well as judgment-based expert opinions. A conventional practice is the selection of weights following consultation with experts. It is worth mentioning here the Analytic Hierarchy Process (AHP) approach introduced by Saaty (1980), which is a commonly used technique to identify stakeholders' preferences and obtain the relative importance of the criteria under analysis (e.g. indicators) by using a pair-wise comparison system. However, these may be relatively subjective methods of weighting, and they are often singled out for their arbitrariness (Booysen, 2002). Alternatively, multivariate techniques (e.g. principal component analysis and factor analysis) present an empirical and more objective option for weight assignment. This technique has the advantage of determining that set of weights which explain the largest variation in the original variables (Slottje, 1991). In contrast, weighting only intervenes to correct for the overlapping information of two or more correlated indicators, and it is not a measure of theoretical importance of the associated indicator (Munda and Nardo, 2005a; Nardo et al., 2005). Therefore, statistical weights do not always reflect the priorities of decision-makers

(Esty et al., 2005); and since they are data-specific, formulations have to be updated when more data become available (Lohani and Todino, 1984).

No weighting system is therefore above criticism. And it is for this reason that equal weighting is often employed. Main argument for equal indicator weights is based on the premise that no objective mechanism exists to assess the relative importance of the different aspects included in the index structure.

In any case, it has been noted that after experimenting with a variety of weighting systems, resulting indices remain fairly well correlated (Booysen, 2002). In terms of index interpretation nonetheless, it is of primary importance to provide an adequate justification for the particular weighting system adopted.

Aggregation methods

In much the same way as with the weighting system, there are many aggregating techniques available for constructing an index. By far, the most commonly used method is the weighted arithmetic mean of subindicators. Other, less widespread, aggregation functions include multiplicative (geometric) and nonlinear aggregations such as multi-criteria analysis. This section discusses about the additive form employed in the original WPI, in which subindices are added together; and the multiplicative form, in which a product is formed of all of the five components. Numerically, they can be formulated as:

$$WPI_a = \sum_{i=R,A,C,U,E} w_i X_i \qquad WPI_g = \prod_{i=R,A,C,U,E} X_i^{w_i} \qquad (1)$$

where *WPI* is the index value for the arithmetic (WPI_a) or geometric (WPI_g) function, *Xi* refers to component *i* of the WPI structure (R, A, C, U, E), and *w* is the weight applied to that component.

Major virtues of an additive approach are simplicity, transparency and ease of understanding for non-experts. However, and although widely employed, this aggregation technique imposes certain restrictions on the nature of indicators and the associated weights, which are often not desirable and may be difficult to satisfy (Esty et al., 2005; Nardo et al., 2005).

When using a linear additive aggregation technique, a necessary condition is the assumption of preference independence (Munda and Nardo, 2005b). Unfortunately, this condition has very strong consequences, as this means that this aggregation form allows for the estimation of the marginal contributions of the variables separately, which can then be added together to yield a total value (Esty et al., 2005; Nardo et al., 2005). This would imply that among different components of the WPI there are no synergies or conflicts, which appears to be quite an unrealistic assumption. For example, the combined effects on water quality of poor sanitation and environmental degradation around the waterpoint are likely to be more severe that the linear addition of each of these impacts alone.

Furthermore, additive aggregations have important implications on the interpretation of weights, as it has been demonstrated that in a linear aggregation framework weights have the meaning of

trade-off (substitution) ratios (Munda and Nardo, 2005a). Therefore, there is a theoretical inconsistency in the way weights are actually used and their real theoretical meaning, since they fail to indicate the importance of the variable associated. For the weights to be interpreted as "importance coefficients", non-compensatory aggregation procedures must be used when constructing composite indicators (Podinovskii, 1994).

Finally, in linear aggregation rules, compensability among the different individual indicators is implicit (Munda and Nardo, 2005a; Nardo et al., 2005). For example in the original WPI, water resources availability would compensate a loss of water quality. Obviously, a complete compensability is not desirable when different goals are equally legitimate, and then a non-compensatory logic might be necessary. In this respect, if multi-criteria analysis entails full non-compensability, the use of a geometric aggregation might be an in-between solution (Hajkowicz and Collins, 2007; Nardo et al., 2005). In the geometric method, poor performance in some attributes is penalized more heavily.

In addition to the two aggregating techniques employed in this analysis (additive and geometric), further investigation on other methods, e.g. non-compensatory outranking approaches, to construct the WPI would be interesting, though it is beyond the scope of this research.

2.2. Revised methodology to construct a water-focused aggregated indicator

The idea of obtaining an "ideal index" that captures and perfectly aggregates variables from different dimensions is an unrealistic goal (Diewert 1986, as quoted in Slottje 1991). Instead, Slottje (1991) claims the need for developing a composite index that balances conceptual clarity (combining as much information as possible) and methodological simplicity (clear understanding of the assumptions that underlie the particular index). Composite indices should remain simple in terms of their construction and interpretation, allowing for the index to be easily comprehensible and readily calculable (Booysen, 2002) and avoiding any complex function which might hinder its transparency. This is certainly imperative regarding the WPI, since it is primarily aimed at informing water planners at local scale in low-income settings.

This section attempts to operationalize the concept of water poverty. However, to propose one fixed set of indicators for each and every context appears to be inappropriate, as every location is unique and specific criteria and indicators may not be available for all cases. Therefore, we direct efforts towards the development of a methodological framework to support the selection of appropriate (site-specific) criteria and indicators, and the integration and transformation of this information into a single value.

In essence, composite indexing involves three key steps (Table 16): 1) selection and combination of key indicators into their corresponding subindices, using an equal and dimensionless numeric scale; 2) determination of weight for each subindices and their aggregation to yield an overall index; and 3) validation of the composite using a sensitivity analysis. A step-by-step procedure for developing the WPI is given herein.

Table 16 Basic steps in index design

1st: Selection of indicators	1.a.	Compilation and validation of available data
	1.b.	Definition and first proposal of indicators
	1.c.	Classification of indicators, based on conceptual framework.
	1.d.	Preliminary statistical analysis of proposed indicators
	1.e.	Selection of indicators at subindex level
2nd: Construction of the index	2.a.	Assignment of weights for subindices
	2.b.	Aggregation of subindices
3rd: Validation of the index	3.a.	Sensitivity analysis

First stage consists in compiling existing sector-related data (1a) and then defining a set of relevant indicators (1b). Information required for good decision-making is seldom available, and an information dilemma is often confronted (Feitelson and Chenoweth, 2002). The use of available data has the benefit of time and cost savings, though in order to assess whether these advantages are sufficient it is imperative that further data collection be considered too. The latter might not be a feasible approach in the vast majority of poor settlements, and an ad hoc selection of variables driven by data availability appears the most cost-effective solution. In any case, proposed indicators should meet some basic criteria (Feitelson and Chenoweth, 2002; Jiménez et al., 2009; OECD, 1993): (i) *available* (measurable at no/reasonable cost), (ii) *understandable* (exactly defined to be easily accepted by those who are likely to use it), (iii) *accurate* (supported by reliable information), (iv) *scalable* at different administrative levels, (v) *relevant* (responsive to changes), (vi) regularly *updatable*, and (vii) *integrative* among the environmental, social and economic aspects.

Next step (1c) is to classify all indicators based on WPI framework; since these five dimensions (subindices) of the index are considered to accurately describe the complexity of water sector in an integrated way. A preliminary assessment of the dataset might be helpful to decide whether proposed indicators are appropriate for this purpose. This decision can be based on expert opinion, though different analytical approaches might also be used to explore statistical structure of the dataset (Booysen, 2002; Lohani and Todino, 1984; Nardo et al., 2005).

After having undertaken this general preliminary evaluation, one should repeat this process at subindex level. The underlying nature of the variables needs to be carefully analysed before the final selection of indicators (1d) (Nardo et al., 2005), which requires a balance between the avoidance of redundancy and comprehensiveness with respect to goals (Keeney and Raiffa 1993, as quoted in Hajkowicz 2006). Lack of correlation is a desired property, which means that each indicator is measuring different statistical dimensions in the data. In contrast, correlated variables cause redundancy and double-counting, which might bias the result. Thus, when two or more indicators duplicate measures of same aspect, removal of correlated elements from the model is advisable. The other requirement is comprehensiveness, and the set of selected indicators must be sufficient to thoroughly describe the phenomenon to be measured (Hajkowicz, 2006). Multivariate statistical techniques are employed in data reduction to determine the number of latent (correlated) variables underlying the data, and to define new factors which reveal the set of indicators having the highest association with it (Booysen, 2002). The idea is to account for the highest possible variation in the indicators set using the smallest possible number of factors. Therefore, the

composite no longer depends upon the dimensionality of the dataset but it is rather based on the "statistical" dimensions of the data (Nardo et al., 2005). The drawback, though, is that in multivariate techniques correlations do not necessarily represent the real influence of those indicators on the problem at hand (Esty et al., 2005; Nardo et al., 2005). Thus, although methodologically sound, the final choice of which variables are selected should be made on the basis of accurate qualitative and theoretical understanding of the phenomena in question (Booysen, 2002; Saisana and Tarantola, 2002).

After deciding the number of factors to keep and calculating all five subindices, the assignment of weights is the following step (2a). As previously mentioned, weights should reflect the relative importance of each of the components. To this end, three different approaches might be in place: (i) not to assign explicit weights; (ii) weights based on expert opinion; or (iii) statistical weights based on multivariate techniques.

The aggregation process of variables (2b) is certainly a critical step in index construction (Singh et al., 2008; Swamee and Tyagi, 2007). It tends to be of either an additive or a functional nature. The former entails the mere addition of component scores to arrive at index values, whereas the latter is based on a functional relationship between certain variables. A key remark in this respect is that it is important to look at the aggregated figures as well as at the underlying ones.

In the last stage, the index needs to be validated. A sensitivity analysis should be conducted (3a) to test the robustness of the composite. Such analysis might improve the accuracy, credibility and interpretability of the final results, and thus minimize the risks of producing meaningless composite indicators (Saisana and Tarantola, 2002).

2.3. Assessing the Water Poverty Index

In previous section, different alternatives to calculate the index have been outlined, and their main strengths and limitations are highlighted. This section is aimed at applying all these methods in order to i) test their validity, ii) understand the impact of the selected alternative on final outcome, and to iii) propose an adequate function for estimation of water poverty. To do this, the abovementioned step-by-step procedure is followed. The Turkana District (Kenya) has been selected as initial case study.

Case study: the Turkana district (Kenya)

The Turkana district is the largest in Kenya. It is also one of the poorest, with frequent droughts and famines, covering 70,720 km^2 of some of the most arid parts of the country. Turkana is located in the Rift Valley Province, and borders on Uganda to the west, Sudan to the northwest, and Ethiopia to the northeast. The district, whose administrative headquarters is at Lodwar, is made up of 17 administrative divisions, 58 locations and 158 sub-locations. The population density in this vast district is low, the total population being estimated at 450,860 (1999 National Census).

To support water supply development and management and assist local authorities with strategic planning in the district, the United Nations Children's Fund (UNICEF) launched a water and sanitation assessment and mapping project. The initiative (United Nations Children's Fund, 2006b) was designed to thoroughly record all water resources, visiting up to 644 water sources; assessing

488 rural water supply and sanitation (RWSS) service level points, and compiling related institutional information for 225 schools and 66 health facilities (education and health sector data has not been included in this analysis). Relevant data for each water source were obtained and entered into a Geographical Information System (GIS). Additionally, information related to RWSS service level was captured through a questionnaire administered at community scale. The waterpoint mapping generated sufficient information required to provide an insight into the essence of the variables that affect water poverty. In contrast, data collection methodology did not allow direct link between different survey instruments at a waterpoint, thus present analysis has been undertaken at sublocation level (lowest administrative scale). Moreover, and due to inaccessibility and insecurity in parts of the district, some waterpoints were not audited, which resulted in various sublocations being not covered (41, the percentage of population excluded of analysis roughly being 20%).

Data conditioning and selection of indicators

In the first stage, and with regard to data compilation, we exploited the database developed by UNICEF (2006b). A battery of indicators were proposed and sorted into five variables of the index. To each parameter, we assigned a score between 0 and 1, where a value of 0 was assigned to the poorest level, and 1 to optimum conditions. Continuous variables were normalized to have an identical range (0, 1), while rest of parameters were divided in four scale scores (0, 0.33, 0.66, and 1). Levels and scores of all parameters are presented in Table 17. A more detailed description of indicators is given elsewhere (Giné Garriga and Pérez Foguet, 2009).

Table 17 Variables used, levels and scores. Source: Giné Garriga and Pérez Foguet (2009)

WPI Component	Indicator	Levels & Scores			
		Fair (1)	*Acceptable (0.66)*	*Poor (0.33)*	*Risky (0)*
Resources	R1: Water Quantity Sufficiency [b]	Always sufficient	For human & livestock	Only for human	Not sufficient for human
	R2: Reliability of supply (% time not operational) [b]	< 5%	5-10%	10-25%	> 25%
	R3: Seasonal variability of water resources (months per year with water) [b]	11-12	9-10	7-8	< 7
Access	A1: Access to safe water [a]	% households with access to improved water supply			
	A2: Access to improved sanitation [a]	% households with access to improved sanitation			
	A3: One way distance to water source (km) [a]	< 1	1-2	2-5	> 5
	A4: Waiting time (minutes) [a]	< 30	30-60	60-120	> 120
	A5: Cost of water (KSh per 20 l container) [a]	< 1	< 2	< 5	> 5
	A6: Operational status of water source [b]	% water sources operational			

Capacity	C1: Management system [b]	% facilities managed at the local level			
	C2: Ownership over water source [b]	% facilities owned at the local level			
	C3: Water Association registered [b]	% facilities managed by associations legally registered			
	C4: Records kept [b]	% water entities which keep records (minutes, correspondences ...)			
	C5: Financial Control [b]	% water entities with financial control system in place			
	C6: Funds Audited [b]	% water entities whose funds are regularly audited			
Use	U1: Domestic water consumption rate (per capita) [a]	Ample (>40 lpd)	Basic (20-40 lpd)	Limited (10-20 lpd)	Scarce (<10 lpd)
	U2: Conflict over water sources (Human – Human) [b]	% facilities in conflict			
	U3: Conflict over water sources (Human – Livestock) [b]	% facilities in conflict			
	U4: Use of local water treatment (boil water) [b]	% households who treat water for drinking			
	U5: Livestock water use (m^3pd) [b]	< 50	50-100	100-200	> 200
Environment	E1: Qualitative assessment of water quality [a]	protected source	Open source but treated	Open source, local treatment	Open source, no treatment
	E2: Protection of water sources [b]	% water facilities protected (fenced)			
	E3: No. of pollution sources (P.S.) around WP [b]	None	1 P.S.	2 P.S.	> 2 P.S.
	E4: No. of environmental impacts (E.I.) around WP [b]	None	1 E.I.	2 E.I.	> 2 E.I.
	E5: Conflict over water sources (Human – Wildlife) [b]	% facilities in conflict			

Note: a = data from RWSS Service Level; and b = data from water sources audit form.

Next step was aimed at deciding if the set of proposed indicators was sufficient or appropriate to assess the five main components of the index. To this end, a principal components analysis (PCA) was performed to explore whether the variables were statistically well-balanced at both index and subindex level. Main goal of this analytical approach is to reduce a complex set of correlated variables into a set of fewer, uncorrelated components. On the issue of how factors should be retained in the analysis without losing too much information, this decision was based on the "variance explained criteria", i.e. to keep enough factors to account for 80% of the variation (Nardo et al., 2005). A Varimax orthogonal rotation was applied to each analysis, in order to maximize variance of factor loadings and thus enhance the interpretability of the results.

When applied at all battery of 25 indicators, this approach showed that 12 factors could explain 81.1% of the overall variability, and that most of them mixed indicators belonging to different subindices. In this case, PCA did not justify current WPI framework, although it neither offered a

better alternative. The adequacy of the original index structure was therefore confirmed in terms of transparency and relevance for the purpose of policy making. The analysis also proved that only two pair of indicators from different subindices presented correlation coefficients higher than 0.5 (but lower than 0.75), which confirms that there were no significant redundancies between them.

At subindex level, a PCA generated 2 components out of the 3 initial indicators for the Resource component (correlation between indicators R2 and R3), which accounted for 85.39 of the variance in the dataset; 4 components out of 6 for Access (85.3%; correlation between A1, A3 and A4); 3 components out of 6 for Capacity (81.0%; correlation between C3, C4, C5 and C6); 4 components out of 5 for Use (89.9%; correlation between U2 and U3); and 4 components out of 5 for Environment (89.5%; correlation between E3 and E4). In brief, from an initial set of 25 variables, they were reduced up to 17 non-correlated indicators.

Based on statistics obtained from previous analysis, all five components of the index were calculated; considering three different alternatives with regard to the contribution (weights) of indicators to each subindex. At this level, since variables can compensate each other's performance, we opted for an additive aggregation.

- Alternative 1 - No PCA. Subindices were determined as the straight average of all indicators. This alternative is used in the original WPI (Sullivan, 2002; Sullivan et al., 2003), and its main advantages are simplicity and transparency to non-technical audience.
- Alternative 2 - PCA. Subindices were described as the average of raw indicators that loaded most heavily on each principal component; i.e. variables that are most representative of each factor. However, and since some variables are more difficult to measure than others, in cases where two or more indicators loaded roughly the same, we selected the most easily available one. On the basis of this criterion, in the Resources component the variable "Seasonal variability of water resources" was preferred to "Supply reliability"; to assess the Access subindex, "% of people who access improved waterpoints" appeared to be more straightforward than "Distance to water source"; and in Capacity, "Legal registration of water entities" was included instead of "Funds audit". This alternative involves fewer indicators (17), and therefore compares favourably with other alternatives in data-scarce contexts.
- Alternative 3 - PCA. Factor loading scores were used to determine the weights. Principal component were weighted with the proportion of variance in the original set of variables explained by the first principal component of that particular component. The greater the proportion, the higher the weight.

The list of 25 selected indicators along with their weights is presented in Table 18. As might be expected, and though each alternative produce slightly different results, it can be seen that greater differences occur with Alternative 2 (with a reduced number of indicators in all five subindices).

Last step prior to the aggregation of the individual subindices was to examine correlation and redundancy within them. All three alternatives presented poor correlation among their components.

Table 18 Weights of indicators (at subindex level)

Indicator	Weights		
	Alternative 1	*Alternative 2*	*Alternative 3*
R1: Water Quantity Sufficiency	0.333	0.5	0.414
R2: Reliability of supply	0.333	0	0.295
R3: Seasonal variability of water resources	0.333	0.5	0.291
A1: Access to safe water	0.167	0.25	0.113
A2: Access to improved sanitation	0.167	0.25	0.220
A3: One way distance to water source	0.167	0	0.140
A4: Waiting time	0.167	0	0.123
A5: Cost of water	0.167	0.25	0.206
A6: Operational status of water source	0.167	0.25	0.199
C1: Management system	0.167	0.333	0.227
C2: Ownership over water source	0.167	0.333	0.213
C3: Water Association registered	0.167	0.333	0.139
C4: Records kept	0.167	0	0.121
C5: Financial Control	0.167	0	0.149
C6: Funds Audited	0.167	0	0.151
U1: Domestic water consumption rate	0.2	0.25	0.254
U2: Conflict over water sources (Human – Human)	0.2	0.25	0.155
U3: Conflict over water sources (Human – Livestock)	0.2	0	0.144
U4: Use of local water treatment (boil water)	0.2	0.25	0.223
U5: Livestock water use	0.2	0.25	0.224
E1: Water quality	0.2	0.25	0.249
E2: Protection of water sources	0.2	0.25	0.236
E3: No. of pollution sources around WP	0.2	0	0.095
E4: No. of environmental impacts around WP	0.2	0.25	0.173
E5: Conflict over water sources (Human – Wildlife)	0.2	0.25	0.248

Note: In bold, indicators included in the Sensitivity Analysis

Calculation of WPI

As discussed above, a major issue in the construction of composite indicators is the choice of the weighting and aggregation model. Since different methods imply different results and given the subjectivity inherent in many of these methods, no alternative employed in composite indexing is above criticism. Keeping this fact in mind, a number of combinations to create the WPI were considered, and each approach was judged based on following criteria (Singh et al., 2008; Sullivan et al., 2003; Swamee and Tyagi, 2007):

- The method should be free or minimize overestimation (ambiguity) and underestimation (eclipsing). Ambiguity problems arise when the aggregate index exceeds the critical level without any of the subindices exceeding the critical levels. In contrast, eclipsing problems exist when the composite does not exceed the critical level, despite one or more of the subindices exceeding the critical levels (Swamee and Tyagi, 2000).
- When competing methods produce similar results with respect to ambiguity and eclipsing, the most appropriate methodology is the one that retains the virtues of simplicity and straightforwardness (Sullivan et al., 2003).
- The approach should also be sensitive to the changes in an individual variable throughout its range.
- The method is successful if it is transparent and the index can be readily disaggregated into the separate components with no information lost.

Last step prior to the aggregation of the individual subindices was to examine correlation and redundancy within them. All three alternatives presented poor correlation among their components.

In brief, two different weighting systems were applied, and two aggregation forms were used to combine the five components of the index. It has been mentioned that the aggregation functions considered were the additive and the multiplicative form. The weights were calculated based on expert opinion and the statistical structure of the data set. In both cases, weights were constrained to be non-negative and sum to one. We first assumed same approach of the authors of original WPI as expert opinion (Lawrence et al., 2002; Sullivan et al., 2003); in which key components are no weighted. Second, we performed a multivariate analysis (PCA), and weights were built on the relative importance of the subindices for the principal components. A separate analysis was required depending on the alternative employed in subindex construction, and for the geometric aggregation, weights were computed from PCA of logarithm of the variables. The calculated weights are shown in Table 19, which confirms that results across different weighting techniques do not differ significantly. It can be seen that the "Use" and "Environment" variables do not completely meet the criterion of independency (lower weights in PCA) for the geometric form. Another overlap applies, to a lesser extent, for the components "Access" and "Capacity" in the additive function. "Resources" is the subindex which appears to be less correlated.

Table 19 Weights and weighting systems

Subindex	No Weights	PCA (Xi) Additive			PCA (Log Xi) Geometric		
		Alt 1	*Alt2*	*Alt 3*	*Alt 1*	*Alt 2*	*Alt 3*
Resources	0.2	0.253	0.251	0.255	0.223	0.221	0.225
Access	0.2	0.172	0.151	0.164	0.224	0.245	0.225
Capacity	0.2	0.187	0.182	0.186	0.218	0.216	0.215
Use	0.2	0.206	0.212	0.206	0.172	0.177	0.174
Environment	0.2	0.182	0.204	0.188	0.163	0.141	0.161

All different combinations to create the index are presented in Table 20. In terms of congruence nonetheless, a logical criterion should be to assume same method for selection of indicators and

assignment of weights; whether the alternative is "no weights" or multivariate techniques. We decided to screen out from the analysis six aggregation functions ($WPI_{1,W,A}$; $WPI_{1,W,G}$; $WPI_{2,NW,A}$; $WPI_{2,NW,G}$; $WPI_{3,NW,A}$ and $WPI_{3,NW,G}$) on the basis of this condition. The index was thus assessed at sublocation scale applying six remaining functions. Similarly, all sublocations were ranked according to the index value, where a rank of 1 denoted "lowest" priority (assigned to the sublocation with the highest WPI and thus being the least water poor) and a rank of n denotes highest priority.

Table 20 Methodologies applied to assess WPI

	Aggregation form	*Additive*		*Geometric*	
	Weighting System	*No weights*	*PCA*	*No weights*	*PCA*
Selection of Indicators	Alternative 1 (no PCA)	**$WPI_{1,NW,A}$**	$WPI_{1,W,A}$	**$WPI_{1,NW,G}$**	$WPI_{1,W,G}$
	Alternative 2 (PCA)	$WPI_{2,NW,A}$	**$WPI_{2,W,A}$**	$WPI_{2,NW,G}$	**$WPI_{2,w,G}$**
	Alternative 3 (PCA)	$WPI_{3,NW,A}$	**$WPI_{3,W,A}$**	$WPI_{3,NW,G}$	**$WPI_{3,w,G}$**

Note: In bold, methods included in the analysis

To enhance comparability of the functions, different histograms were developed to show the distribution of the resulting indices. From the graphs, it can be seen that regarding the method of variables selection at subindex level, Alternative 2 produce slightly higher results (Figure 21) since its histogram appears shifted to the left (higher values of WPI). This is basically because of the "Capacity" component, in which three indicators scoring considerably low were removed (C4, C5 and C6). As a clear example to show how the input information used when constructing the index might determine both the final value and the ranking, this particular option (Alternative 2) raises the "Capacity" subindex average from 0.342 (Alternative 1) or 0.411 (Alternative 3) up to 0.561; i.e. by 64% or 36.5%. Likewise, geometric forms score lower than additive functions (Figure 22), and this has been further discussed in next section.
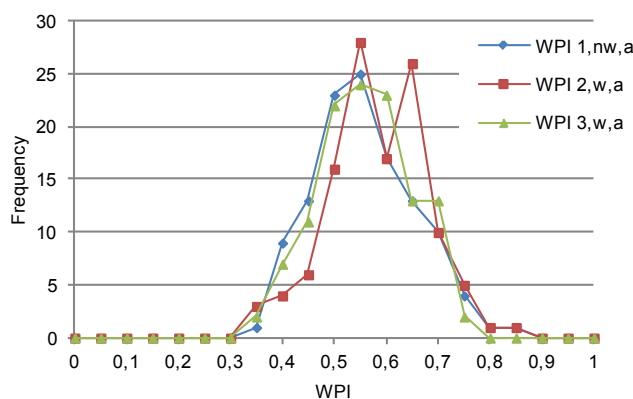

Figure 21 Comparison of the method of variables selection at subindex level
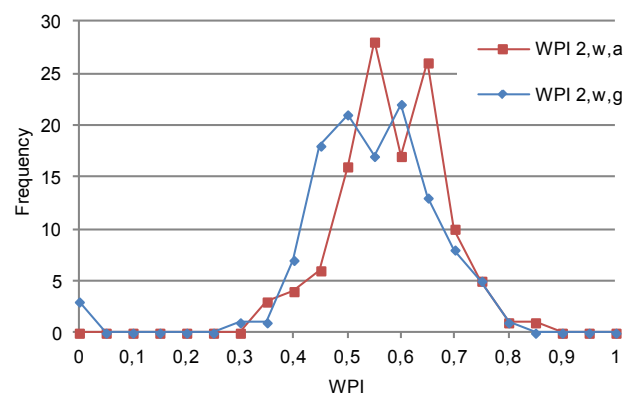
Figure 22 Comparison of the aggregation method of variables

Sensitivity analysis

Index construction involved three stages where subjective judgment was made; i.e. the selection of variables, the attribution of weights, and the choice of aggregation model. Since the quality of WPI significantly depends on the soundness of previous assumptions, sensitivity analyses can help gauge the robustness of the composite and improve its transparency. We thus analysed the sensitivity of the results for some sublocations (the highest, medium and the lowest-scoring ones). The results are shown in Table 21. Similarly, an additional sensitivity analysis of the six functions with respect to the changes in two of the most and least significant variables from Table 22 ("Water quantity" and "Human-Human conflict over water sources") was performed independently.

According to Table 21, it is confirmed that water poverty levels appear to increase (lower values of WPI) if a geometric function is applied, though this difference might be extremely inflated if only lowest positions are considered. In particular, the additive form raises the average WPI score from 0.492 to 0.535 for Alternative 1 (i.e. by 8.56%); from 0.515 to 0.557 for Alternative 2 (8.16%); and from 0.496 to 0.537 for Alternative 3 (8.28%). This is also depicted in Figure 23, in which the variation of $WPI_{2,W}$ values for the geometric aggregation with respect to the changes of its respective linear function is plotted. In this respect, and though both indices remain fairly well correlated, it has to be noted that all values are located below the x (additive) = y (geometric) line. A similar plot could be observed (not shown here) and analogous conclusions could be reached for the two remaining pair of indices ($WPI_{1,NW}$ and $WPI_{3,W}$). Another remark regarding the geometric aggregation is that some sublocations scored 0, as this method does not allow compensation in case null values in any variable.

Despite being meaningless in terms of water poverty, this result supports the fact that multiplicative forms more accurately identify the hot spots of the dataset.
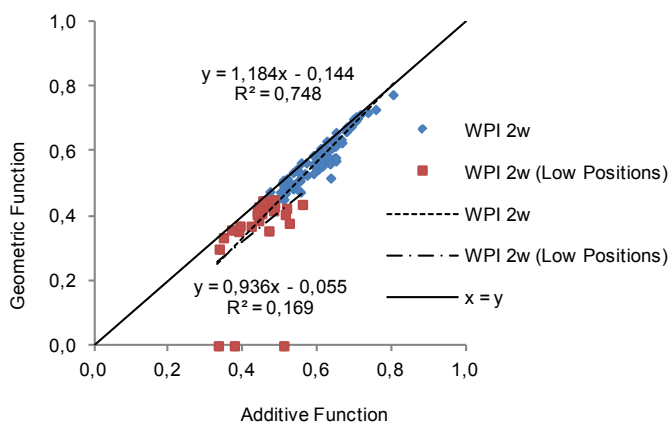
Figure 23 Geometric Function vs. Additive Function. Values of $WPI_{2,W}$
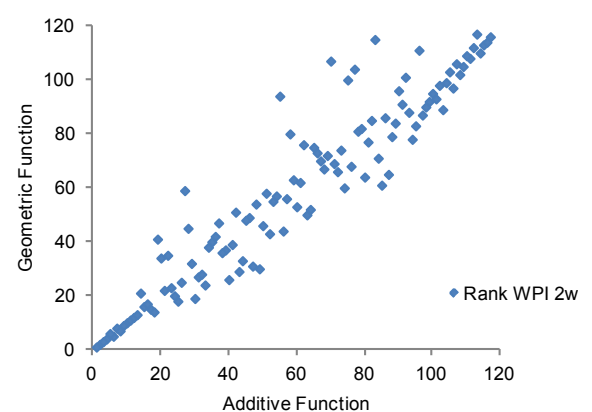
Figure 24 Geometric Function vs. Additive Function. Rank of $WPI_{2,W}$

The rankings are also affected, though no clear rule could be established (see also Figure 24). It is gleaned from Table 21 that at the top end nothing changes very much, apart from three sublocations which show a slight tendency to slip to a lower position. At the medium of the list, ranks vary significantly, and greater differences occur depending on the method employed to select the variables, being "Alternative 2" considerably more sensitive. It is also noted that significant gains in rank position (more than ten points) when a multiplicative aggregation form is employed

always occur at the bottom of the list and when the index is not penalized by any variable. At the very bottom of the list we mainly find the same sublocations, though as mentioned above, scores are much lower if a geometric function is used. As might be expected, the biggest changes in rank (loss of more than ten positions because of the aggregated function) are for locations which score less than 0.2 at least in one variable. Concluding, we highlight the fact that rankings are not always robust and thus aggregation methods are exposed to certain extent to different uncertainty sources. The structuring process, and in this case above all, the method used for the selection of indicators clearly determine the ranking.

Table 21 Sensitivity Analysis results for the choice of weights and aggregation function.

Sublocation	WPI$_{1,NW,A}$		WPI$_{2,W,A}$		WPI$_{3,W,A}$		WPI$_{1,NW,G}$		WPI$_{2,W,G}$		WPI$_{3,W,G}$	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Kapedo	0.807	1	0.756	2	0.697	4	0.803	1	0.728	2	0.683	5
Lokori	0.753	2	0.690	10	0.721	2	0.734	2	0.676	10	0.714	1
Lodwar Town	0.721	3	0.635	27	0.699	3	0.692	5	0.517	59	0.656	10
Lokichar	0.719	4	0.693	9	0.697	5	0.714	3	0.686	9	0.697	3
Kalomae	0.710	5	0.803	1	0.723	1	0.697	4	0.774	1	0.697	2
Lotubae	0.703	6	0.649	19	0.689	8	0.655	13	0.570	41	0.649	14
Lopiding	0.700	7	0.704	6	0.694	6	0.690	6	0.706	5	0.692	4
Nakwamekwi	0.698	8	0.715	4	0.692	7	0.678	8	0.713	4	0.674	6
Lorugum	0.685	9	0.639	25	0.653	15	0.680	7	0.634	18	0.654	12
Nachokui	0.528	62	0.527	69	0.513	69	0.495	58	0.492	72	0.482	63
Kanamkonyi	0.522	63	0.633	28	0.526	62	0.464	67	0.561	45	0.471	71
Nakurio	0.513	64	0.554	58	0.519	64	0.451	75	0.474	80	0.437	87
Kalapata	0.511	65	0.534	64	0.497	81	0.494	59	0.534	52	0.486	61
Katilia	0.511	66	0.512	80	0.498	79	0.484	60	0.505	64	0.483	62
Lomekui	0.506	67	0.649	20	0.527	61	0.454	71	0.580	34	0.475	69
Atalakamusio	0.505	68	0.481	93	0.484	86	0.442	80	0.450	88	0.437	86
Kalemungorok	0.504	69	0.530	68	0.507	72	0.483	62	0.499	67	0.488	60
Loruth/Esokon	0.385	111	0.347	115	0.353	115	0.364	104	0.333	113	0.345	110
Kochodin	0.384	112	0.421	110	0.389	110	0.375	103	0.369	109	0.384	105
Loremeit	0.382	113	0.333	117	0.354	114	0.306	113	0.000	116	0.297	115
Nakalalei	0.378	114	0.441	107	0.373	112	0.344	108	0.386	106	0.348	109
Loito	0.358	115	0.336	116	0.357	113	0.306	114	0.298	114	0.309	114
Kobwin	0.357	116	0.376	113	0.327	117	0.000	117	0.000	117	0.000	117
Nanam	0.325	117	0.369	114	0.337	116	0.304	115	0.357	110	0.319	113
Average	**0.535**		**0.557**		**0.537**		**0.492**		**0.515**		**0.496**	

Note: In bold, sublocations included in the second Sensitivity Analysis

For performing second sensitivity analysis, three sublocations were selected based on their rank position (top, medium, and low position). The indicator value of "water quantity" and "human-human conflicts" was varied from 0 to 1 in the original data set, and the WPI values using above six aggregation functions were computed. Table 7 shows the percentage variation of the WPI values over the minimum value for the indicator variation (X_i=0) for all the three sublocations. The coefficients of determination (R^2) of respective linear regressions are also presented to illustrate the linear behaviour of all aggregations with variations in the indicator value.

As in first analysis, it can be observed in Table 7 that functions $W_{2,W,A}$ and $W_{2,W,G}$ exhibit highest sensitivity in comparison to other aggregation functions, though all methods are to some extent sensitive to the indicator variation. At the top positions (Kalomae), no significant changes occur. However, positions at the medium (Nachokui) and bottom (Loito) of the rank appear to be more sensitive. We see a different pattern depending on the indicator, and this is due to the lower values of the "Use" subindex (regardless the alternative for selection of indicators), while the "Resources" component exhibits the highest scores. For example for the "water conflicts" variable (included in the "Use" component), geometric functions show biggest changes with respect to indicator variations. Furthermore, all six functions selected for the sensitivity analysis show a uniform and linear behaviour ($R^2 \approx 1$) with changes in the variable value for both selected indicators (Table 22).

Table 22 Sensitivity Analysis results for change in two variables value

Aggreg. Function	Water Quantity						H - H Water Conflicts					
	Kalomae		Nachokui		Loito		Kalomae		Nachokui		Loito	
	Δ (%)	R^2	Δ (%)	R^2	Δ (%)	R^2	Δ (%)	R^2	Δ (%)	R^2	Δ (%)	R^2
$WPI_{1,NW,A}$	10.36	1	13.54	1	19.61	1	5.97	1	8.15	1	11.59	1
$WPI_{2,W,A}$	18.53	1	27.34	1	41.68	1	7.07	1	11.10	1	16.67	1
$WPI_{3,W,A}$	17.18	1	23.28	1	32.32	1	4.62	1	6.61	1	9.22	1
$WPI_{1,NW,G}$	10.76	0.997	9.94	0.997	9.59	0.997	5.36	0.999	13.99	0.978	31.11	0.995
$WPI_{2,W,G}$	16.55	0.994	17.70	0.993	19.04	0.994	6.47	0.998	27.08	0.838	111.68	0.977
$WPI_{3,W,G}$	16.13	0.995	14.95	0.996	14.43	0.996	3.63	1	10.99	0.978	27.26	0.996

Discussion

The aim of previous analysis has been to test the applicability and validity of different methodologies to estimate the degree of water poverty at local scale. To exemplify the utilization of the WPI, an initial case study has been developed for the Turkana District. The most appropriate aggregation function is to be selected on the basis of the abovementioned criteria.

In this respect, the results show that no proposed method produce ambiguous results, in which final index would indicate areas suffering from high levels of water scarcity as non-water poor locations. In contrast, all aggregation functions suffer to a certain extent from the eclipsity problem. It is gleaned from the results nonetheless that linear aggregation functions are more eclipsed in comparison to multiplicative function. According to each ranking (for additive methods), 30 top positions include a not inconsiderable number of locations who suffer at least from one variable (X_i<0,3); i.e. 4 ($WPI_{1,NW,A}$); 1 ($WPI_{2,W,A}$); and 2 positions ($WPI_{3,W,A}$). If similar

analysis is undertaken for the multiplicative functions, the eclipsity produced is smaller; i.e. 1 ($WPI_{1,NW,G}$); 0 ($WPI_{2,W,G}$); and 1 position ($WPI_{3,W,G}$). It can also be seen that usage of less indicators (Alternative 2) shows far lower eclipsity as compared to two other alternatives, and this is acknowledged by Swamee and Tyagi (2000) who state that "with the increase in the number of variables, the eclipsing problem progressively worsens". With regard to the weighting techniques, one has to note that introduction of multivariate analysis does not change the results spectacularly. On the basis of this criterion, the weighted geometric mean method $WPI_{2,W,G}$ produces the least eclipsed results.

Similarly, it has been discussed earlier that an additive aggregation function should be applied only if indicators are mutually preferentially independent. It is unrealistic to assume that no synergies exist among the variables of the index. Furthermore, an undesirable feature of additive aggregations is the implied full compensability. As in the water poverty context different goals need to be considered simultaneously (all variables of the WPI are equally legitimate), non-compensatory aggregation procedures are recommended, and the use of a geometric function might be an in-between solution.

Based on the sensitivity analysis of six aggregation methods, it is inferred that $WPI_{2,W,G}$ exhibits highest sensitivity and a linear behaviour with variations in indicator values. In accordance with all specified criteria, it can thus be concluded that the weighted multiplicative function ($WPI_{2,W,G}$) is the most appropriate aggregation method for estimation of water poverty.

In following sections, we apply the method for index construction described above to develop two alternative indices. Each one assesses water problems from different perspectives.

2.4. The enhanced-Water Poverty Index

In this first example, a system approach has been adopted to develop a structured framework for a multi-dimensional evaluation of water poverty in basins. Specifically, it takes the WPI definition as a starting point, and integrates the concept of causality through the Pressure-State-Response (PSR) model, as an attempt to assess the diverse, interacting components of catchment's processes, societal pressures, and policy actions. Therefore, an enhanced Water Poverty Index (eWPI) is proposed as an alternative composite to original WPI.

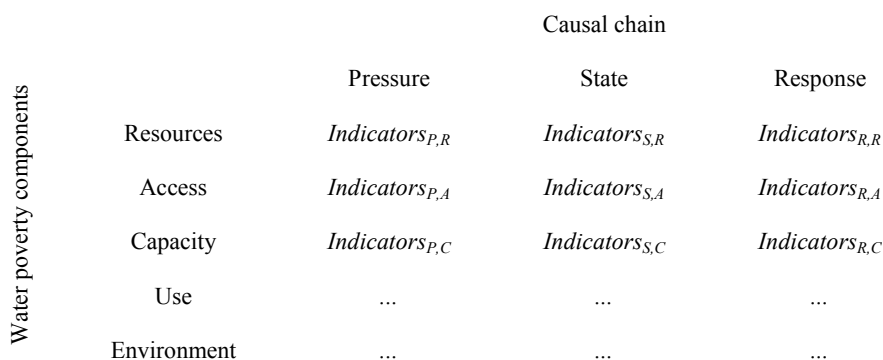|		Causal chain		
		Pressure	State	Response
	Resources	$Indicators_{P,R}$	$Indicators_{S,R}$	$Indicators_{R,R}$
	Access	$Indicators_{P,A}$	$Indicators_{S,A}$	$Indicators_{R,A}$
Water poverty components	Capacity	$Indicators_{P,C}$	$Indicators_{S,C}$	$Indicators_{R,C}$
	Use	...	...	...
	Environment	...	...	...

Figure 25 The eWPI framework

The conceptual framework of eWPI comprises two dimensions (see Figure 25), combining a classification in terms of subject (based on the components defined in the WPI structure) with a classification in terms of the position along a causal chain (integrating the PSR model). As previously mentioned, the WPI encompasses the issues of water availability, people's capacity to get and sustain access to water, to use this resource for different purposes, and the need to allocate water for environmental services (Sullivan et al., 2003).

The PSR model accommodates the causal inter-relations between the components of the WPI, and integrates the policy cycle of problem perception, policy formulation, monitoring and policy evaluation (OECD, 1993). It links social and economic developments that exert Pressure on the water resources, to State variables that provide an insight into the nature of water poverty, and to societal Responses, which feeds back on the pressures or on the state. Such a comprehensive frame for identifying sector-related indicators supports the analysis of the system. This conceptual model has been widely applied to environmental issues (EEA, 2002; Esty et al., 2005; OECD, 2003; UNEP, 2002), though in the water sector it has also been successfully implemented as an aid to watershed management (Chaves and Alipaz, 2007; Chung and Lee, 2009; Walmsley, 2002). The idea is that by placing indicators in the context of a causal chain, the cause-effect relationships and interconnections between the parameters become obvious. Within the PSR classification, indicators are split into three categories:

- First category includes pressure (P) variables that are exerted on the environment, particularly on the water resources. "Pressures" here mainly cover indirect pressures (i.e. human activities themselves and development trends and patterns of significance), but direct pressures (e.g. the existence of environmental conflicts) are also captured.
- State (S) variables evaluate the current status of the water resources, in terms of quality and quantity, as well as the existing capacities to suitably manage them. They depict the current situation (the state) concerning major issues affecting water poverty, and as such they reflect the ultimate objective of societal responses.
- Response (R) variables relate to the social response, in the form of national and local legislation, catchment management plans, sector monitoring, research etc. They refer to individual and collective actions intended to (i) mitigate, adapt to or prevent human-induced negative effects on water resources; (ii) reverse environmental damage already inflicted; and (iii) preserve and conserve water resources (OECD, 1993).

In the end, variables of pressure, state and societal response are defined for each of the five components of WPI. For instance, one could describe the "Resource" component with an indicator tracing the intensity of water withdrawal as a major "pressure" on freshwater resources, the "state" indicator might be defined as a quantitative assessment of water availability, and society's efforts to improve resource management could be evaluated as indicator of "response".

In terms of the method, index construction is based on the step-by-step procedure described above: i) selection of key variables for each sub-index (P, S and R states of five WPI components); ii) combination of these sub-indices to yield an overall index; and iii) visualisation of the index and its underlying components to support decision-making.

Case study: The Jequetepeque Basin (Peru)

In 2009, the Government of Peru launched a new National Water Policy (Law No. 29338). And one year later, the subsequent National Water Resource Regulation was developed to put policy in a functional framework and provide a regulatory regime for watershed management. Under this new legislation, the river basin becomes the territorial planning unit, and a series of institutional changes are introduced for implementation of the water regulations. However, a major constraint to be dealt with is related to the ability of newly created basin bodies to effectively fulfil their management commitment. They lack strategic oversight and appropriate resources, which seriously hampers their involvement as regulatory entities. Moreover, water resources rarely conform to political and administrative boundaries, where most socio-economic data is being collected. Therefore, among the problems that are impeding successful watershed institutional strengthening, there is the lack of consistent baseline data needed to avoid planning decisions based on false assumptions.
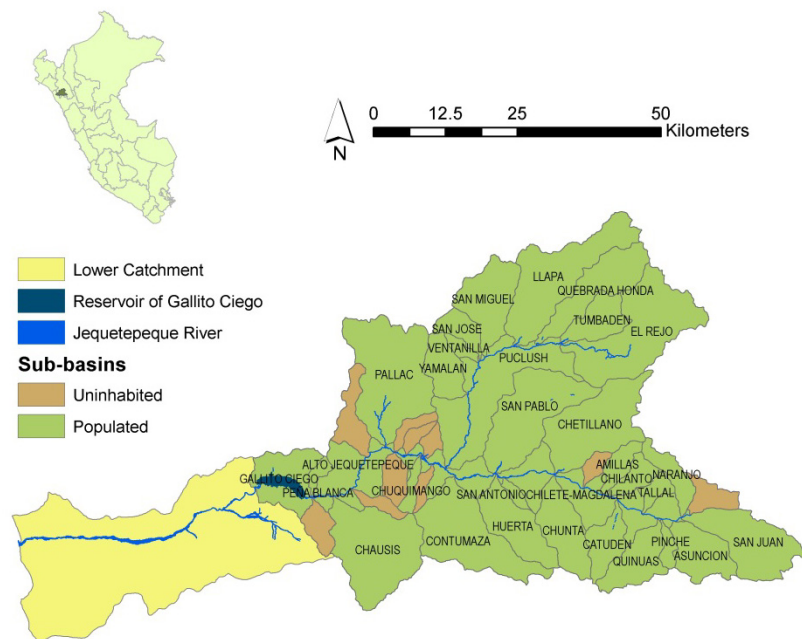
Figure 26 The Jequetepeque River Basin and its sub-basins

Against this background, a Peruvian watershed has been selected as initial case study to exemplify the development of the eWPI: the Jequetepeque basin. It is a 4,372.5 km^2 catchment located in the north part of the country that flows into the Pacific. The "Gallito Ciego" reservoir separates the upper-middle part from the lower part of the watershed. This study focuses on the upper-middle part, which is made up of 41 sub-basins, covering 3,564.8 km^2 (see Figure 26). However, as the index is aimed at identifying the water poor, 10 sub-basins have been screened out from the analysis as they are considered to be uninhabited. In the end, a single number will represent the water poverty situation at each remaining 31 sub-catchments. This value might be used as a performance indicator to identify water-related strengths and weaknesses for that location, as well as to discriminate between different locations (Sullivan and Meigh, 2007).

Selection of variables

The first step in index construction involves the selection of relevant variables and their classification within the eWPI framework. The index identifies five main components and three different states, thus 15 sub-indices. Each component, in turn, encompasses a set of indicators (13 indicators). Each indicator builds on related pressure, state and response data sets for a total of 43 variables. However, to rely on a fixed set of variables appears to be inappropriate, as every context is unique, and specific data may be neither pertinent nor available for all cases. In addition, in low-income settings, an ad hoc choice of variables driven by data availability might provide a cost-effective solution. On the basis of this criterion, site-specific indicators and variables have been defined from existing information sources, avoiding further data collection efforts. Multiple types of data have been obtained through consultation with a variety of stakeholders, including among others literature review (national documents, sector papers, progress reports and unpublished documents), population census, health surveys, environmental data, and catchment's plans. It is important, though, to note that the need to compile harmonised data at sub-basin level for all 31 catchments has also generated many other indicators (not shown here) which have been identified but not included in the analysis, since they fed on information that either was (i) heterogeneous throughout the area of intervention, (ii) not available for some watersheds, or (iii) presented at regional or basin scale (therefore being useless for purposes of current study). Field work for data collection has been carried out in two different periods: July – September 2008, and July – August 2009.

To each selected variable a score between 0 and 1 is assigned, where lower scores indicates higher pressures, a more extreme case of water poverty or poorer societal responses. Table 23 shows in summary the eWPI selected indicators within all five components of the index (R, A, C, U, E). The indicators are disaggregated into three states, comprising all Pressure, State and Response (P, S, R) variables. The set of variables included is presented separately and briefly discussed below.

Resources. The Resources component measures availability of water. It combines two separate indicators: first is related to water quantity, and the second to resource management.

In the case of water quantity, the increase in population places new demands on water resources, and it has been taken as the pressure parameter (United Nations, 2001b; Walmsley, 2002). The state variable averages the basin aridity index and the per capita water availability. The natural supply of water in a catchment is provided by the precipitation on that catchment. However, the quantity of water available depends on climatic conditions, so a basin aridity index is calculated to reflect the perceived water scarcity. As the demand required by all water use sectors is largely unknown, an accurate balance to assess resource availability cannot be performed. Instead, the parameter considered is the per capita water availability per year, based on the mean annual rainfall. This value is compared to the Falkenmark indicator, in which water stress occurs when water availability falls below 1,700 m3/person year (Falkenmark and Widstrand, 1992).

Table 23 eWPI components, indicators and variables used at watershed level

Indicators	Variable - Pressure	Variable - State	Variable – Response
Resources			
Water availability	Population growth rate	Per capita water availability	
		Aridity Index	
IWRM	Annual variation in the HDI-Education	*Institutional framework in IWRM*	Adequacy of programmes to support IWRM
Access			
Access to safe water	Annual variation in safe water accessibility	Access to safe water	Improvement in water supply infrastructure
		Continuity of service	
		Operational status of water supply	
Access to sanitation	Annual variation in improved sanitation accessibility	*Access to improved sanitation*	*Improvement in sanitation facilities*
Equity in access	*Population living in non-durable dwellings*	*Inequality index in terms of access to water and sanitation*	
Capacity			
Human Development	Annual variation in the HDI	HDI	Educational level of household head
Institutional Capacity	% water supplies managed by water committees	% of water committees with qualified staff	*% technicians in relation to the labour force*
Gender Issues	*Annual variation in the women HDI-Education*	*Equally distributed index, in relation to educational level*	
Use			
Hygiene promotion	% households with point-of-use water treatment	Prevalence of water-related diseases	
Agricultural water use	% irrigated land with proper technological approach	Agricultural water use (ratio of irrigated land to total cultivated land)	Improvement in agricultural water-use efficiency
Environment			
Environmental Preservation	Arable land as a percent of potential arable land	% of area with natural vegetation	*Adequacy of the environmental institutional framework*
	Grazing land as a percent of potential grazing land	*% of area under protected status*	% of prioritized protected area
	Soil erosion		
	Reports of environmental conflicts		
Drinking Water Quality	*% water systems correctly treated*	% water systems with faecal contamination	% water systems regularly treated
Agricultural Water Quality		*Agricultural water quality*	*Surface water quality surveillance*

Note: In italics, variables removed based on correlation criterion (multivariate analysis)

The second indicator measures the institutional strength in integrated water resources management (IWRM). The pressure parameter is the variation in the educational level in the period studied, since it has been observed that high values of this variable would correlate with people's ability to

participate in and improve the watershed management (Chaves and Alipaz, 2007). The state variable focuses on the institutional framework in IWRM. It particularly assesses the suitability of the Catchment Management Plan. The Response parameter is evaluated by the existence of sector-related initiatives that support IWRM. Both state and response parameters are qualitative, and they might vary from watersheds with no institutions or water sector-related planning (lowest scores) to locations where specific basin authorities are provided with adequate resources to tackle existing water problems (best scores).

Access. The Access component takes into account whether or not people have access to safe water and improved sanitation, as it is defined in the Global Assessment Report (Joint Monitoring Programme, 2000). The pressure parameter compares the water and sanitation coverage in the period analysed. Negative values would indicate that access to these basic services has worsened. In the state parameter, besides percentage of population accessing an improved drinking water source and a latrine, two additional variables have been measured: continuity of the water service and operational status of the supply. The Response variable is estimated by adequacy of foreseen investments to improve water and sanitation infrastructure.

Even if water coverage is high, this alone does not ensure that access to the supply is equitable. Equity in service provision is thus assessed to guarantee that the poor are not priced out of the opportunity to access to basic services. This variable is calculated as the quotient of non-durable dwellings that have access to drinking water and sanitation (in percentage) by improved housings that have access to these services (in percentage). It thus ranges from complete inequality (0, non-durable housings do not access water and sanitation) to equity in access (1).

Capacity. The Capacity component comprises a set of socio-economic indicators which can impact on people's ability to supply and manage water and sanitation services. It includes measures of human development, adequacy of sector-related institutional framework, and gender issues.

The first indicator is related to human welfare and quality of life, and this is captured through the basin Human Development Index. It is a simple and available variable, which facilitates its use. The parameter selected for the response is the educational level of the household head, as a proxy measure of well-being at the family level.

The second indicator gauges the capacity of water sector-related institutions. The legal framework in Peru (embodied in the National Housing and Water Plan 2006-2015) bestows the responsibility of rural water and sanitation service provision to local water committees, who are committed to meet all maintenance costs of water supply facilities. Therefore, local management of schemes compares favourably with other centralised types of system management, and this has been considered as the pressure parameter. The state variable is related to ability of these local entities to oversee operation and management of the supply. As a response, the parameter is assumed to be the proportion of technicians to the labour force, which gives an indication of the basin technological capabilities as a requirement to address development issues.

Another crosscutting issue to be included within the "Capacity" structure is the gender perspective (Mlote et al., 2002). It is acknowledged that female education contributes as an important factor to livelihood improvement and socio-economic development (Esty et al., 2005; United Nations, 2001b). This parameter has been estimated by an equally distributed index in relation to the

educational level, as the harmonic mean of the male and female education indices. It rewards gender equity and penalizes gender inequality.

Use. Water is used in a variety of both productive and consumptive activities. In Peru as in many developing countries, agriculture and livestock are main sources of livelihood for the majority of rural people, being the former the major user of fresh water resources. Therefore, this component tries to take into account that water availability for growing food is as important as for domestic and human consumption. It should be thus computed as the average of (i) domestic water use, taking 20 litres per capita per day as a minimum target for developing countries (Howard and Bartram, 2003; Joint Monitoring Programme, 2000), and (ii) share of water use by productive sectors. Specifically at Jequetepeque basin, core economic activities include mining industry (in the upper part of the catchment) and extensive agriculture.

Reliable data to assess water consumption at the household was not easily obtained. Instead, prevalence of water-related diseases has been evaluated as a state proxy of inadequate water use and poor hygienic practices (Cairncross and Feachem, 1993). Along the same line, and though there is considerable debate about the impact of point-of-use water treatment on health (Schmidt and Cairncross, 2009), this variable has been employed to assess domestic hygiene.

In the case of water for irrigation, the pressure parameter aims to show the potential environmental impact from agricultural activities. The changes that enable increased food production include, among others, technological innovations intended to correct problems such as declining soil fertility, low water productivity, environmental degradation (Cook et al., 2009). The technological approach employed in agriculture has thus been evaluated as the pressure parameter. The state variable of agricultural water use is estimated by the proportion of irrigated land to total cultivated land. On a sustained basis, water-use efficiency has been qualitatively evaluated as a response parameter.

Finally, water use in mining industry is largely unknown. Since accessed information sources were not reliable, this variable has been discarded from analysis.

Environment. This component tries to capture a number of environmental indicators which not only cover water quality and 'stress', but also indicators that are likely to impact on ecological integrity.

Major water quality problems stem from environmental degradation (poor land use practices including intensive agriculture and overgrazing, soil erosion ...), and this has been considered as the pressure parameter. The state variable averages the percentage of basin land area dedicated to protected areas and under natural vegetation, as a key aspect for biodiversity conservation (Chaves and Alipaz, 2007; Esty et al., 2005). The response variable analyses implementation of sector-related policies to protect the environment as well as the envisaged basin sector expenditures. Specifically, it calculates percent of prioritized protected areas as a percent of total basin area. All these variables should reflect the capacity of institutions in tackling environmental problems.

In case of surface water pollution, this certainly threatens availability of water resources. Since there was no quantitative data to assess water quality, it is estimated by a qualitative analysis. Against this current lack of data, surface water quality monitoring has been included as a response

parameter. In contrast, the Regional Health Authority is implementing a water quality surveillance programme for drinking water supplies. As microbiological quality is the principal health concern (Howard, 2002), it has been selected as the state quality parameter, in the form of thermotolerant coliforms. Routine monitoring and treatment efficiency (presence of free chlorine residual) are also taken into account to evaluate adequacy of the surveillance.

Multivariate Analysis. As mentioned in previous section, the nature of the variables needs to be evaluated before their final selection (Nardo et al., 2005), and multivariate statistical techniques are employed to explore whether selected variables are statistically well-balanced. A Principal Component Analysis (PCA) is performed at each sub-index with the objective of determining the number of correlated variables underlying the data. From Table 23 and Table 24, it can be seen that that this approach generates 28 principal components, thus removing 15 variables from eWPI final calculation. The percentages of the variance in the dataset that principal components accounted for are presented in Table 24.

Table 24 PCA: Principal components, removed variables and total variance at sub-index level

Variables	Pressure	State	Response
Resources	2 out of 2 (100%)	2 out of 3 (1 variable discarded, 81.53%)	1 out of 1 (100%)
Access	2 out of 3 (1 variable discarded, 88.25%)	3 out of 6 (3 variables discarded, 75.67%)	1 out of 2 (1 variable discarded, 96.88%)
Capacity	2 out of 3 (1 variable discarded, 88.0%)	2 out of 3 (1 variable discarded, 96.75%)	1 out of 2 (1 variable discarded, 96.51%)
Use	2 out of 2 (100%)	2 out of 2 (100%)	1 out of 1 (100%)
Environment	3 out of 5 (2 variables discarded, 85.7%)	2 out of 4 (2 variables discarded, 71.4%)	2 out of 4 (2 variables discarded, 71.53%)

Note: In brackets, number of removed variables and the total variance explained by principal components

The sub-indices are described as the average of raw variables that load most heavily on each extracted component.

Calculation of eWPI at basin scale

After deciding the number of factors to keep and calculating all 15 sub-indices (V_{ij}, $i = R, A, C, U, E$; $j = P, S, R$), the combination of the three states (V_{ij}) for each index component (X_i, $i = R, A, C, U, E$) is the next step. At this level, since states can compensate each other's performance, an additive aggregation is employed. Furthermore, all states are considered having the same importance, i.e. no weighting is introduced (Equation 2).

$$X_i = \frac{1}{3} \sum_{j=P,S,R} V_{ij} \qquad (2)$$

Next step is the aggregation of components. A weighted multiplicative function is employed, and the weighting system is assigned through multivariate techniques (Giné Garriga and Pérez Foguet, 2010). Numerically, it can be formulated as:

$$eWPI = \prod_{i=R,A,C,U,E} X_i^{w_i} \qquad (3)$$

where *eWPI* is the value of the index, X_i refers to component *i* of the eWPI structure, and w_i is the weight applied to that component.

Much like the composite, and with the aim of enhancing data analysis, overall states (*eWPI$_j$*, *j = P, S, R*) could be calculated individually by applying Equation 4.

$$eWPI_j = \prod_{i=R,A,C,U,E} V_{ij}^{w_i} \qquad (4)$$

Discussion

To start with, a map is presented in Figure 27 to illustrate the level of water poverty at sub-basin scale, based on the index values. It is gleaned from the map that at the Jequetepeque basin water poverty follows a heterogeneous spatial pattern, although index values for the majority of sub-basins range from 0.45 to 0.55. Two watersheds where eWPI reveals highest levels of water poverty appear to be most in need relative to the others (Chuquimango and Chunta). When we dig deeper, it can be seen that all five catchments ranking in the lowest positions (eWPI < 0.45) are for those locations which score less than 0.3 at least in one variable. It is noted in this regard that the geometric function employed in index construction does not allow compensability among the different variables of the index. At the top end, Chetillano and Quebrada Honda basins appear as the least water poor (eWPI > 0.55). As might be expected, top five watersheds are not penalized by any index variable, and at least two of them score higher than 0.6.

Much like the WPI, eWPI appeals to policy-makers since it simplifies a complex reality when adequately presented and disseminated. Yet, it is worthwhile to examine in more detail what this composite can and cannot reveal.

In case index values are used as performance indicators, this approach demonstrates its soundness to discriminate among basins, and allows comparisons to be made by identifying their strengths and weaknesses. However, the distinction between different water poverty indicators might be of primary importance since policy and sector strategies depend on the facets of water scarcity being addressed. For example, to improve water coverage and to strengthen sector-related institutional framework, two sets of interventions would be required. Consequently, eWPI's components might be also evaluated individually, as thematic indicators rather than a composite. By showing the values of all five components in a visually clear way, it directs attention to those water sector needs that require urgent policy attention. Similarly, separate analysis for the Pressure, State, and Response states help cause-effect relationships not be lost.
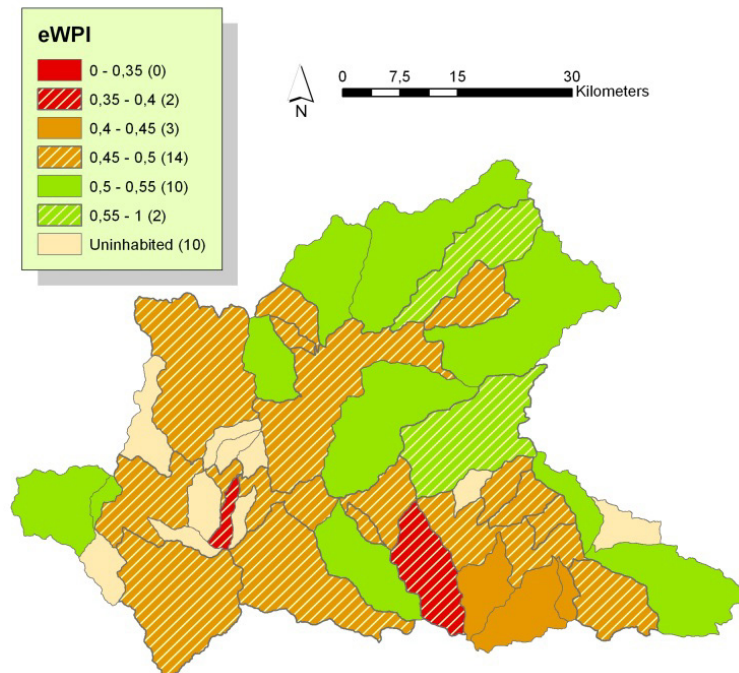
Figure 27 The eWPI values at sub-basin level. In brackets, number of sub-basins

Table 25 eWPI component scores

	eWPI	Resources	Access	Capacity	Use	Environ.	Pressure	State	Response
Mean	0,485	0,547	0,576	0,437	0,439	0,480	0,569	0,487	0,183
Minimum	0,355	0,248	0,430	0,304	0,167	0,289	0,389	0,000	0,000
Maximum	0,567	0,804	0,751	0,600	0,579	0,695	0,703	0,645	0,444
Std. Dev.	0,047	0,122	0,078	0,059	0,096	0,108	0,081	0,106	0,173

To begin, and in accordance with maps from Figure 28 and Table 25, aspects demanding attention by water managers are those related to the "Capacity" and "Use" components. These two components present an average value of 0.437 and 0.439 respectively, while three remaining components score slightly higher; i.e. Environment (0.480), Resources (0.547), and Access (0.576). When the analysis focuses on the states (Figure 29), the "societal response" map appears critically low (0.183). This indicates that not only the present basin conditions are far from being adequate (State: 0.487), but a worsening trend is foreseen in the near future. It is noted however that "response" variables are mainly qualitative and to some extent imprecise, which highlights that one composite will only be reliable when underlying data are accurate. The PSR model is dependent on a large number of variables and extensive amount of data – cited as a core drawback insofar as continued engagement with relevant stakeholders is not promoted to access additional and more accurate information sources.
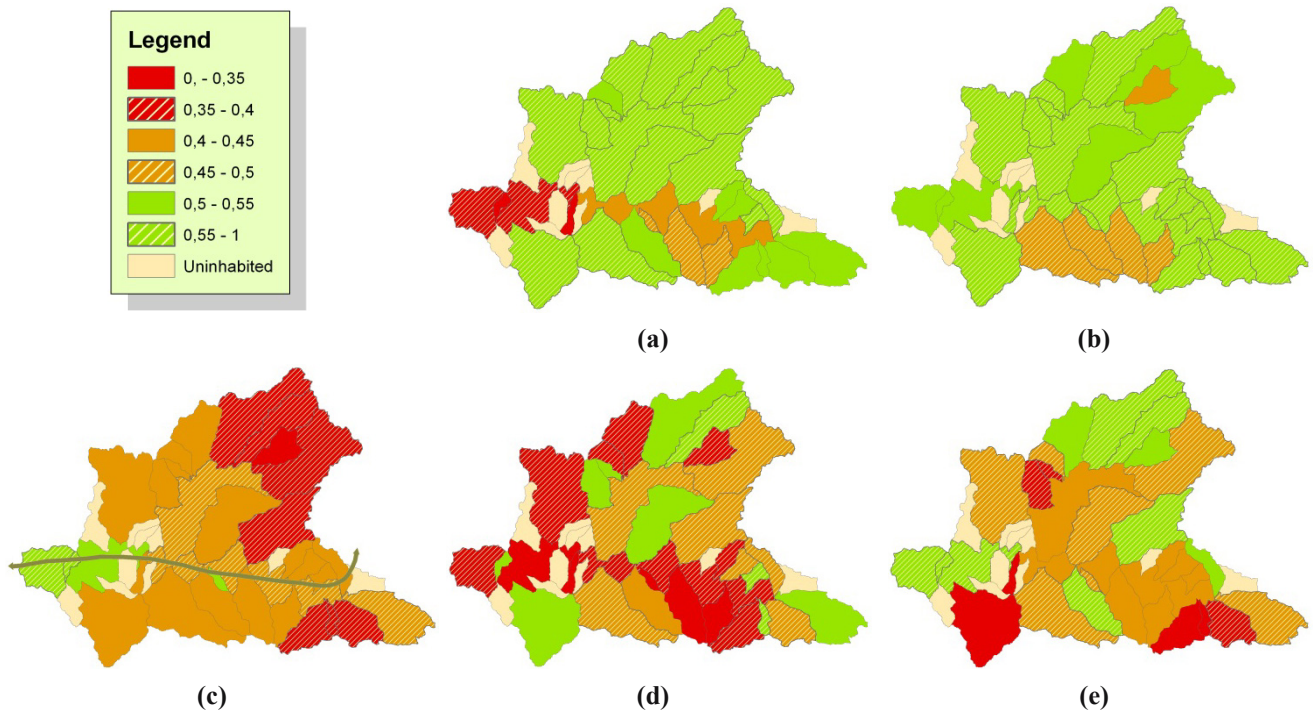
Figure 28 eWPI components. a) Resources; b) Access; c) Capacity; d) Use; e) Environment
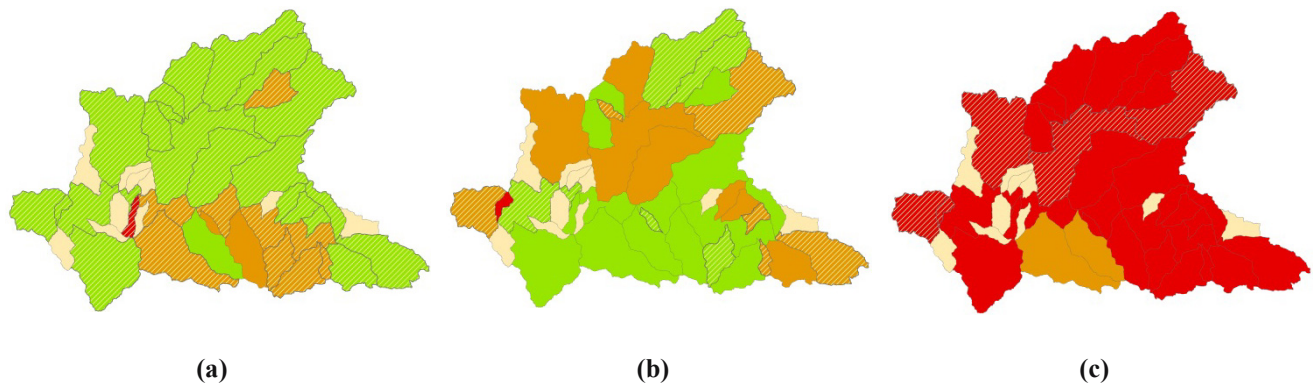
Figure 29 The eWPI states. (a) Pressure; (b) State; (c) Response

A closer analysis of the data shows in the "Resources" map (Figure 28a) that higher values occur at the upper sub-basins of the catchment, where water availability is abundant. In contrast, even though there is legal framework available to support IWRM, basin institutional capacity remains inadequate. From the "Access" map (Figure 28b), and contrary to what might be expected, it is observed that access to improved waterpoints and adequate sanitation is relatively high, and that service coverage is fairly homogeneous throughout the watershed (standard deviation of 0.056 for the State parameter). According to the "Capacity" map (Figure 28c) one might conclude that institutional framework to support communities to manage water facilities is far from being adequate. In fact, although by and large water entities are legally registered, they are not able to assume their management commitment as qualified staff is rarely available. The average basin HDI is 0.55 and is thus classified as intermediate human development. It is also observed that this variable slightly improves in those catchments that are located along the main route which

connects the coast with the city of Cajamarca, as depicted in the map. In much the same way as with "capacity", water use is generally poor, and this is visualized in the "Use" map (Figure 28d). Although the present conditions score fairly well (State: 0.618), there are pressures (0.327) which threaten efficient use of water, specifically in agriculture. Further, institutional responses to mitigate them are not yet in place (0.371). It is also noted that a reduced number of indicators have been used to define this variable, thus not only a deeper analysis might be needed, but also improved access to additional data sources, in order to complete a more precise picture of the situation. Finally, it is gleaned from the "Environment" map (Figure 28e) that environmental impact of water use seems to be quite severe. As a result, 72% of improved drinking water supplies suffer from bacteriological contamination. To reverse this situation, water quality surveillance needs to improve, both in terms of effectiveness and periodicity.

If the focus is on causal relations, Figure 29a shows that pressures exerted on the catchment are not high (0.569, lower values being assigned to stronger pressures). The reality, though, is that mining industry and extensive agriculture noticeably impact on the environment. These activity-environment interactions are however seldom documented, and more accurate data would be required to adequately assess these pressures and their impacts. From the maps it is also observed that "societal responses" (Figure 29c) are major concerns. As previously mentioned, the water-related regulatory regime is experiencing significant improvements. And particularly the Jequetepeque basin has been prioritized as one of the pilot basins in the country to test the recently developed National Water Resource Regulation, since sub-basins located downstream (the Jequetepeque Valley) are one strategic agricultural area in Peru. Consequently, improved institutional responses are envisaged in the near future.

2.5. The WASH Poverty Index

The second example aims to capture the complexity inherent in rural poverty and understand to what extent water, sanitation and hygiene are central to poverty alleviation. As discussed in a previous chapter, the different individual fields of the WaSH sector can each be measured by a single indicator, as the JMP. But an assessment of the overall context requires integrating all these individual fields. To this end, an inter-disciplinary and WaSH-focused approach is adopted herein through a multidimensional estimate, the WASH Poverty Index (WASH PI). Its theoretical foundations build on a combination of three composites that are not aggregated to produce a single value. Rather, index components are presented individually as parts of a thematic indicator. The rationale for this is to keep the water, sanitation and hygiene idiosyncrasies in focus, as in practice institutional roles and responsibilities of WaSH issues in many developing countries are assumed by different stakeholders. Likewise, it might not be practical to merge water supply with sanitation and hygiene promotion from an operational point of view, since the latter often suffer from the budgetary dominance of water and to be effective demands a gradual implementation (Cairncross et al., 2010a). Any aggregation process would thus reduce the validity of the measure for decision-making purposes. A brief description of each composite follows:

- The water-related index is founded on the Water Poverty Index (WPI) framework from Sullivan (2002) and Sullivan *et al.* (2003), and tackles the priority water-related challenges in low-income settings: availability of water (Resources, R_{WPI}), access to water (Access, A_{WPI}), capacity for sustaining access (Capacity, C_{WPI}), ways in which water is used for different purposes (Use, U_{WPI}), and the environmental factors impacting on the ecology which water

sustains (Environment, E_{WPI}). Environment-related aspects, though, are partially assessed by indicators included in the sanitation and hygiene indices; hence, this component has been removed from the WPI structure to avoid the inclusion of redundant information.

- The Sanitation Poverty Index (SPI) aims to assess whether or not people use basic sanitation, and not the mere existence of infrastructure. Ideally, a toilet should be hygienic and private; accessible within, or in the immediate vicinity, of each household; available at a price that everyone could afford it; and of a culturally acceptable quality (United Nations General Assembly, 2009). Therefore, SPI not only gauges the extent of access to sanitation, both in terms of accessibility and affordability (Access, A_{SPI}), but assesses people's ability to construct and repair the latrine (Capacity, C_{SPI}), and includes those hygienic factors that enable a continued usage of the facility (Use, U_{SPI}).

- The Hygiene Poverty Index (HPI) is measured by the aggregation of four different components (Webb et al., 2006). Each component represents a different transmission route by which oral–faecal contamination may occur: drinking-water (DW_{HPI}), food (F_{HPI}), personal hygiene (PH_{HPI}); and domestic household hygiene (DH_{HPI})

Case study: The Government of Kenya and UNICEF water supply and sanitation programme

In Kenya, the Government identified through a consultative process with primary stakeholders the vulnerable populations living in rural areas, where access to safe drinking water and sanitation is particularly acute (United Nations Children's Fund and Government of Kenya, 2006). In these settings, the situation in relation to WaSH is assessed through a cluster sampling household-survey, conducted during 2010 (from January to March). This study focuses on these populations (see Table 10 and Figure 6, Chapter 2) and exploits the baseline data.

In brief, the survey shows that only 43.5% of households get their drinking water from an improved source. Besides coverage data, it is seen that a large percentage of people (45.4%) spend more than half an hour per round trip to collect water. Since distance shows a negative association with water consumption, it is not rare to observe that almost two thirds of households (62%) do not meet their minimum daily drinking-water needs (less than 20 litres per capita per day, based on WHO standards). Another remark with regard to water collection is related to gender disparities, since by and large it is women (87%) who go to the source to haul water for domestic purposes. In terms of sanitation coverage, data show an alarming situation, averaging only 21.6% for the whole survey. Among those who do not use an improved facility, latrine sharing is a common practice (33.7%), although the majority of households (41%) opt to defecate in the open. As regards personal and domestic hygiene, the survey reveals that household water treatment is to certain extent common throughout the area of intervention, since almost half of households (47.1%) adequately treat water before consumption. Another hygiene behaviour which is of greatest likely benefit to health relates to safe disposal of the stools of children under age three; and on average 58.1% of children's faeces are disposed of hygienically. Finally, it is noted that almost everyone washes their hands, although both the method employed and handwashing frequency is inadequate.

Despite the importance of previous estimates to inform policy development, they prove insufficient to produce an overall picture of the sector. The WASH PI approach is more adequate to assess in an integrated way the links between poverty and the delivery of WaSH services. Specifically, the composite identifies deprivations in water, sanitation and hygiene issues at the household level, as this is the scale where poverty is better understood. The following sections

provide a detailed account of the method employed for index construction. Achieved results are then presented, and the utility of the tool for the analysis of WaSH and poverty linkages is promoted.

Data collection

As mentioned above, the survey is household-based, and therefore the sample is drawn from the population residing in households in the area of intervention. In all, 5050 households were surveyed to allow for separate estimates for each of the targeted districts. The sample design is coherent with methodological principles implemented in similar surveys (Bennett et al., 1991; United Nations Children's Fund, 2006a), and specifically it is based on the Kenya National Bureau of Statistics (KNBS) fourth National Sample Survey and Evaluation Program (NASSEP IV). In every visited household, service level is captured through a structured questionnaire administered to primary care-givers and direct observation.

Calculation of WASH PI at household level

The household survey produces a comprehensive and accurate baseline data, in which base the definition of indicators given their relevance to the index framework. In terms of technique, index construction relies on a methodology described above for the estimation of WPI (Giné Garriga and Pérez Foguet, 2010), which has been adapted to the WASH PI structure.

The first step involves a revision of survey data and selection of appropriate indicators, which are then classified according to each sub-index framework (Table 26). The data are represented on different scales (e.g., percentage of households reporting "yes", distance to source in meters, water consumption in litres per capita, and so forth), and they have therefore to be normalized prior to their analysis. To each parameter, a score between 0 and 1 is assigned when transforming categorical variables into ordinal response scales, where 1 represents best performance.

Next step seeks to validate each sub-index and decide whether selected indicators are appropriate in terms of redundancy and comprehensiveness. For this purpose, statistical assessment of the dataset (Principal Component Analysis, PCA) is performed at the component level. PCA proves to be helpful in determining the number of latent variables underlying the data, and reduces the initial set of 36 indicators into a smaller group of 28 "uncorrelated" components (see in Table 26 all correlated indicators removed from analysis). Based on statistics obtained from the analysis, WPI, SPI and HPI components (i.e., R_{WPI}, A_{WPI}, C_{WPI}, U_{WPI}; A_{SPI}, C_{SPI}, U_{SPI}; and DW_{HPI}, F_{HPI}, PH_{HPI}, DH_{HPI} respectively) are then calculated as the average of raw indicators that load most heavily on each principal component.

Table 26 The WPI, SPI and HPI structure: components, indicators and statistical weights (PCA)

WPI / SPI / HPI component	Indicator	Weight
WPI - Resources (4, *1*)	Availability of water for domestic purposes; % of households using their main drinking-water source all year-round –*households reporting* seasonality issues or *low yield*-; and water quality (user perception)	0,303
WPI - Access (6, *2*)	% of households with access to improved waterpoints; *% of households reporting functionality issues of the waterpoint*; time spent in fetching water; *time spent in queuing at the source*; % of water carried by woman or by children under 15; and payment for water (user satisfaction)	0,214
WPI - Capacity (4, *1*)	% of households involved in waterpoint management; management of the waterpoint (user perception); *% of households paying for water*; and % of households contributing to the maintenance of the waterpoint	0,180
WPI - Use (3, *1*)	Domestic water consumption rate; % of households using main drinking-water source for other domestic purposes; *% of households using main drinking-water source for other non-domestic uses*	0,303
SPI - Access (2, *0*)	% of households with no latrine because of a lack of economic resources (affordability issues); % of households accessing a toilet facility located in the same compound	0,326
SPI - Capacity (3, *1*)	% of households with no latrine because of a lack of capacities to construct; % of households accessing adequate skills for repairing the latrine; *% of households accessing adequate materials for repairing the latrine*	0,397
SPI - Use (2, *0*)	% of households using improved sanitation facilities; latrine sanitary conditions	0,277
HPI - Drinking water (2, *0*)	% of households correctly handling and storing drinking water; % of households with an adequate point-of-use water treatment	0,317
HPI – Food (2, *0*)	% of households with a drying rack for plates and cups; % of caregivers who wash their hands at critical moments	0,160
HPI - Personal Hygiene (5, *1*)	% of caregivers correctly handling baby excreta; % of households with an adequate hand-washing device around the latrine; % of households whose members participated in hygiene promotion campaigns; % of caregivers with adequate hand washing behaviour; *% of caregivers with adequate health knowledge*	0,221
HPI - Domestic Hygiene (3, *1*)	*Presence of human/animal faeces in the compound;* Animals running around freely in the compound; Compound swept on day of visit	0,302

Note: (a) In brackets, number of identified indicators; (b) In italics, indicators removed based on PCA and therefore not considered in the assessment.

For the assignment of weights before components' final aggregation, a multivariate analysis is applied at the sub-index level, and the weighting system is therefore built on the relative importance of the index's components for the principal factors. The components are finally aggregated together using a weighted multiplicative function (Giné Garriga and Pérez Foguet, 2010), and numerically the sub-indices can be formulated as:

$$WPI = \prod_{i=R,A,C,U} X_i^{w_i} \qquad SPI = \prod_{i=A,C,U} X_i^{w_i} \qquad HPI = \prod_{i=DW,PH,F,DH} X_i^{w_i}$$

where WPI / SPI / HPI are the values of the sub-index for a particular household, X_i refers to component i of the sub-index structure, and w_i is the weight applied to that component.

In the last stage, the composite is validated as final estimates might be too subjective due to the assumptions in data selection, scaling, weighting and aggregation. A combination of uncertainty and sensitivity analysis help gauge the robustness of the composite and ultimately improve its overall quality (Saisana and Tarantola, 2002).

Aggregating WASH PI data to the district level

To obtain the index values for the district is straightforward as the sampling procedure for households' selection is self-weighting (i.e. clusters are sampled with probability proportional to size). For this reason, district indicators' values are calculated as the average of respective household's values.

For monitoring and planning purposes, the district becomes an adequate scale of analysis. A lower administrative scale (e.g. division or location) would not be reliable as data are not statistically representative. On the contrary, valuable resolution would be lost in the aggregation process when generating values for the province, and results might mask regional disparities.

Discussion

This section attempts to unravel the linkages between poverty and access to basic services. To do this, we demonstrate that an integrated indicator approach comes out feasible and relevant. WASH PI proves useful to assist policy makers in capturing a more comprehensive picture of sector constraints and challenges; and by improving the identification of target groups, the index ultimately allows a more equitable allocation of available resources and supports poverty reduction initiatives. However, the way the index is disseminated is essential for this purpose. The goal is to provide clear messages and to communicate a picture to decision-makers quickly and accurately.

To start with, a map has been developed (Figure 30) to geographically display the sub-index scores in a visually clear way. The values of each sub-index and summary statistics are also presented in Table 27. It is observed that all three sectors require urgent policy attention. The water-related sub-index presents the lowest average (0.43; where 1 is the best achievable score and 0 denotes highest level of poverty), and although two remaining sub-indices (SPI, 0.50; and HPI, 0.48) score higher, sanitation shows marked regional disparities (Std. Dev. 0.14). The map better describes the spatial distribution of poverty within the study area. Specifically, the worst situation corresponds with the northern – eastern districts, particularly with regard to sanitation; while western districts achieve the highest values, thus representing the least WaSH poor districts. In terms of prioritization, a crucial factor is to determine the neediest. Then, sub-index values might be used as performance indicators to rank all districts and establish priorities, where a rank of 1 denotes the "highest" priority and is assigned to those districts with lowest WPI, SPI and HPI values. With regard to water, while Kajiado is at the bottom of the ranking (WPI: 0,54), Mwingi scores the lowest WPI value (0,30) and represents the highest degree of water poverty. Much like the WPI, Turkana (SPI: 0,21) and Marsabit (HPI: 0,31) are straightforwardly identified as the areas of greatest need, in terms of sanitation and hygiene respectively. It is noted that few districts rank in the same quartile for all three sub-indices, thus areas in which to focus attention widely vary between and within districts.
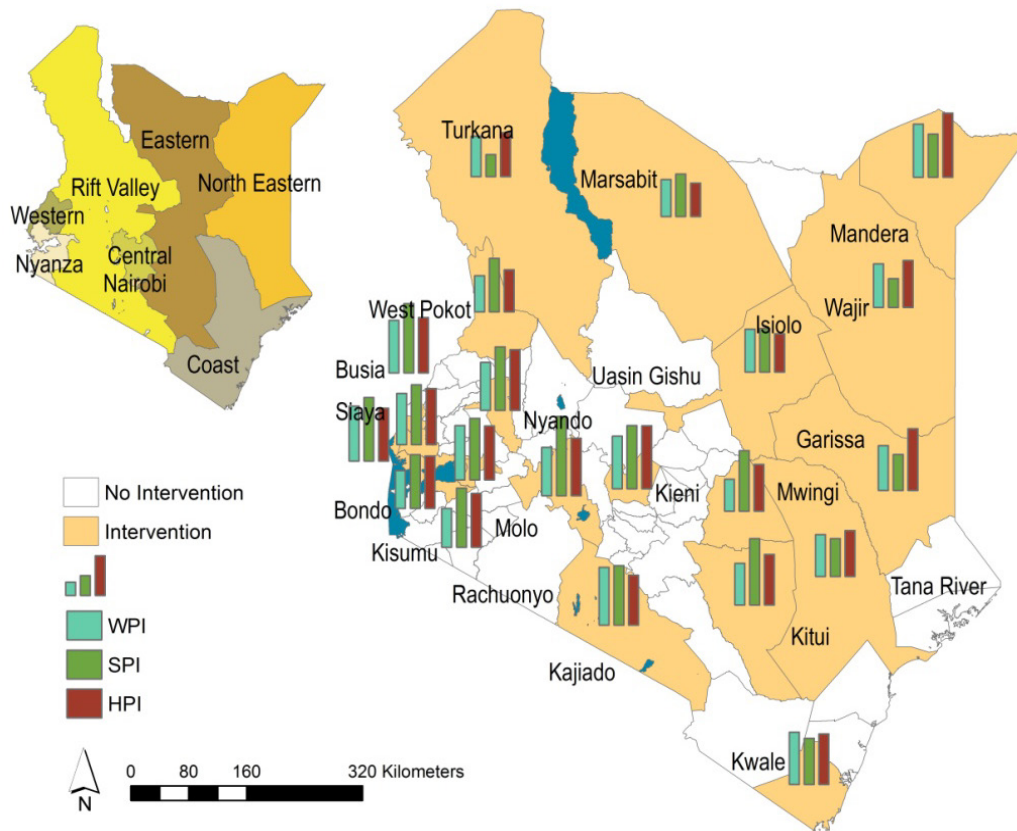
Figure 30 WASH PI results for all 21surveyed districts (in separate map, Kenya's provinces)

The table, in which districts are sorted in order of descending population density, also reveals that most densely populated districts score considerably better in all three sub-indices. And this confirms that provision of WaSH services in sparsely populated and remote areas remains elusive, as achieving adequate service level would require a huge investment of resources (i.e. high number of new waterpoints, district-wide hygiene campaigns, etc.).

Table 27 WASH PI values and ranks (in descending order of population density)

District	WPI	Rank WPI	SPI	Rank SPI	HPI	Rank HPI
Kisumu	0,52	20 (4)	0,60	18 (4)	0,50	12 (3)
Busia	0,50	16 (4)	0,65	20 (4)	0,52	15 (3)
Rachuonyo	0,37	5 (1)	0,56	11 (3)	0,51	14 (3)
Siaya	0,48	14 (3)	0,56	13 (3)	0,53	16 (4)
Nyando	0,51	19 (4)	0,58	15 (3)	0,51	13 (3)
Uasin Gishu	0,45	12 (3)	0,60	17 (4)	0,57	18 (4)
Bondo	0,36	4 (1)	0,51	10 (2)	0,50	11 (3)
Molo	0,46	13 (3)	0,75	21 (4)	0,54	17 (4)
Kieni	0,50	17 (4)	0,60	16 (4)	0,60	20 (4)

Kwale	0,49	15 (3)	0,43	8 (2)	0,48	9 (2)
Kitui	0,39	7 (2)	0,63	19 (4)	0,48	10 (2)
West Pokot	0,34	2 (1)	0,51	9 (2)	0,40	3 (1)
Mwingi	0,30	1 (1)	0,57	14 (3)	0,44	6 (2)
Mandera	0,50	18 (4)	0,41	6 (2)	0,60	21 (4)
Kajiado	0,54	21 (4)	0,56	12 (3)	0,47	8 (2)
Garissa	0,42	11 (3)	0,34	3 (1)	0,58	19 (4)
Marsabit	0,35	3 (1)	0,40	5 (1)	0,31	1 (1)
Turkana	0,38	6 (2)	0,21	1 (1)	0,42	4 (1)
Wajir	0,41	10 (2)	0,27	2 (1)	0,44	7 (2)
Isiolo	0,40	9 (2)	0,41	7 (2)	0,36	2 (1)
Tana River	0,39	8 (2)	0,36	4 (1)	0,43	5 (1)
Min	0,30		0,21		0,31	
Max	0,54		0,75		0,60	
Mean	0,43		0,50		0,48	
Std Dev	0,07		0,14		0,08	

Note: (a) In brackets, classification based on quartiles

A closer look at the three sub-indices and its components produce complementary results. They help identify the source of the problem in particular places, and direct attention and target efforts to those sectors most in need.

WPI and its components. As regards water-related issues, results suggest that aspects requiring urgent intervention are those related to the "Access" and "Capacity", averaging 0.25 and 0.21 respectively (see Table 14, Chapter 2). Two remaining components, i.e. "Resources" and "Use", score considerably higher (0.66).

As might be expected, the "Resources" component shows lower values in those districts classified as arid and, to a lesser extent, in some semi-arid districts (being Garissa and Mandera the exception). That is, water poverty is linked to aridity, a problem which will be exacerbated by climate change. However, this sub-index includes two indicators of doubtful reliability when assessed at the household, i.e. seasonality of water resources and water quality perception, so it might fail to accurately reflect conditions on the ground. With regard to "Access", it is observed that coverage of improved waterpoints is not only poor (43.5%) but also with remarkable regional differences (Std. Dev. 0.22). Moreover, quantity of water that will be collected for domestic purposes may reduce where fetching water is time consuming or tariffs are unaffordable. These two indicators also show poor performance (0.27 and 0.28 respectively). According to the "Capacity" values, one might conclude that institutional framework to manage water facilities at the local level is by and large inadequate. Beneficiaries are rarely involved in the management committees (0.07). And a considerable number of water entities do not have a payment system in place (0.1), therefore hindering their ability to meet ongoing operation and maintenance costs. The

"use" sub-index shows that domestic water consumption is low throughout the area of study (0.42). Specifically, two out of three households (62%) consume less than 20 l.p.c.d., though this percentage dramatically increases (73.4%) in arid districts. Conversely, the large majority of households (83%) uses same water source for all domestic purposes.

SPI and its components. A major sanitation challenge is undoubtedly related to the marked heterogeneous pattern (Std. Dev. 0.14). A closer look at the components, though, points out a clear distinction between access to / use of basic sanitation and abilities to construct / repair the facility. As seen from the statistics (see Table 14, Chapter 2), while the "access" and "use" indicators average 0.44 and 0.4 respectively, the "capacity" component scores noticeably higher (0.72).

From the "Access" component, it is noted that the great majority of households (77.8%) practising open defecation cite cost-related issues as the reason for not having their own latrine, which highlights that affordable sanitation technologies are not available. As regards physical accessibility, it is observed that 88.7% of inspected latrines are located inside the house (1.75%) or in same compound. According to the "Capacity" variables, only a small proportion of households (3.25%) state that lack of capacities is a major limitation for having a latrine, although it is believed that this does not necessarily mean that access to skills and materials is adequate when needed. In particular, the results indicate that only half of households have access to skills (52%), while the proportion of households with access to materials is slightly lower (40.7%). The current "use" of basic sanitation is low countrywide, standing at 21.6% (Std. Dev. 0.2). In contrast, it is remarkable that in those households where a latrine is being used, the facility is generally kept in acceptable sanitary conditions (62.5%).

HPI and its components. This composite reveals as most risky regions the northern districts, although geographic differences are not pronounced (Std. Dev. 0.07). Much like the previous indices, HPI's sub-indices contribute differently to the aggregated composite; and specifically, poor personal hygiene (0.36) represents the most likely pathway by which oral-faecal contamination may occur. On the other hand, handling practices, storage and point-of use treatment of drinking-water perform reasonably high (0.64).

First sub-index (DW) assesses the hazards and contaminant pathways into the drinking-water tank that may cause contamination to occur (Howard 2002). And to a large extent, it is observed that storage of water is adequate. Another indicator evaluates adequacy of point-of-use water treatment, and data show that of those who treat water (nearly half of households) the methodology employed is correct in almost all dwellings (94%). The "Food" component performs poorer. First indicator shows that not even half of child caregivers (47%) wash their hands at critical times (i.e. before food preparation, before feeding children and before eating). And the other proxy analysed, i.e. existence of a drying rack for dishes, scores even lower (0.37). Regarding the "Personal Hygiene" sub-index, it is observed that more than half of households (58.1%) employ a sanitary method to dispose children's stools, despite marked regional differences (Std. Dev. 0.29). Another indicator assesses handwashing behaviour of child caregivers, and shows that 86.1% wash their hands acceptably. In contrast, hygiene promotion campaigns have not been launched as countrywide strategy, since only 12.6% of households report their participation in such initiatives during the year preceding the survey. Last variable gauges hygiene-related issues in the vicinity of the toilet, and it is observed that a water point is only found in 7.7% of facilities, while soap is available in less than 1% of inspected latrines. Finally, presence of animals that can transmit faecal

contamination represents a remarkable domestic hygienic risk, and this is observed in 40% of households. Also, households swept on the day of visit only accounted for less than half (46.7%). In all, the "Domestic Hygiene" component averages 0.53 for the whole study area, indicating poor home hygiene.

Aggregation of three sub-indices into one WASH PI. As discussed above, the WASH PI is disseminated as a thematic indicator in order to simultaneously keep water, sanitation and hygiene issues in focus. From a research perspective, though, to yield one single value from the three sub-indices provides a further aspect of analysis. Hence, much like the WPI, SPI and HPI, the WASH PI might be calculated at household level through a weighted multiplicative function. The more one aggregates the data the more resolution is lost, but for the purpose of policy-making such a composite approach may come out relevant.

From the graph in Figure 31a it is observed that poverty levels increase significantly in the aggregation process, as the final index averages 0.06 with five districts scoring 0. It is recalled in this regard that the geometric aggregation does not allow compensation in case null values in any component, which is the case in 92% of surveyed households (4568 out of 5050). Although the rankings are less affected (Figure 31b), these results demonstrate that applying two geometric functions within the index structure is not adequate, as this overshadows the existing disparities within districts.

In consequence, to opt against aggregating the three sub-indices to form one composite index appears appropriate both in terms of methodology (combination of two geometric functions mask regional disparities) and policy-making (the aggregation process reduces the validity of the final outcome as the sub-indices provide more reliable information if examined separately).
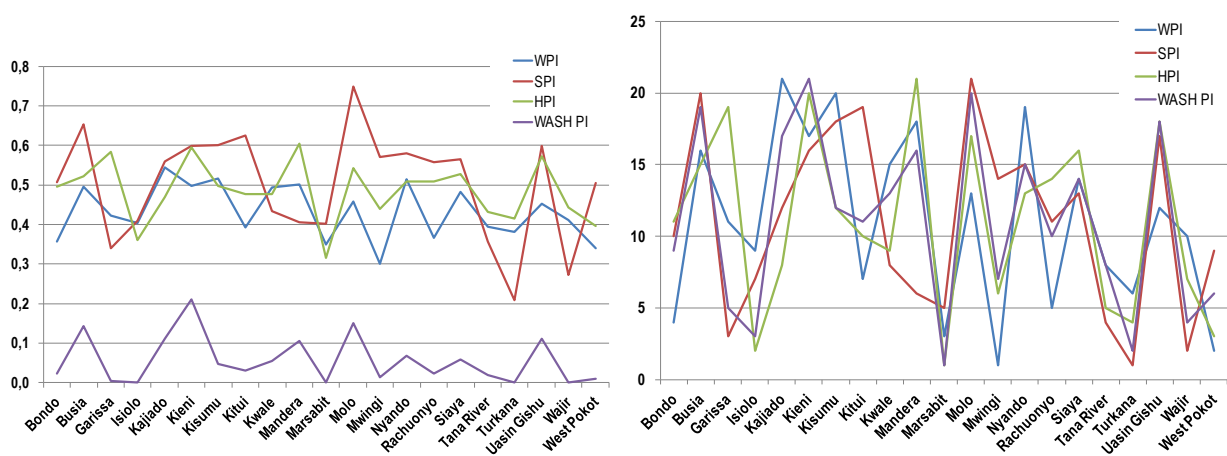

Figure 31 Comparison between WASH PI and its three sub-indices. a) Values. b) Ranks

3. Planning Indices

As discussed in Chapter 2, the practical usefulness of composite indices in local policy-making has been challenged on several grounds. Lack of reliable data to produce the index, poor capacities to

construct a meaningful indicator and, most importantly, loss of information in the aggregation process, hinder the significance of these tools in decentralized contexts.

An alternative approach may focus on separately identifying emerging development challenges to provide clear evidences that determine what gets done, and where. To do this, a set of simple and thematic planning indices serves as the basis to rank population groups and reveal the neediest areas (Giné Garriga et al., 2015). The criteria in which base the indices should encompass key priorities of local planning; and particularly, each index should reflect a specific need (e.g. poor functionality of water infrastructure) and be easily linked to an efficient remedial action (e.g. rehabilitation of waterpoints). In brief, the proposed planning tools should be not only user-friendly (easy to assess, easy to use), but presented in a way that provides clear messages to decision-makers and potential beneficiaries. In following section, the methodology employed for data collection and analysis is outlined, and the approach adopted for planning is presented. The situation of WaSH issues in the area of intervention is then examined based on a reduced set of planning indices.

3.1. Methodology

In terms of method, study's implementation is two-fold. First, a comprehensive baseline data of WaSH issues at the local level is implemented through the data collection method described in Chapter 1 (Giné Garriga et al., 2013b). Second, the analysis of the baseline is carried out through a set of easy-to-use planning tools (Jiménez and Pérez Foguet, 2010a). They help decision-makers identify sector priorities and articulate remedial proposals to overcome major development challenges.

Assessment of water, sanitation and hygiene issues

The key features of the methodology for data collection include (Giné Garriga et al., 2013b): i) an exhaustive identification of enumeration areas (administrative subunits); ii) audit in each enumeration area of all improved waterpoints accessed for domestic purposes; and iii) random selection of a sample of households that is representative at the local administrative level (e.g. district, municipality, etc.) and below. The proposed framework thus makes use of two widely accepted methods, i.e. the waterpoint mapping and the household survey, to collect WaSH data in an efficient manner.

Moreover, in order to produce a complete picture of how well the sector is faring, it is essential that the evaluation framework looks beyond data on service coverage and integrate a broader view of service delivery (Giné Garriga and Pérez Foguet, 2013a; Jiménez and Pérez Foguet, 2012; Joint Monitoring Programme, 2011a). Amongst others, information about institutional, financial, management and environmental issues should be adequately addressed.

Design of planning tools

In data analysis, it is essential to balance exhaustiveness with simplicity. In this study, despite the comprehensiveness of the baseline data, a reduced set of indices are defined on the basis of simple planning criteria (Jiménez and Pérez Foguet, 2010a). For each index, one ranking is produced and transposed into one league table to denote priorities. A different threshold limit is set per list for

this purpose; and whenever two administrative subunits score same index value in one ranking, the most populated one is first positioned to maximize number of beneficiaries. To show at a glance both index values and priorities, different maps are developed, which enable a quick identification of key focus areas. Finally, each priority list is related with specific remedial actions to be accomplished by the local government, ultimately translating development challenges into beneficial development activities. A proposed list of indices is summarized in Table 28.

When defining priorities, a key issue is to guarantee reliability of the outcomes produced and thus avoid decisions based on false assumptions. The data collected at the waterpoint is exhaustive –all waterpoints are included in the mapping exercise- and thus can be meaningfully analysed at different geographical scales. This offers advantages over household data in terms of statistical precision and accuracy. In consequence, water-related indices are computed on WPM data. On the other hand, household estimates are inferred from a representative sample taken from the overall population. Therefore, some basic statistics are needed to analyse the sanitation and hygiene-related indices. Most importantly, they have to be assessed at the administrative scale considered during the sampling design to guarantee data reliability.

Case Studies

This research documents three different case studies in East and Southern Africa, namely the district of Kibondo (Tanzania, 2010), the district of Homa Bay (Kenya, 2011) and the municipality of Manhiça (Mozambique, 2012). Kibondo is one of the 4 districts of the Kigoma Region of Tanzania. It is administratively divided into 20 wards. According to the 2002 National Census, the population is estimated at 414,764. The District of Homa Bay is located in Nyanza Province, in western Kenya. The total area is 1,169.9 Km^2 and the population is estimated at 366,620 (2009 census). Administratively, the district is divided into five divisions, and the divisions are further sub-divided into 25 locations and 63 sub-locations. The Municipality of Manhiça is located in Manhiça District - Maputo Province, in southern Mozambique. It has 19 bairros and covers a rough area of 250 km^2. According to the local estimates, the population roughly totals 61,000 distributed in peri-urban and rural contexts.

3.1. Results and Discussion

This section presents situational analysis of WaSH issues. To do this, we make use of the indices listed above. However, the aim is not to provide an in-depth assessment of those regional sectors and geographic areas that require urgent policy attention, it is more about showing an improved approach for local planning. In other words, the focus is not on a comparative analysis of WaSH-related challenges in the selected study areas, but rather on testing the validity of the indices as targeting and prioritization tools. To support formulation of tailored interventions, the discussion groups (classifies) planning indices and related remedial actions based on their nature, i.e. i) water supply, and ii) sanitation and hygiene.

Table 28 Indices used for planning

Index	Definition	Formula	References	Remedial Action
INDICES RELATED TO WATER SERVICE COVERAGE				
Coverage index	% of covered population by improved waterpoints(IWP) in a location, according to the standards of service level (e.g. 1 waterpoint / 250 people)	$\dfrac{\text{Number of IWP}}{\text{Population}} * 250$	(Jiménez and Pérez Foguet, 2010a; WaterAid and ODI, 2005)	Construction of New waterpoints
INDICES RELATED TO THE MANAGEMENT OF THE SERVICE				
Functionality Index	% of functional improved waterpoints (FIWP), compared to the total number of IWP	$\dfrac{\text{Number of Funct IWP}}{\text{Total IWP}} * 100$	(Jiménez and Pérez Foguet, 2010a; WaterAid and ODI, 2005)	Rehabilitation of existing waterpoints
Management Index	% of FIWP with declared income and expenditure in the year before the survey	$\dfrac{\text{Number of Man FIWP}}{\text{Total FIWP}} * 100$	(Jiménez and Pérez Foguet, 2010a)	Management supporting activities, particularly those related to creation / establishment of water entities or to financial issues (tariff collection systems)
Maintenance Index	% of FIWP with good / acceptable access to technical skills and spare parts	$\dfrac{\text{No. of Maintained FIWP}}{\text{Total FIWP}} * 100$		Management supporting activities, particularly those related to technical issues. Improve spare parts accessibility
INDICES RELATED TO THE QUALITY OF THE SERVICE				
Seasonality Index	% of FIWP that are year-round	$\dfrac{\text{No. of Year - Round FIWP}}{\text{Total FIWP}} * 100$	(Jiménez and Pérez Foguet, 2010a)	Actions to increase reliability of the source (catchment's protection, regulation of different uses) and/or finding of additional sources
Water Quality Index	%of FIWP with acceptable bacteriological quality	$\dfrac{\text{No. of Safe FIWP}}{\text{Total FIWP}} * 100$	(Jiménez and Pérez Foguet, 2010a)	Actions to improve quality of water: catchment's protection, protection of WP, water treatment, etc. If salinity is high and becomes dangerous, check other alternative sources WP

INDICES RELATED TO SANITATION SERVICE

Coverage Index	% of covered households by improved sanitation facilities (ISF)	$\dfrac{\text{No. of HH with ISF}}{\text{Total HH}}$	(Joint Monitoring Programme, 2008, 2006)	Construction of new facilities
Open Defecation Index	% of households that practice open defecation (OD)	$\dfrac{\text{No. of HH practicing OD}}{\text{Total HH}}$	(Joint Monitoring Programme, 2008; WaterAid, 2009b)	Community-led Total Sanitation

INDICES RELATED TO HYGIENE

Latrine Sanitary Conditions Index	% of latrines that are maintained in adequate sanitary conditions. Risky conditions might prevent an adequate use	$\dfrac{\text{No. of Sanitary Latrines}}{\text{Total Latrines}}$	(WaterAid, 2009b)	Hygiene promotion campaigns
Handwashing index	% of adults with appropriate handwashing (HW) knowledge	$\dfrac{\text{No. of Adults with HW}}{\text{Total Adults}}$		Hygiene promotion campaigns, particularly focused on handwashing

Water Supply Planning Indices

Access to water is determined primarily by distance to the source, since quantity that will be collected will probably not reach a minimum requirement for domestic purposes where fetching takes more than 30 minutes (Cairncross and Feachem, 1993). Other aspects which may hinder accessibility are seasonality, quality and affordability (Howard and Bartram, 2003; Jiménez and Pérez Foguet, 2012). Therefore, water coverage can be categorised in terms of service level, by considering a combination of aforementioned requirements. However, where optimal access is provided but the supply is not functional, other unimproved sources might become a temporary solution (Hunter et al., 2009). This draws attention to the issue of service management.

Access to water. As mentioned in Chapter 2, a common method to estimate coverage is based on standard assumption on the number of users per improved water source, i.e. the source:man ratio. First index depicts the number and geographic distribution of improved waterpoints in terms of the population living in the area, and thus identifies those administrative subunits most in need of new waterpoints' construction.

It is gleaned from the map (Figure 32) that current availability of improved sources in Kibondo District is not only poor, i.e. 50.26% of population are properly covered by improved waterpoints, but regional disparities also impact on equity issues. There are some villages with no access to improved waterpoints (red coloured in the map), while in 33 villages the man:source ratio is lower than the policy target (coloured in dark green).
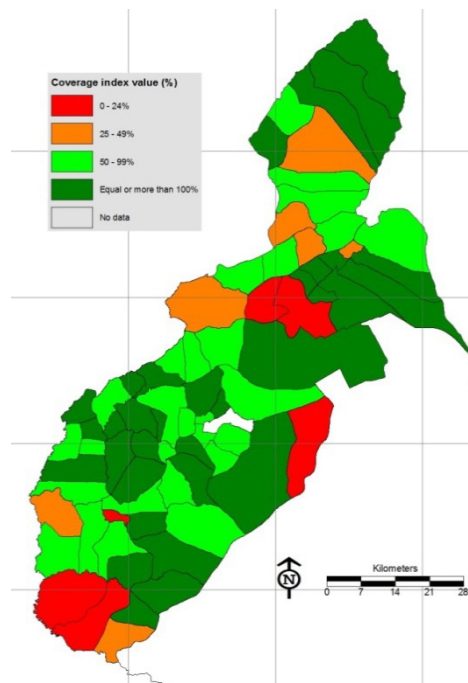

Figure 32 Coverage Index (Kibondo District)

To tackle water shortages, various approaches may be adopted when defining the list of priorities. In terms of regional equity, the goal would be to reach a minimum coverage threshold in every administrative unit, as commonly established in national policies. For example, the rural WaSH

initiative launched by the World Bank in Tanzania aims to increase coverage nationwide and reach at least 80% in all districts by 2025 (Government of United Republic of Tanzania, 2006). The focus in these cases should be on underserved areas, and for instance target in first place the villages included in the poorest and least-served quartile. Based on an efficiency criterion, however, those administrative units with highest number of potential beneficiaries would be first targeted, regardless of coverage. The equity criterion has been opted for in this planning exercise. It emphasizes those underserved locations with lowest source:man ratios, where vulnerability is higher due to total absence of improved supplies (Jiménez and Pérez Foguet, 2010a).

Functionality of waterpoints. A second group of indices aims to analyse those key aspects that enable a water scheme to remain operational over a long period of time, and therefore identify the facilities in need of soft-based support. A water supply can be interrupted because of functionality / management reasons or seasonality issues. Regardless the cause, lack of continuity may lead to prolonged periods without supply, obliging households to search for alternative sources, often of inferior availability and poorer quality. Service continuity is therefore essential in benefiting health.

Functionality is defined in this exercise as the percentage of improved sources that are functional at the time of spot-check. In those locations with lowest index values, the strategy should consider the rehabilitation of non-operational waterpoints as an alternative to the construction of new infrastructure. In parallel, and to reduce recidivism, management and operation capacity gaps should be properly identified to promote long-term sustainability. More specifically, soft-based support initiatives to water user entities emerge as efficient solutions, such as promotion of their legal registration, and financial and technical support to build up capacities of managers and technicians.
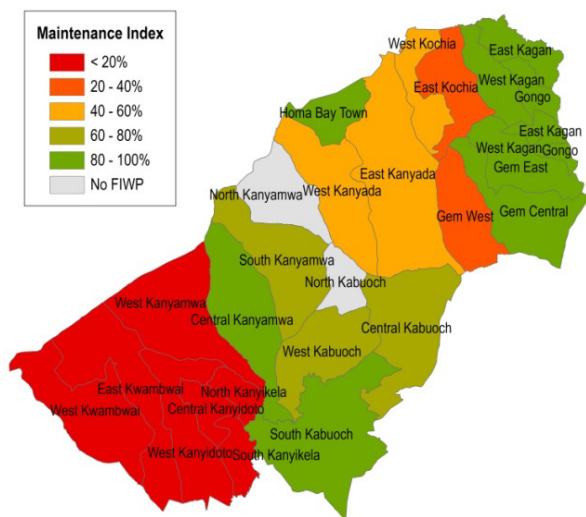

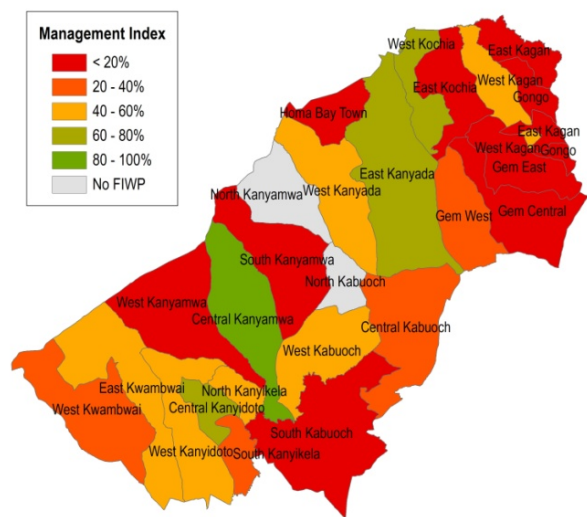**Figure 33** Maintenance Index (Homa Bay District)

Figure 34 Management Index (Homa Bay District)

To further the analysis on functionality issues, two additional indicators are analysed, one related to management and another one related to maintenance. For service management, a financial criterion has been employed, and the proportion of functional waterpoints with declared incomes and expenditures has been taken as proxy (Jiménez and Perez-Foguet, 2011b). From the map in

Figure 34, it can be seen that a considerable number of water entities do not have an appropriate payment system in place, therefore hindering their ability to meet ongoing O&M costs. To draw attention to maintenance needs, a complementary index estimates the percentage of waterpoints that are operational and have easy access to a reliable supply chain and to qualified technicians. It is gleaned from Figure 33 that such access remains elusive in some locations, where neither technical skills nor a reliable supply chain are locally available.

Seasonality of water sources. Service continuity also depends on seasonality issues; and where seasonality of water resources is high, people often need to search for alternative sources during dry season. This planning indicator estimates the percentage of functional waterpoints that are year-round (not seasonal), where seasonality is defined as more than one month of water shortage. It can be observed from the map (Figure 35) that 84% of supplies are year-round. Therefore, and though this figure slightly varies across the locations, seasonality is not an issue in Homa Bay. Remedial actions where seasonality is high would include catchments' protection, improvement of water storage, research on water technologies in dry areas, etc.
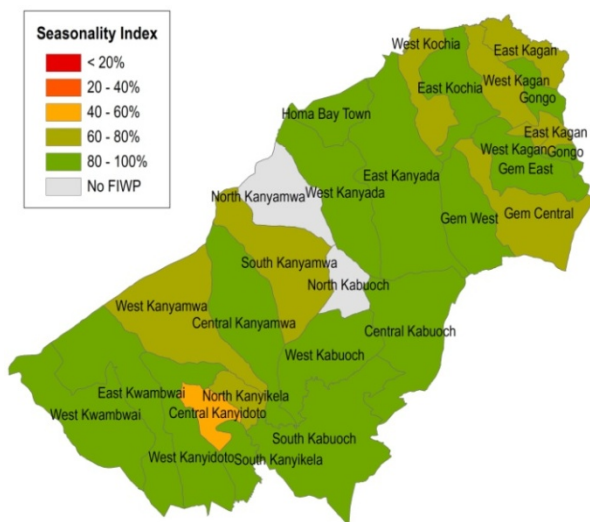

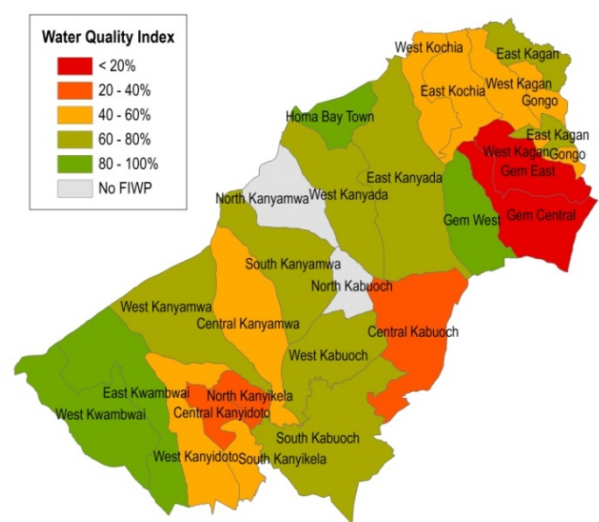**Figure 35** Seasonality Index (Homa Bay District)

Figure 36 Water Quality Index (Homa Bay District)

Water quality. Water quality surveillance should be a required activity in any monitoring framework, since the relevance of accessing safe water for disease prevention is widely recognized (Esrey et al., 1991). Water safety is herein understood as non-presence of faecal coliforms; i.e. the planning index informs about the proportion of operational sources with a faecal coliform count of more than zero. It can be seen in the map in Figure 36 that three out of ten (30.8%) water sources are affected by microbiological contamination, which emphasizes the fact that improved waterpoints do not always supply safe water. Again, regional differences are pronounced. And interestingly, the map depicts that those areas showing faecal contamination are to certain extent geographically clustered.

Water sources may be contaminated because of poor sanitary protection measures due to inadequate design, sitting, construction or operation and maintenance. Therefore, in those prioritized locations, interventions are required in the form of engineering interventions to improve the protection or the environmental hygiene around the source; or actions to promote good

community management. The design of abovementioned activities could be supported by regular sanitary inspections (Howard, 2002).

Sanitation and Hygiene Planning Indices

Sanitation monitoring often focus on the "hardware" -for example, number of latrines or sewerage systems- whilst neglecting the "software" -hygiene knowledge and behaviours- (Dreibelbis et al., 2013). However, beyond access to infrastructure, it is well known that lack of latrine maintenance results in a focus for the transmission of diseases, apart from hindering a continued use (Scott et al., 2003). Personal hygiene (principally hand-washing), on the other hand, is the only protective barrier which can effectively block all faecal-oral routes of disease transmission (sanitation hardware only prevents faeces contaminating the environment; transmission via fingers is also common), and research has demonstrated that increased hand-washing significantly diminishes the incidence of diarrhoea (Curtis and Cairncross, 2003; Luby et al., 2005). For planning purposes, sanitation monitoring needs to be defined in a broad and more holistic sense (Breslin, 2010). Thereby the previous challenges have been translated into respective planning indices.
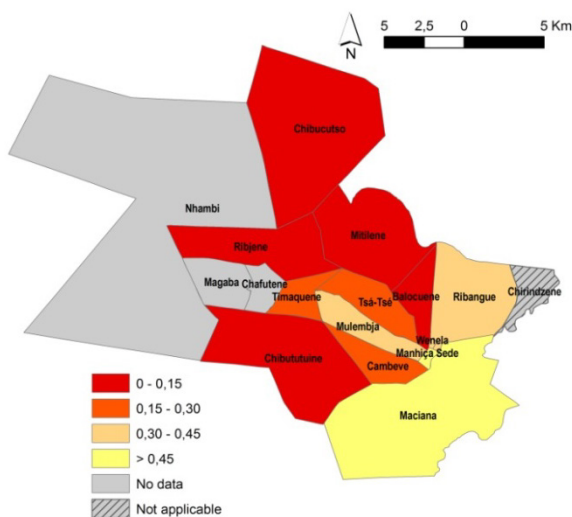

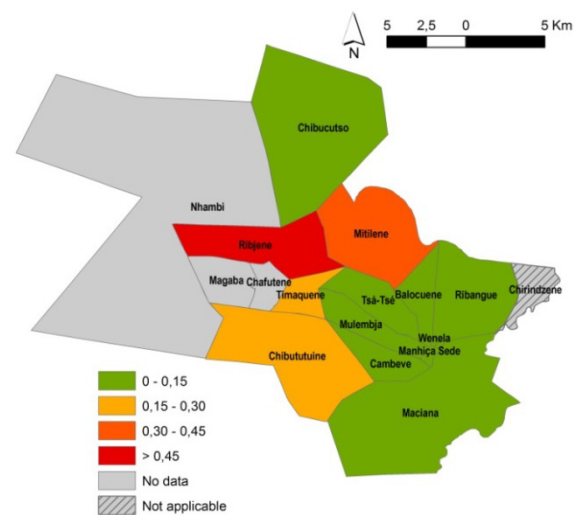**Figure 37** Improved Sanitation Index (Manhiça)

Figure 38 Open Defecation Index (Manhiça)

Use of sanitation. As mentioned above, a technology-based approach is adopted when estimating the sanitation figures. Specifically, coverage is presented as a four-step ladder that distinguishes between open defecation, unimproved, shared, and improved sanitation (Joint Monitoring Programme, 2008).

Two complementary indices are designed to assess the "hardware" component at the dwelling: i) use of improved sanitation, and ii) practice of open defecation. As visualized in the maps (Figures 37 and 38), the situation in the municipality of Manhiça is far from being adequate: use of improved infrastructure stands at 26.4%, and 14.2% of total population has no access to sanitation at all. In addition, disparities exist by bairros, and for instance population in Manhiça Sede (coverage of 58,7%) is nine times as likely to use an improved sanitation facility as the population in Mitilene (6.7%). On the other hand, a large majority of households defecate in the open in Ribjene (61.3%), while in other bairros this practice has been almost eliminated.

In those locations where sanitation coverage is lowest and open defecation is widespread, the coordination of initiatives to support new construction of facilities, the implementation of social sanitation marketing strategies or the launch of total sanitation campaigns, such as those focused on the Community Led Total Sanitation (CLTS) approach (Kar and Chambers, 2008), would emerge as potential remedial actions. They all would trigger a movement on the sanitation ladder.

Latrine sanitary conditions. The sanitary condition of the facilities may be assessed by means of four different proxies (cleanliness, presence of insects, smell and privacy). Figure 39 confirms that sanitation strategies should not only focus on the provision of the hardware, but on ensuring that it is safe, physically acceptable and hygienically maintained. In Tanzania, for instance, the district of Kibondo would do wise to facilitate and support campaigns for safe hygiene practices in the vicinity of the latrine, particularly in those highly prioritized wards.
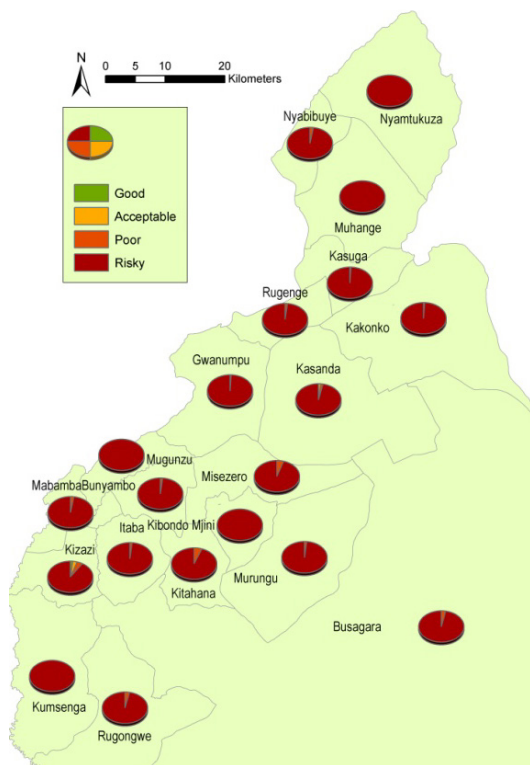
Figure 39 Index of Latrine conditions (Kibondo District)
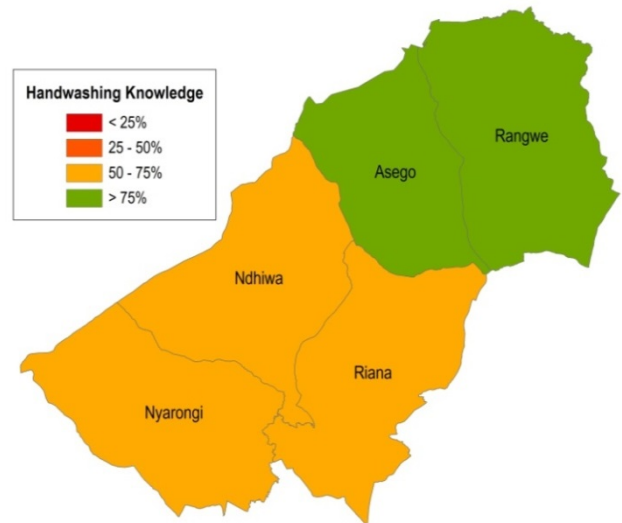
Figure 40 Index of Handwashing knowledge (Homa Bay District)

Handwashing knowledge. It is well established that improvements in personal hygiene are of greatest likely benefit to health, and particularly handwashing with soap is one of the most effective ways to break the faecal-oral route of disease transmission (Curtis and Cairncross, 2003). An index for planning is thus proposed to assess the proportion of adults with adequate handwashing knowledge[8].

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[8] Assessment of handwashing behaviour requires specific evaluation techniques, which were out of the scope of this study

It is observed from Figure 40 that the index scores relatively high in all divisions, i.e. seven out of ten adults know how to wash their hands. However, an evaluation (not shown here) of handwashing devices around the toilet points out that on average, a waterpoint is only found in less than 5% of facilities; and soap is available in 2.1% of inspected latrines (Craven et al., 2013). This spotlights that while handwashing knowledge is adequate, handwashing behaviour is not. The launch of handwashing campaigns and other hygiene-related initiatives to promote hygiene education often become effective where handwashing behaviour is poor.

In sum, the previous examples show that local planning may be improved by the design of simple indices. However, the criteria upon which the indices are based should be objective and transparent. To be efficient, they should reflect real local priorities.

4. Bayesian Networks

A Bayesian network (Bn) is a type of decision support system based on probability theory using Bayes' rule. Bns are directed acyclic graphs that exploit the duality between an interaction graph and a probability model (Castelletti and Soncini-Sessa, 2007). The graphical structure provides a visual representation of the logical relationship between variables, while conditional probabilities quantifies this relationship and are thus required to fully run the network. They are made up of three different elements (Bromley, 2005); i) a series of nodes representing a set of variables that are relevant to the problem at hand, ii) the links between these variables which express cause-effect relationships among them, and iii) the conditional probability tables (CPTs) behind each node that are used to assess the extent to which one variable is likely to be affected by the others. The conditional probability values in the CPTs of different nodes are independent from each other, and consequently, they can be populated individually with best information available for each variable. As more data or knowledge is accessed, the relevant CPTs might be updated to reflect the improved data set (Bromley et al., 2005; Castelletti and Soncini-Sessa, 2007).

In this respect, Bns are powerful for incorporating data and knowledge from different sources and domains (Bromley et al., 2005; Castelletti and Soncini-Sessa, 2007; Henriksen and Barlebo, 2008), such as the economic, social, physical or environmental; and this key characteristic makes them particularly suited for addressing the water assessment issue in an interdisciplinary, holistic way. Similarly, this technique might be especially helpful when there is scarcity or some degree of uncertainty in the data (Bromley et al., 2005; Henriksen and Barlebo, 2008). In those situations involving uncertain knowledge or when a large number of factors that are linked together need to be taken into consideration, Bns might be used to support decision-making. Again, this makes this technique an adequate policy tool in the field of water resource management, where dealing with complex environmental systems is inevitable, and since data are often uncertain and scarce.

Nevertheless, a conventional Bn is unable to receive or transmit information from outside the system (Molina et al., 2009). Instead, an ooBn model provides a suitable framework that allows different networks to be linked together. In brief, an ooBn is a network that, in addition to the usual nodes, contains instance nodes. These nodes in effect represent an "instance" of another network, and are thus employed to import (input node) or export (output node) the information within different networks. In an ooBn, the following notations are used: input nodes are ellipses

with shadow dashed line borders, and output nodes are ellipses with shadow bold line borders, as shown in Figure 41.
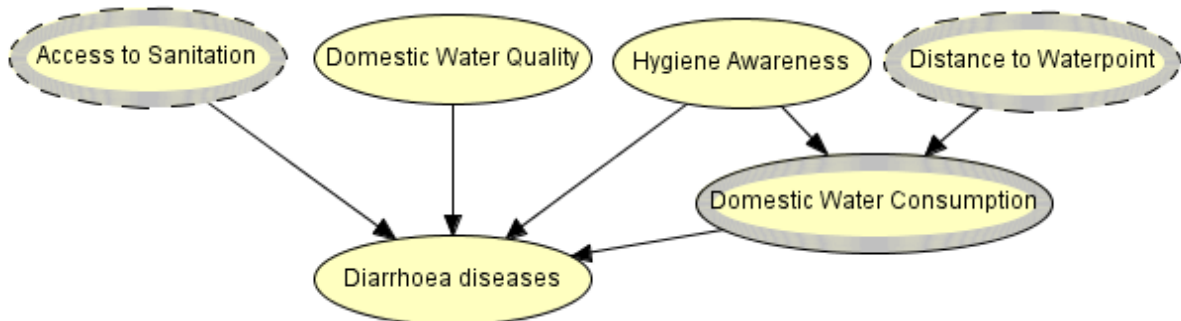

Figure 41 Simplified OOBN for assessing incidence of diarrhoea

Case study: the Turkana district (Kenya)

As described in previous Section 2, the district of Turkana is located in the Rift Valley Province. The main strategic challenges affecting water provision in the district include poor access to basic services, inadequate quality of water, weak control and regulation of water use, dam silting, lack of maintenance of water supply facilities, and inadequate rain water harvesting (Government of Kenya, 2005; United Nations Children's Fund, 2006b). In particular, and based on data at the national scale, only 31% of the population living in rural areas are using improved sources for drinking water, while 36% of people have access to adequate sanitation facilities (United Nations Children's Fund and Government of Kenya, 2006). As a consequence, the prevalence of water-related disease is increasing, contributing to higher rates of mortality among children under five years old. This currently stands at 115 per 1,000 children, of which diarrhoeal diseases account for about 20% of cases (United Nations Children's Fund and Government of Kenya, 2006). A priority concern is thus to address the major underlying causes of all these water-borne diseases; i.e. water quantity is insufficient and it is often unsafe to drink and to prepare food; the majority of households do not have toilet facilities; and primary caregivers do not have adequate hygienic practices.

Against this background, the Government of Kenya in collaboration with UNICEF launched, with support from the Dutch Government, the Programme of Cooperation "Acceleration of Water Supply and Sanitation towards Reaching Kenya's Millennium Development Goals (2006 – 2011)" (United Nations Children's Fund and Government of Kenya, 2006). This initiative was aimed at increasing the access to improved water, sanitation and hygiene in 22 districts (see Figure 42), contributing to the achievement of the sector-related Millennium Development Goals. As a pilot, this study focuses on one of these 22 districts, Turkana
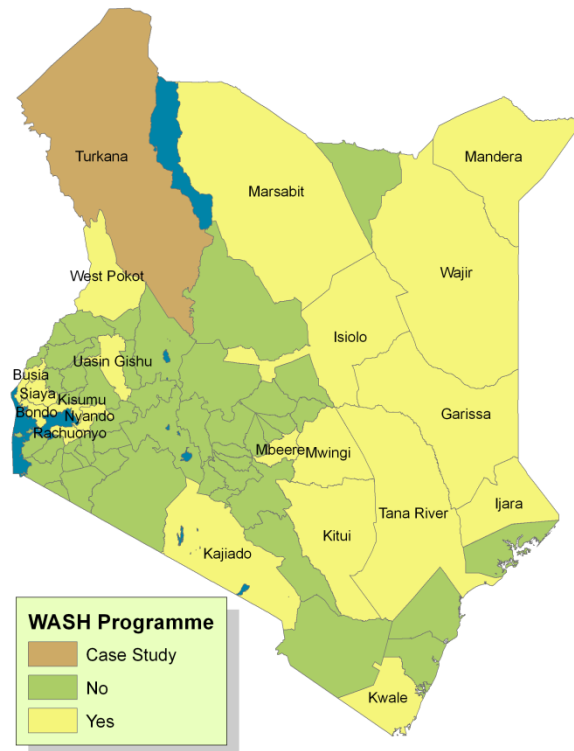
Figure 42 The Program districts and the specific location of Turkana District

4.1. Development of Networks

This section deals with the development of an ooBn to be used as a decision support tool, targeting the water poor at a local scale. In particular, the aim is to build a network to help assess the impact of the implementation of the WaSH Kenyan Programme on water poverty at the lowest Kenyan administrative scale, namely the location. To this end, a commercial software package produced by HUGIN has been used for Bn construction.

The method of network construction involves three key steps.

1. *Identification of the variables relevant to the problem* and definition of key linkages among them. To assess the level of water poverty, the network has been divided into five sub-networks to represent the five components of the WPI. A large number of variables (81) have been identified and classified based on their nature (Bromley, 2005): "Objectives" are those variables the Programme aims to improve, and are depicted graphically in green ; "Interventions" are all the actions to be implemented through the Programme to achieve these objectives (in grey); "Intermediate Factors" are all the elements that link "Objectives" and "Interventions" (in blue); and "Controlling Factors" (in orange) are other variables which somehow influence the system but cannot be controlled (Table 29).

Table 29 Classification of variables at sub-network level

Sub-network	No. of Variables	Category			
		Objective	Interventions	Interm fact.	Control fact.
Resources	13 (4)	3 (1)	1 (1)	5 (1)	4 (1)
Access	21	3	2	13	3
Capacity	18 (1)	3	5	10	(1)
Use	9 (3)	4 (2)	2	3 (1)	---
Environment	20 (3)	3 (1)	2	14 (2)	1
Total	81	16	12	45	8

Note: In brackets, number of input nodes.

2. *Data collection for the probability tables that lie behind the variables*. A key part of the process is to make sure that the tables constructed for each variable are based on the best information available. Trying to influence and support decision-makers when the information provided is scanty or inaccurate would lead to meaningless results. In this study, data used have been generated through a combination of relevant literature review and two major information sources: i) the 'Water, Schools and Health Management Information System (MIS) for the Turkana District' (United Nations Children's Fund, 2006b), which was developed as a comprehensive record of all water sources available in the district; and ii) the main report of the Kenyan WaSH Programme (United Nations Children's Fund and Government of Kenya, 2006). However, it has been noted that available data has been insufficient to accurately assess some nodes, and further refinements to the networks have been required in this regard.

3. *Assignment of the states for all variables and completion of the conditional probability tables* (CPTs). Once the variables have been defined and grouped, their states and probabilities are assigned using available data or expert knowledge. The CPTs are the core of the network since it is their values that will determine the outcomes, and thus special care should be given to this stage. The complexity and size of the CPTs depends on the number of parents and the number of states the respective variable has (Bromley, 2005). It is, therefore, advisable to construct the network with a limited number of parents and states; in this way the CPTs become much more manageable.

Explaining the meaning of each individual variable is not feasible, therefore, only a broad outline of the sub-networks follows.

Water Resources - Water resources in Kenya have been diminishing because of environmental degradation, lack of water conservation, and spread of pollution sources: diffuse pollution sources such as silting and agrochemicals, and point pollution sources including industrial wastewater effluents, solid wastes, and domestic sewage (Odada et al., 2003). But the most influential factor has been the variation in climate (United Nations Children's Fund and Government of Kenya, 2006).

Turkana district is particularly prone to frequent droughts. It receives an annual average rainfall of 120 mm, and the district is classified as arid (Government of Kenya, 2005). The rainfall pattern

and distribution is erratic both in time and space, although the probability of rainfall is the highest during the long rainy season between April and August. The district's main sources of water are ephemeral rivers, Lake Turkana, underground water, springs, dams and pans. This resource is mainly exploited via gravity (basin irrigation) and direct access for domestic and livestock water supply (United Nations Children's Fund, 2006b). Above all, the population relies on river and shallow wells for water, especially the shallow groundwater aquifer associated with dry riverbeds (Odada et al., 2003). The district has 4 main seasonal rivers (Turkwel, Kerio, Suguta and Tarach), though the most important tributary of Lake Turkana is the River Omo, which enters the lake from Ethiopia and contributes more than 90% of the total inflow. The lake has no outlet, and water is lost mainly by evaporation. Very little hydrogeological data is available for effective evaluation in the region, and groundwater recharge zones and amount of groundwater recharge to the lake are largely unknown (Odada et al., 2003). However, because of land degradation and the increasing number of settlements, it is likely that groundwater recharge has, to some extent, decreased (Odada et al., 2003). There is thus a need to establish the extent and volume of groundwater resources and to initiate its sustainable development as a source of potable water in the region

The freshwater resources are critical for the livelihoods of the pastoralists and agro-pastoralists in this largely arid district. With the very low rainfall in the region, food security is inextricably linked to the water resources. However, the rate of abstraction is currently unsustainable and freshwater shortage is likely to become more acute (Odada et al., 2003). There are thus a number of key strategic challenges in managing water resources that are constraining the capacity of the people to build a sustainable livelihood system around livestock (Government of Kenya, 2005). At least, communities need to be empowered to manage existing water facilities responsibly; and sources should be protected from domestic and livestock contamination.

The **Resources sub-network** measures availability of water resources (Figure 43). It is based in the context of diminishing water availability as a result of inadequate management of water resources on the supply side, and increasing use of water as a function of population growth and local livelihoods on the demand side.
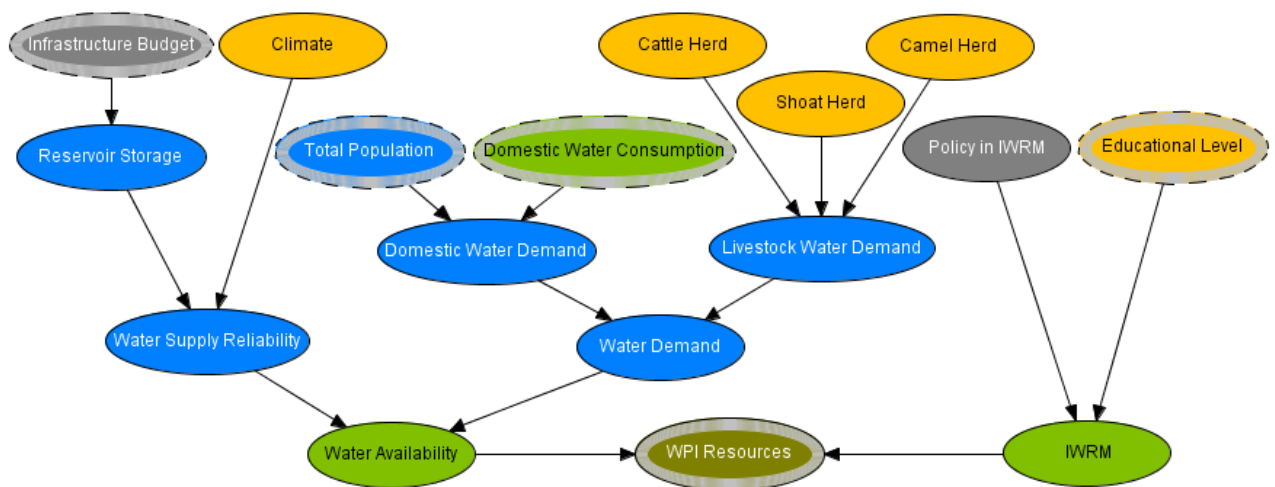

Figure 43 The Resources sub-network

In this respect, a set of variables determine water quantity as a balance between water demand and

availability. The seasonal resource variability is another factor that has been taken into account. However, lack of relevant data is a major constraint when these variables are assessed at local scale. Hydrogeological data are basically non-existent and groundwater recharges unknown. Information sources employed to assess these nodes have thus been qualitative.

At the same time, studies are required to quantitatively determine the effects of reservoirs construction on freshwater shortages and on water supply reliability. As distinct from this supply-side focus on developing the "water resource" by investing in infrastructure, Integrated Water Resources Management (IWRM) emphasizes the need to also embrace demand-side management, so that the needs of all users are met, while at the same time maintaining a healthy environment. On the whole the ability to make headway towards IWRM is currently limited.

Access - In the Turkana District, lack of access to safe water and adequate sanitation remains particularly acute. It is estimated that only 28% of households have access to potable water, while proper sanitation facilities are basically non-existent (United Nations Children's Fund, 2006b). Moreover, about 20-30 per cent of the community-managed water supplies developed over the past 20 years are no longer functional. This high rate of malfunction is caused by poor access to a reliable supply chain for spare parts; a lack of capability of institutions to help the recipient communities manage the services; poor governance at the community level; and a reduced ability of the population to pay for water. Although construction of new schemes is required to increase coverage, the Programme also needs to focus on building up recipient capacity to maintain them.

The *Access sub-network* assesses whether or not people have access to improved water supplies and sanitation (Figure 44).
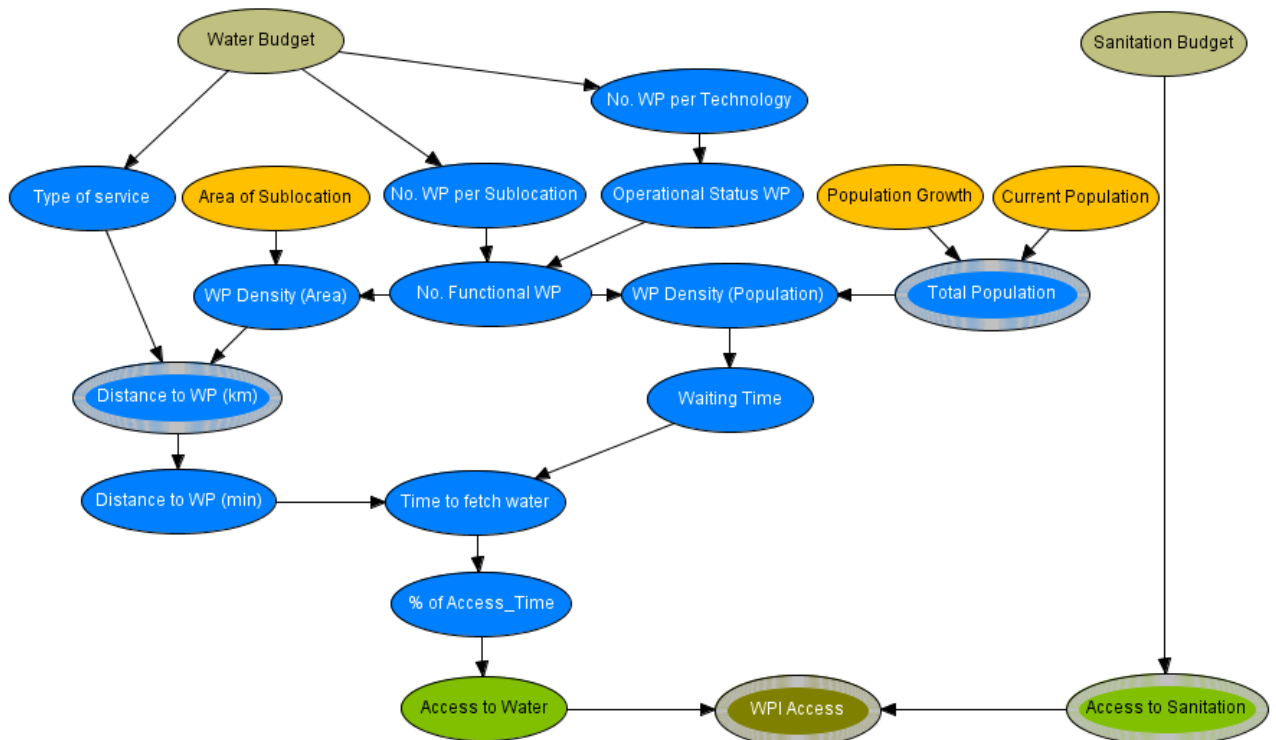

Figure 44 The Access sub-network

As a key measure of accessibility a set of variables are used to determine the reduction of time invested in securing water after the Programme completion. However, no data was collected on water user fees, which can be a big burden for the most vulnerable groups within the community. In case of unaffordable expenses, the poor might be forced to collect water from unprotected sources — when available — or to manage with minimum amounts at other times. Therefore, if the project is aimed at poverty eradication, the "Access" variable would need to target poor people living in rural areas that currently do not use safe drinking water and/or sanitation facilities and do not practice appropriate hygiene. The sanitation component considers the number of people to be served by the project.

Capacity - The poor performance of centrally managed rural water supply programs implemented in the past has caused a shift towards local governance. Such decentralization process can only be achieved through a variety of institutional arrangements, and the Water Act provides for a decentralized structure to separately improve water resources management and water services delivery (Government of Kenya, 2002). The Act establishes an autonomous Water Resources Management Authority (WRMA), destined to manage and protect Kenya's resources. It also shapes an adequate institutional sector reform that give responsibility for providing decentralized services to regional Water Services Boards (WSB). In relation to WaSH, the new framework adopts a demand based approach where the communities will take leadership in planning, preparing proposals, implementation and post-completion maintenance and management of their water and sanitation facilities. To this end, WaSH Committees are created to represent the users. The Programme is also aimed at developing community ownership over the water schemes. The Water Service Boards, in turn, are committed to manage water supplies assets and provide capacity building support to create an enabling environment that promotes user participation. In short, these boards are responsible for appraising the community proposals and contracting during the implementation activities. After project completion, they need to regulate Water Service Providers as well as to monitor the sector. The Water Service Providers (WSPs) will be responsible for operating and managing water supplies. They may be from the private sector, NGOs, CBO, and others. In this respect, community groups may also apply to the WSB to be licensed as a WSP; and particularly the registration of women groups is to be encouraged to establish an effective community based management system of the schemes, since it has been shown elsewhere that waterpoints managed by women groups perform the best (United Nations Children's Fund and Government of Kenya, 2006).

The biggest challenge lies within the capacity of all these new institutions to perform as expected and lead in revitalising the water sector. Thus, emphasis should be placed on building up capacities of the recipient organizations, and on institutional support from the Government and non-Governmental organizations. At present, not all the communities are equally prepared to efficiently fulfil their responsibilities; and local authorities lack strategic oversight. Another constraint is low levels of literacy, which directly affects effective operation and maintenance of water facilities.

Equally important, the problem of supplying spare parts in rural areas for water schemes and the availability of technicians needs to be highlighted. Despite the robustness of the private sector in Kenya, it is not uniformly strong in water, sanitation and hygiene related supplies and services in the Turkana district. Such gaps are currently filled through sourcing from neighbouring districts or from Nairobi. Therefore, private sector capacity building and development of a reliable supply chain needs to be supported to ensure sector skills and spare parts availability when the need

arises; minimizing the time required repairing the scheme and thus improving its effectiveness.

The *Capacity sub-network* (Figure 45) aims to represent all key variables that determine to what extent the decentralization process is to be implemented throughout the Programme.

The first group of nodes focuses on the institutional framework required to properly manage the services. Integral to this set of variables, an assessment of the community financing strategies appears essential, to understand which mechanisms are in place for revenue collection that contribute towards the cost of running the water supply. However, no reliable data relating to this aspect was available so this information has been omitted from the model. Another group of variables determines the status of the supply of equipment and spare parts in the local markets, as well as the private sector skills and capacities. Both aspects are required to properly operate and maintain the facilities once the intervention is completed. Finally, it should be noted that the "output" node "*WPI Capacity*" is likely to be related to the long-term functionality of the water schemes (in the Access sub-network). However, this variable appears itself as an "objective" node, and therefore this causal relationship has not been considered in order to avoid redundancy and double-counting, which might bias the result.
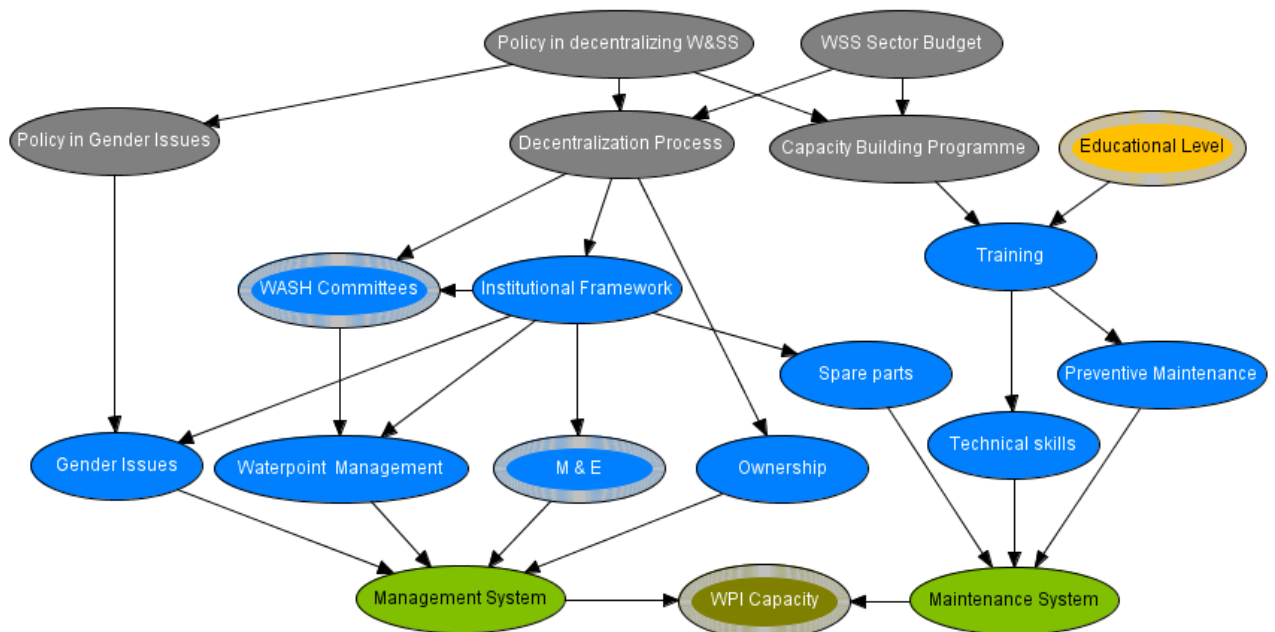
Figure 45 The Capacity sub-network

Use - The people in the area are mainly pastoralists, and to a lesser extent, agro-pastoralists. Therefore, although the primary purpose for investment should be to increase the use of safe domestic water for households, the promotion of low cost water saving technologies that can be used to increase food production is also essential. In agro-pastoralist societies, small-scale irrigation and livestock watering are key components for sustaining livelihoods. These activities require an adequate water supply.

Equally important, lack of access to safe water and adequate sanitation are major underlying causes of several diseases, including diarrhoea, intestinal helminths, schistosomiasis, common eye

infections such as trachoma, and skin diseases. In this region, it is expected that more than 25% of the population are affected by bacterial-related gastroenteritic disorders (Odada et al., 2003). However, water and sanitation improvements do not automatically produce the desired effects on population health, and the inclusion of hygiene education is required. Certainly, the reduction of water-related diseases depends on multiple improvements in home hygiene. In brief, of primary importance is the safe disposal of human faeces, thereby reducing the pathogen load in the ambient environment. Similarly, increasing the quantity of water allows for better hygiene practices, while raising the quality of drinking water reduces the ingestion of pathogens. Therefore, if health benefits are to be realized, many other changes must be brought about in rural communities besides simply installing new hardware. At least, it involves changing hygiene habits, otherwise health indicators may not improve. In this respect, it is noted that health benefits associated with better water quality are smaller than those obtained through improving accessibility of water, if this leads to an increase in the volume of water used for personal and domestic hygiene practices (Cairncross and Feachem, 1993; Esrey et al., 1991; Huttly et al., 1997) In consequence, programme managers should not expect significant health benefits associated with increased accessibility of water unless i) traditional water sources are particularly far away, ii) queuing is time-consuming, or iii) where water can be supplied to each household26.

The *Use sub-network* captures the use communities make of the water, and tries to highlight that water availability for growing food (agriculture and livestock) is as important as domestic consumption (Figure 46). The network identifies two potential types of action for promoting an adequate water usage: hygiene awareness-education campaigns, and implementation of low cost water saving technologies.
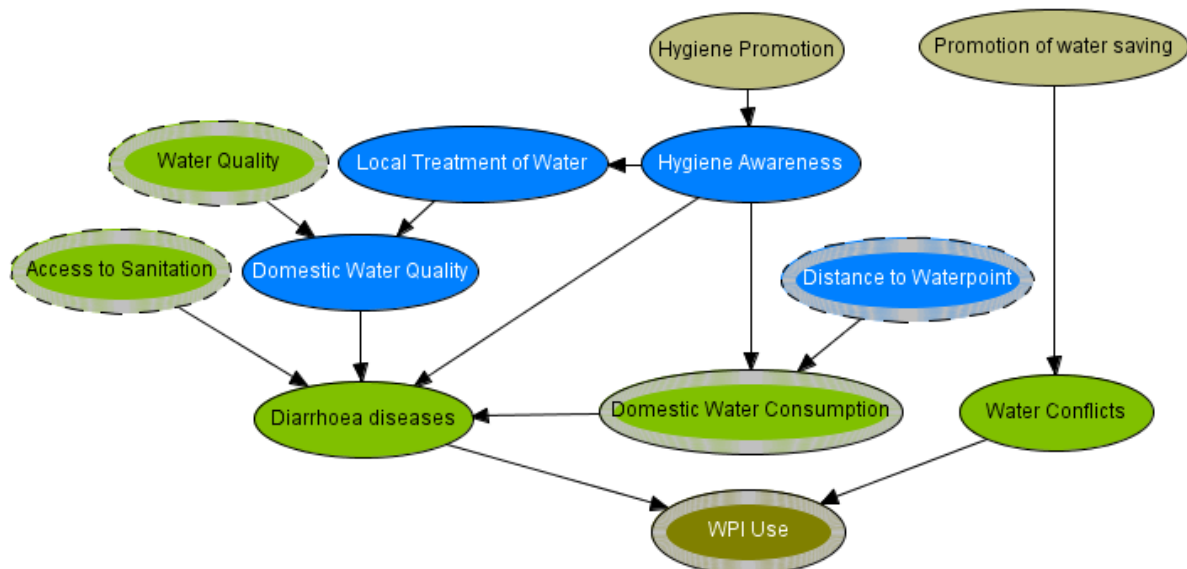
Figure 46 The Use sub-network

First, a set of nodes determine reductions in diarrhoeal diseases due to improvements in water and sanitation infrastructure and hygiene education. It indicates that water may become contaminated by poor collection, transportation and handling practices; as people collect it from a source and take it home. Therefore, safe storage of drinking water might substantially decrease the burden of water-borne diseases. On the other hand, there is considerable debate about the impact of

household water treatment on diarrhoea (Schmidt and Cairncross, 2009), so its promotion as an effective practise appears to be premature. In any event, since accurate health data is lacking, a comprehensive literature review has provided an adequate starting point to report median reduction in morbidity from each type of intervention (Esrey and Habicht, 1986; Esrey et al., 1991; Fewtrell et al., 2005).

Second, the amounts of water required for purposes other than domestic needs are often larger, and this can lead to competition between uses. Reports of conflicts over water sources are included as a variable in this respect.

Environment - Improvements in water supplies should not lead to environmental damage. A primary concern with environmental degradation is its likely impact on water resources, especially on water quality.

The Lake Turkana water itself is not suitable for drinking due to its moderate salinity (2.5‰), high alkalinity (pH = 9.2) and total dissolved solids concentration (Odada et al., 2003), but as previously mentioned, the affluent river waters and shallow wells along the rivers are being used as sources of potable water. At present, there is no evidence to show that microbiological and chemical pollution, solid wastes, and spills are of any threat to the lake and its rivers; since there is basically no industrial, large scale agricultural, or other type of development that can significantly contribute to contamination of the water bodies. On the other hand, populations close to the riverbanks are likely to pollute the waters to not inconsiderable levels, thus rendering the freshwater shortage more acute because of its reduced quality. In particular, contamination of point sources may occur because of inadequate sanitary protection measures due to poor design, siting, construction or lack of maintenance (Howard, 2002). Therefore, a range of measures might be in place to protect the source from becoming contaminated, not only those in the immediate area of the waterpoint but also broader protection measures. Besides source protection, and since water quality may change very rapidly over time and short distances, appropriate routine monitoring programmes are also required.

The Water Resources Management Authority (WMRA) is responsible for the protection of the water resources, and an effective sector coordination mechanism should be in place to strengthen collaboration with the National Environment Management Authority (NEMA), which has the legal mandate for environmental protection. In short, potential environmental impacts that could arise include i) abovementioned contamination of water bodies; ii) land degradation, increased erosion rates and deforestation; iii) conflicts over grazing; iv) intense cultivation which require application of fertilisers and pesticides; and v) proliferation of human settlements. Although there is no direct information to assess previous impacts in the district, it is known that they all will lead, to some extent, to the depletion of natural water supplies (both surface and groundwater), with evident adverse consequences.

Finally, construction of dams in the region may have impacted negatively on the livelihoods of downstream river users and the lake ecosystem, through increased freshwater shortage and lowered lake levels (Odada et al., 2003). Studies are, however, required to quantitatively determine the environmental effects of dam construction.

The *Environment sub-network* combines a number of environmental indicators which not only

cover water quality, but also variables that are likely to impact on ecological integrity (Figure 47).

This sub-index is thus calculated on the basis of an average of two different nodes: (i) water quality, as an important factor influencing its availability; and (ii) an environmental impact assessment, which considers all potential environmental impacts on water resources. In terms of water quality, it should be noted that no data was collected on microbiological quality and other biochemical parameters, and information was obtained through qualitative questionnaires. Further refinements to the network include the provision of sound data in this regard. The second subgroup of variables deals with major potential environmental hazards.
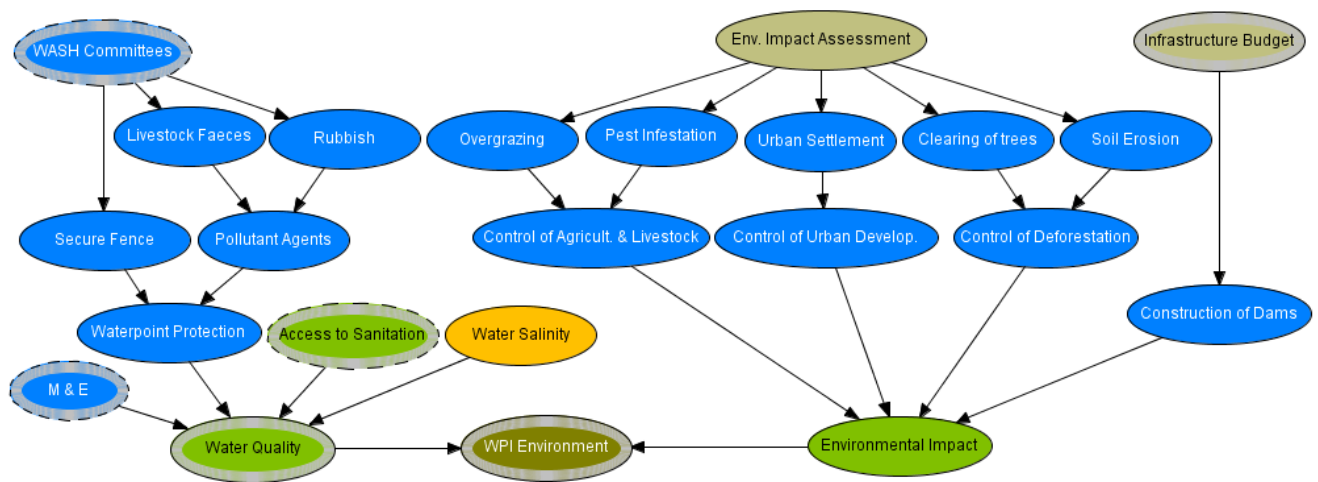

Figure 47 The Environment sub-network

The Water Poverty Index, through an object oriented Bayesian network

To represent the theoretical framework of the water poverty index, an ooBn approach has been used to exploit the flexibility of Bns. In this respect, in previous sections each variable of the original index has been presented as a separate sub-network. In these five sub-networks, the "objective" variable appears as an output node, but also as an input node in an additional master network that has been developed to integrate all the index variables. These "instance" nodes thus enable the link between five sub-networks and the master network. At the same time, simple causal relations are not very conducive to a good understanding of the system. It is believed that some variables are relevant for multiple sub-networks, and to accommodate them in one single sub-network leads to oversimplification and fails to capture the crosscutting nature of water poverty issues. These variables are represented as interface nodes in more than one sub-network, as shown in Figure 48.

It can be seen from the graph that any refinement in a variable of any sub-network will result in a chain reaction of impacts on all the linked variables, affecting the outputs of the whole system. In consequence, a major advantage of this tool is that it can easily predict the impact of a number of potential interventions on all interrelated factors; and therefore to identify which action, or combination of actions, will produce desired results appears straightforward.

In terms of method, the aggregation function employed in index construction is the summation of

the equally weighted sub-indices (Resources, Access, Capacity, Use and Environment). Within a network, links between variables are not restricted to probability tables, and they can also be specified through a standard mathematical expression. Thus, and equal to the original index (Sullivan, 2002; Sullivan et al., 2003), the final "objective" node "*Water Poverty Index*" is assessed through the unweighted average of the five parent variables.
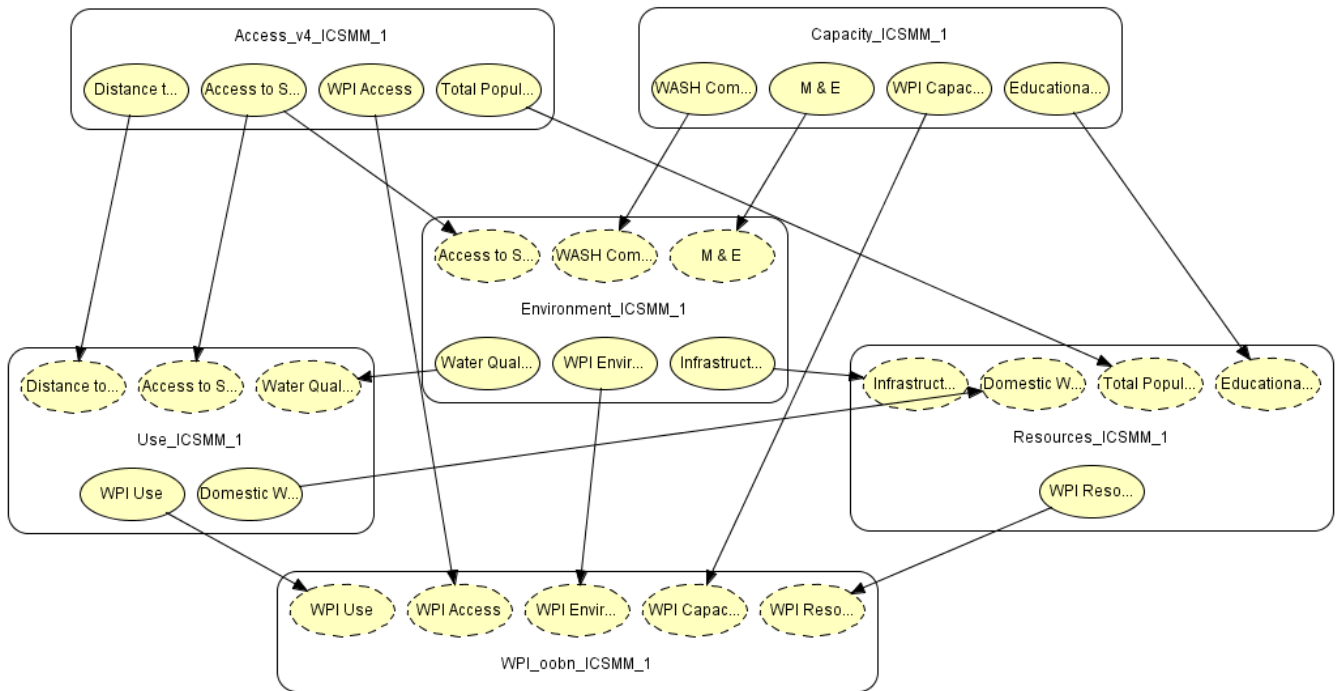

Figure 48 Scheme of the ooBn master network

4.2. Results and Discussion: Assessing the impact of the WASH Programme

The task of evaluating the overall impact of a WaSH intervention on water poverty is a daunting task. It goes beyond simply determining an objective number of beneficiaries or assessing a defined set of verifiable indicators. This involves the integration of a large number of variables, which are in turn marked by some degree of uncertainty. It thus requires a transparent means of representing the produced effects of different project approaches while dealing with different uncertainty sources that inevitably exists with development interventions in the water sector. As mentioned, an ooBn approach has been adopted for this purpose. The results shown in this section represent a first attempt of the development and application of an ooBn to assess the water poverty index at local scale. Therefore, rigorous checking to prove that the index values are coherent with the true degree of water poverty remains elusive. Rather, such a tool might serve to assist with a preliminary evaluation of the targets set by the WASH Programme.

Two different scenarios have been simulated. The first scenario is assumed to be described by the current situation, where no intervention has been undertaken; whereas the second scenario adopts the project approach. In accordance with the Programme strategy, the set of actions to be implemented have been represented in the networks as "intervention" variables (listed in Table 30). It is by acting on these nodes that the software has simulated both scenarios.

Table 30 CPTs of the "intervention" variables in two simulated scenarios

Sub-network	Variable	States	No Intervention	WaSH Programme
Resources	Policy in IWRM	Non-existence of policies to promote IWRM	1	0.5
		Existence of policies to promote IWRM	0	0.5
Access	Water Budget	No Intervention	1	0
		Rehabilitation	0	0
		New Infrastructure	0	0
		Rehab. + New Infrastructure	0	1
	Sanitation Budget	No Intervention	1	0
		Intervention – Poor	0	1
		Intervention – Adequate	0	0
		Intervention – Universal Programme	0	0
Capacity	Policy in decentralizing W&SS services	Non-existence of policies to decentralize services	0	0
		Existence of policies to decentralize services	1	1
	WSS Sector Budget	Non-existence of budget to decentralize services	1	0.5
		Existence of adequate budget to decentralize services	0	0.5
Use	Hygiene Promotion	Non-existence of hygiene promotion campaigns	1	0
		Existence of hygiene promotion campaigns	0	1
	Promotion of water saving technologies	Low cost water saving technologies are not promoted	1	0.5
		Promotion of low cost water saving technologies	0	0.5
Environment	Environmental Impact Assessment (EIA)	No EIA + No mitigation measures to minimize environmental impacts	1	0.5
		EIA + Mitigation measures to minimize environmental impacts	0	0.5
	Infrastructure Budget	Low	1	0.5
		Low – Medium	0	0.5
		Medium – High	0	0
		High	0	0

The impacts of the WaSH initiative have been determined and compared with respect to the present condition, and such changes are presented in Figures 49 and 50. According to both graphs, the intervention would produce a positive impact on overall water poverty, since values of the index slightly improve after the project completion. However, the index provides a starting point for analysis. An accurate focus on the five variables might help to direct attention to those water sector needs that require special policy attention.
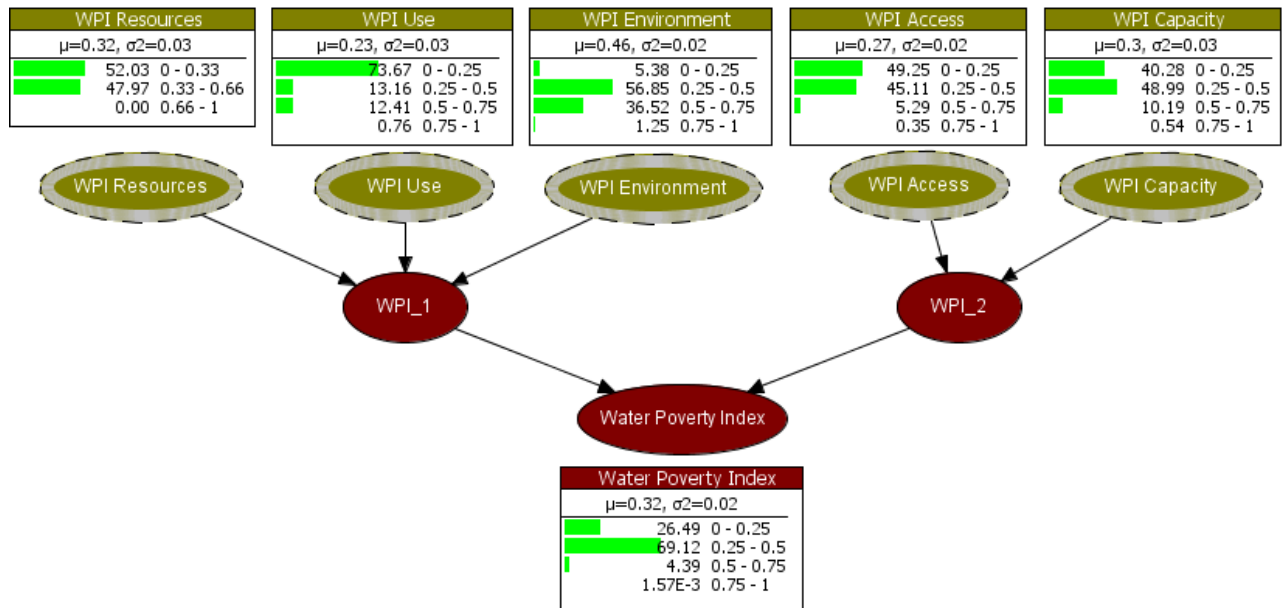
Figure 49 Final WPI Values: No Intervention

For example, and in accordance with Figure 49, aspects requiring urgent intervention are those related to the "Use" components, though "Resources", "Access" and "Capacity" variables are also far from being adequate. If this situation is compared to that represented in Figure 50, it can be seen that the Programme primarily impacts on the "Use" sub-network, while it also improves to different extent the rest of variables. A more detailed description of achieved results at sub-network level follows.

Figure 50 Final WPI Values: WASH Programme

Improving water resources management - The Programme aspires to promote awareness creation, policy dissemination and appropriate support from relevant authorities and effective

community management structures (e.g. WaSH committees) to improved water resource management. The concern is not only for degradation of rivers and water catchments, where WRMA are committed to water resources conservation, but also at the micro-level. Inadequate designs of schemes to prevent source pollution and poor manageme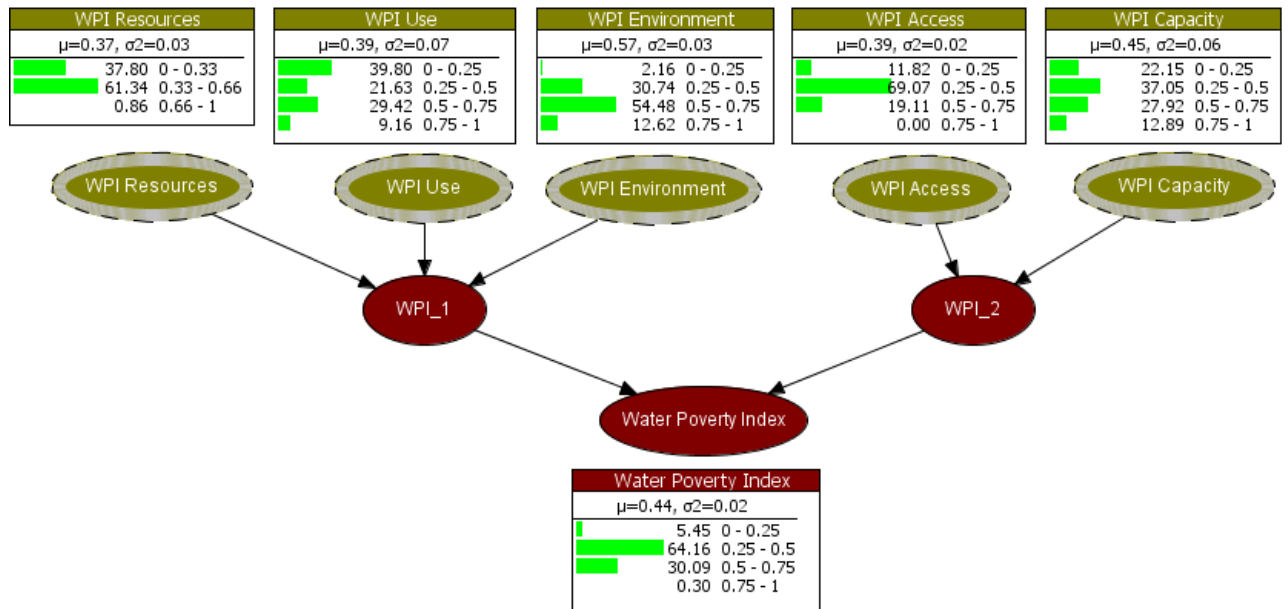nt of water points may lead to increased pollution of the water bodies, and building up recipient capacity is foreseen in this regard. It can be seen in the figures that the "Resources" component slightly improves after project completion. However, the freshwater shortage still remains a priority concern for sustaining the livelihoods in the district.

Construction / Rehabilitation of new infrastructure - The rural water supply component of the intervention includes in the Turkana District the development of water sources for new users (32,500 beneficiaries) currently unserved, and the rehabilitation of existing dysfunctional water systems that will be used by additional 42,000 people (United Nations Children's Fund and Government of Kenya, 2006). Various technological options will be employed to develop new sources, with strong emphasis on appropriate and local sustainable options (i.e. deep boreholes, rock catchments and rain water harvesting). The promotion of household sanitation will be closely linked to the provision of water facilities and to promotion of hygiene. However, Government allocation and expenditure for environmental health is very low compared to expenditures for curative health. Sanitation and hygiene promotion therefore enjoys a very low profile. The implementation strategy relies on a competitive marketing approach, and the target is to ensure at least 23,320 households properly using a toilet at home. For the "Access" component, and contrary to what might be expected, the project investment is unlikely to meet the MDG water and sanitation targets. According to Figure 50, it is estimated that more than half of the rural population still do not have access to safe drinking water and basic sanitation after the Programme completion.

Building up recipient capacity - Capacity to manage water facilities is required both at local and regional scale, and a major challenge is thus to address the existing gap in institutional performance. The project will help the new sector-related organizations to meet the necessary skills and abilities to assume their commitment. In particular, the capacity building process includes the provision of basic equipment and training in planning, procurement and management skills. At community level, women groups will receive priority in the ownership of the water facilities and in the process of hygiene and sanitation promotion. Equally important, stimulation and strengthening of the local private sector for the development of adequate spare parts supply chain will be supported. It is concluded from the results obtained that the institutional framework to aid communities to manage water facilities is far from adequate; there is still room for improvement in the majority of communities in terms of capacity building and institutional support.

Promoting hygiene - Hygiene education and promotion is expected to be a core activity within the Programme. It will consist of two different components (United Nations Children's Fund and Government of Kenya, 2006): promotion of behavioural changes and promotion of appropriate technology. In the same way as with sanitation, the target is to cover 23,320 households through direct marketing, though larger numbers are likely to be reached by mass marketing (e.g. radio, local newspapers and promotional campaigns). At the end of the promotion, communities should have a good level of understanding of the link between poor hygiene and diseases. At the same time, the project will foster hygienic handling of water as well as point-of-use treatment. It is

assumed that direct beneficiaries of the Programme access potable water sources and that good hygiene will ensure safety at the point of use. For the un-served population, household water treatment is promoted to improve their drinking water from whatever source they use and thus ensure safety. Technologies for treatment at the point of use will include solar disinfection, filtration and chlorination. Finally, and with the new water supplies, some of the multiple uses of water (e.g. livestock watering, the production of fodder for animals, small-scale irrigation) are to be encouraged to increase food security and thus reduce the vulnerability of the people living in the area. The results depicted in Figures 49 and 50 reveal that major impact after project completion is related to the "Use" component. This highlights that hygiene promotion might be a true cost-effective intervention.

Protecting the environment - Preservation of the environmental integrity appears crucial. In this respect, it is the NEMA who has the legal commitment to protect and maintain the environment. Its regulations require EIAs to be carried out before approval of any major water projects; with the aim of minimizing potential environmental impacts. This clearly affects all the investments to be implemented throughout the Programme. In parallel, the WMRA is responsible for the adequate management of the water bodies. As a key activity, a drinking water surveillance programme is to be developed for continuous water quality monitoring. The "Environment" variable exhibited the highest scores; results show that promoting EIAs would allow the maintenance of the environment. On the other hand, more efforts are required to guarantee safe water for domestic consumption.

5. Conclusions

The delivery of water and sanitation services has shifted to decentralized approaches, where control over management and implementation of activities devolves to local governments. The underlying hypothesis is that local authorities will be more responsive to the needs of the poor. Any prospect for effective pro-poor policies, though, depends upon real efforts to improve local strategic planning. This requires, among others, the need to strengthen the capacity of decentralized authorities to spotlight the neediest areas and identify the most vulnerable populations. The goal would be to assist policymakers in directing efforts towards more equitable allocation of resources. This chapter presents various monitoring tools to support targeting and prioritization, which exploited further, can guide the elaboration of development initiatives.

The role of aggregated indicators is first discussed. To start with, an improved method for index construction is described, which may be summarized in three key steps: i) selection and combination of key indicators into their corresponding subindices, using an equal and dimensionless numeric scale; ii) determination of weights for all subindices and their aggregation to yield an overall index; and iii) validation of the composite using a sensitivity analysis. Three different alternatives to select and combine indicators at subindex level have been proposed, two different weighting systems have been applied, and two aggregation forms have been used to construct the index. In all, six alternative methods are compared. It has been found that the weighted multiplicative function $WPI_{2,W,G}$ (selection of indicators based on PCA, and weighted geometric mean of subindices) presents less eclipsing problems. Furthermore, this function does not allow compensability among the different variables of the index. Based on the sensitivity analysis, it is inferred that it also exhibits highest sensitivity and a linear behaviour with variations

in indicator values. Therefore, this alternative is presented as the most suitable aggregation method for assessment of water poverty.

Taking this methodology for index construction as a starting point, two composites are presented to unravel the linkages between water and poverty from different perspectives, namely the enhanced Water Poverty Index (eWPI) and the WASH Poverty Index (WASH PI). The eWPI approach combines the physical, environmental and social dimensions which are influencing sustainable development of water resources, and integrates within the indicator framework the existing pressures and policy responses to explicitly incorporate the cause-and-response logic. The applicability and usefulness of this index is tested through a real case study in a Peruvian watershed. The results indicate that at the Jequetepeque basin, water poverty follows a heterogeneous spatial pattern. The WASH PI is aimed at offering an objective evaluation tool for assessment of rural poverty issues, with a focus on water supply, basic sanitation and household hygiene. The index is not presented in the aggregated form but as a thematic indicator, i.e. the three sub-indices are examined individually. Kenya is selected as initial case study to illustrate the validity of the index, and results show that those arid and less densely populated districts seem to suffer increased levels of WaSH poverty. Above all, improved access to water supplies, use of basic sanitation country-wide and promotion of personal hygiene are identified as sectors which require urgent policy attention.

In an effort to improve decentralized planning, a short battery of thematic indices is also proposed to highlight which areas require policy attention and identify the most vulnerable populations. Specifically, six indices deal with water-related problems, and four indices describe the top sanitation and hygiene priorities. All of them have been disseminated through league tables and priority maps, which are easily understood by both policymakers and non-technical stakeholders. Three different case studies from East and Southern African countries (Kenya, Tanzania and Mozambique) are presented. Results indicate that by linking sector priorities with specific remedial actions, the indices translate development challenges into beneficial development. They ultimately assist decision-makers in guiding appropriate action towards better service delivery.

Finally, last section discusses the relevance of the use of an ooBn approach as an effective tool to aid water planners to make informed choices between alternative actions. Specifically, it discusses the advantages of applying Bns as decision support systems in the WaSH sector. The study shows that they are powerful for combining the wide variety of information sources relevant to water, sanitation and hygiene issues. Different sets of data from economic, environmental, physical and social domains have been used, and in those cases where data are limited or non-existent, the method falls back on "expert opinion". In addition, uncertainty of the data is dealt with in a transparent way and is explicitly represented in the output, which is particularly important in data-scarce contexts. The model also provides a transparent and holistic framework on which decisions can be based. Finally, the impact of a number of potential actions, or combination of actions, can be simulated very quickly. Therefore, Bns enable policy planners to easily identify the type of intervention in which to direct their efforts for maximum impact. In contrast, a major drawback is that Bns are computed using software that needs to be used by highly qualified people. This clearly hinders its wider implementation in low-income regions, where resources are limited and stakeholders often lack capacities to profit from the model once developed.

Overall, it is clear that aggregated indicators, planning indices and Bns appeal as policy tools for sector planning, performance monitoring, and resource allocation. However, this study is first iteration of these instruments, and as such, further efforts are needed to refine and upgrade them. It is proposed, for example, a better definition of indicators and indices on the basis of available data. The integration of different information sources (e.g. the water point, the household and public institutions schools and health centres-) might be relevant for this purpose. But it is first crucial to develop sustainable data updating mechanisms, which demands a trade-off between the scope and quality of the data and the complexity of updating methodologies. Another area for exploration is the analysis of the data itself. Simple indices and league tables can be easily computed through pre-programmed spreadsheets, but more advanced statistical analysis or GIS-based tools demand improved skills that may not be easily found at the local level. In the end, the effective implementation of these instruments in poverty alleviation strategies will demand continued engagement with relevant stakeholders and end-users in various ways.

CHAPTER 4

MECHANISMS TO EXPLOIT AND DISSEMINATE DATA FOR PLANNING PURPOSES

Abstract

The appropriation and continued use of planning instruments for decision-making purposes remains elusive, and the uptake and usage of such instruments by decision-makers is, at best, challenging. It is against this background that this chapter is concerned with the implementation of mechanisms to promote the exploitation of these tools at the local level. In particular, it presents various approaches to enhance data interpretation and promote data dissemination. The ultimate aim is to improve targeting and prioritization, these being central planning activities to guide appropriate action and policymaking towards improved service delivery.

In terms of data analysis, a focus on poverty reduction in planning requires a selection of beneficiaries based on needs and real hardship. A simple classification process is first proposed to prioritize among various populations. Also, the regional and socio-economic disparities should be adequately visualized, and equity issues are addressed in this chapter to identify population groups at risk. The goal is to assess the gaps in service provision between the poor and the better off. Finally, the issue of scale is discussed, in terms of both spatial and temporal variability, and the challenges associated with the application of indices and indicators at different scales are pointed out. As regards the dissemination of achieved results, two alternatives are proposed. First, poverty maps are developed to show at a glance the level of water poverty and its heterogeneous pattern within different geographic and administrative units. Second, a cluster analysis is performed to classify large amounts of information into manageable sets. Specifically, it is used to group information on populations based on their similarity on different indicators. The chapter suggests that previous approaches are helpful to easily and meaningfully interpret data, and there is thus potential for wider implementation.

Keywords: classification process; equity; scale; poverty maps; cluster analysis

This chapter is partially based on:

- **Giné Garriga, R.**, & Pérez Foguet, A. (2011). Application of a revised Water Poverty Index to target the water poor. *Water Science and Technology*, 63(6), 1099-1110.
- **Giné Garriga, R.**, Jiménez Fdez. de Palencia, A., Pérez Foguet, A. (2015). Improved monitoring framework for local planning in the water, sanitation and hygiene sector: From data to decision-making. *Sci. Total Environ*, 526, 204-214.

1. Introduction

In local planning, specific problems that the sector is trying to address range from improving the availability of reliable information, to enhancing the interpretation of information by all relevant stakeholders, and to encouraging the use of this information in decision-making processes (WaterAid, 2010). It is noteworthy, indeed, that even when information is accessible, there is no guarantee that it is adequately exploited for planning purposes. Much of what is labelled as monitoring stops at the level of reporting, with little action taken as a result of monitoring. Two elements are necessary to promote use of available information in policy-making (Grosh, 1997): the data must be analysed to enable an adequate interpretation of the problem at hand, and the outcomes produced in data analysis must be effectively communicated to end users. In an attempt to address these challenges, this chapter presents various mechanisms to enhance data interpretation and to promote data dissemination.

To start with, the data has to be exploited meaningfully and comprehensively, in order to produce outcomes that are relevant to the policy question and easily transferable to end users. In terms of poverty reduction, successful planning relies on selecting beneficiaries based on needs and real hardship. In consequence, a major concern in local decision-making is related to the lack of transparent mechanisms to target the neediest. Ideally, the most vulnerable segments of the population should be precisely identified, and their priorities determined (Giné Garriga et al., 2015; Jiménez and Pérez Foguet, 2011). The promotion of pro-poor prioritization mechanisms would ensure that they are recipient of policy attention and public resources. Also, few would dispute that equity-oriented planning should be promoted to help address the issue of non-discrimination (United Nations General Assembly, 2010a). The underlying hypothesis is that service level is highly dependent on social and economic conditions of population. Again, it is accepted that monitoring frameworks should correctly identify the high-risk groups (Joint Monitoring Programme, 2012a). Finally, from a planning perspective, evidence shows that to address scale issues and the dynamic linkages across scales is needed in data analysis to assess problems and find solutions that are more politically and environmentally sustainable (Cash et al., 2006).

Second, the way the data is disseminated is essential for decision-making purposes, as this might influence the interpretation of the outcomes and the communication of the policy messages. In consequence, user-friendly alternatives need to be exploited in an effort to communicate a clear picture of the problem in question to decision-makers quickly and accurately. In the water-poverty context, maps have come out a powerful tool for identifying and targeting the most water poor, and ultimately for allotting efforts and resources in accordance with efficiency and equity criteria (Cullis and O'Regan, 2004). Maps are therefore adequate to inform sector planning, and specifically to support poverty reduction initiatives. Similarly, clustering techniques may be useful to simultaneously deal with large amount of data and classify a number of population groups into manageable sets (i.e. clusters) by exploiting their similarity on the WaSH-related dimensions.

This chapter describes previous approaches to enhance the interpretation of the data. Specifically, Section 2 presents four mechanisms to improve data analysis; and Section 3 discusses about two alternatives to promote the visualization of the results achieved in data analysis.

2. Analysis of the data

One key challenge to promote evidence-based planning and encourage the use of available information in decision-making processes is related to the process of data analysis. In particular, the data has to be exploited meaningfully and comprehensively, in order to produce outcomes that are relevant to the policy question and easily transferable to end users. A variety of approaches are adopted herein to address this challenge. First, the risk of producing redundant information is minimized by performing correlation analysis during the validation stage of the policy tools. Second, a simple classification process to target the neediest and prioritize among various populations is described. Third, socioeconomic groups at risk are identified to support a pro-poor approach to planning. This is done by developing a wealth index, as a background characteristic that is used as a proxy for the long-term standard of living of the household. Fourth, the difficulties associated with the combination of data from different disciplines are discussed, and the issue of scale - in terms of both spatial and temporal variability - is highlighted. These approaches are described below.

2.1. Correlation issues

In index construction, when integrating large amounts of data, it may happen that - by combining variables with high degree of correlation - one may introduce an element of double counting (Nardo et al., 2005). Two collinear indicators measure same dimension, and including both indicators in the composite index may thus produce misleading results. Similarly, the accuracy of proxy measures developed to assess the various aspects of water poverty should be checked through correlation analysis. In particular, the lack of correlation in the different subindices of one aggregated indicator is a useful property of the composite. It indicates that the subindices are tackling different "dimensions" of a complex reality. The response is often testing indicators and indices for statistical correlation, for example with the Pearson correlation coefficient or the Principal Component Analysis (Nardo et al., 2005).

It is noticed that there will almost always be some positive correlation between different measures of the same aggregate; and a rule of thumb is thus to define a threshold beyond which the correlation is a symptom of double counting (Nardo et al., 2005). In those cases where some correlation is detected, one option is to choose only indicators exhibiting no clear links. Minimizing the number of variables in the index is also desirable on other grounds such as simplicity. Alternatively, one may opt for adjusting weights correspondingly, i.e. giving less weight to correlated indicators. As concluded in previous chapter, removal of indicators showing a low degree of correlation is recommended when computing the different subindices of one index, particularly in data-scarce contexts. In contrast, we propose the use of statistical weights to balance the different subindices of one composite in the aggregation process.

For illustrative purposes, taking as case study the data from Turkana District (Kenya), it is gleaned from Figure 51 that poor correlation exists among the five sub-indices of the WPI and the composite (low regression coefficients).
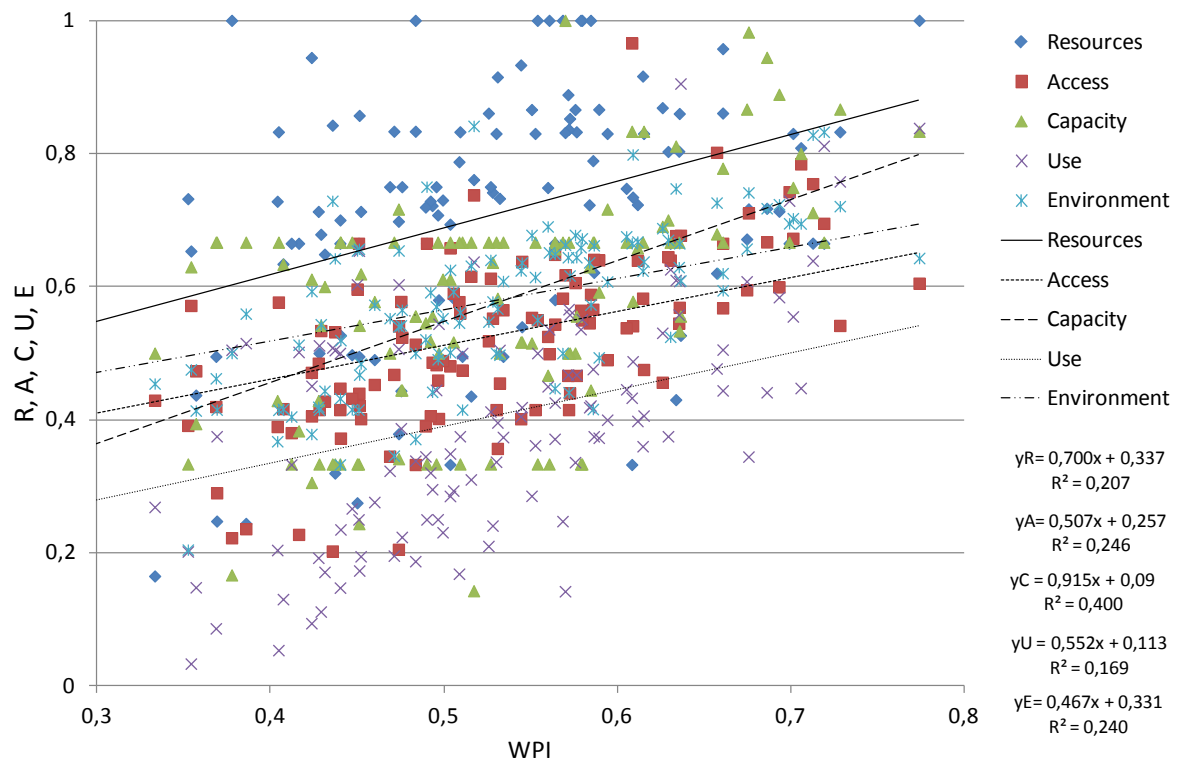
Figure 51 Correlation analysis of the Water Poverty Index and its five sub-indices. *Source*: Giné Garriga and Pérez Foguet (2011)

A revision of the Pearson's correlation confirms that variables are not redundant within them (Table 31). It is shown that some positive correlation exists between the "Use" and "Environment" components (Correlation Coefficient: 0.547), and this is main reason why lower weights have been statistically assigned to these variables.

Table 31 Correlation Matrix of the sub-indices of WPI

	Resources	**Access**	**Capacity**	**Use**	**Environment**	**Weight**
Resources	1	-0.064	0.101	-0.026	0.128	0.221
Access		1	0.221	0.102	0.380	0.245
Capacity			1	-0.129	-0.052	0.216
Use				1	0.547	0.177
Environment					1	0.141

As in the previous example, it is noted that in the Jequetepeque basin case study (Peru) poor correlation exists between five components and the final index (Figure 52). Specifically, the correlation coefficients (CC) prove that variables are not redundant within them, being all coefficients lower than 0.7.
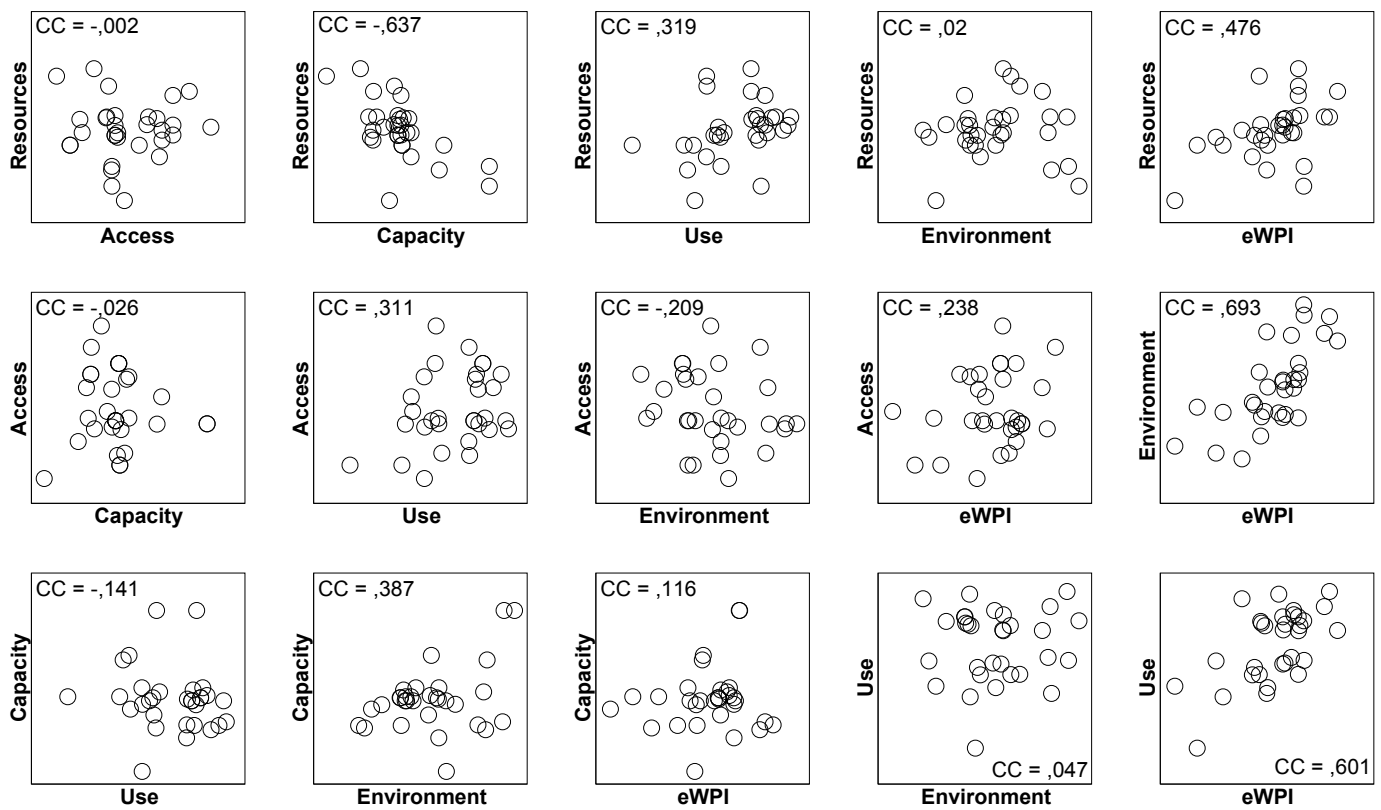
Figure 52 Scatter graphs of eWPI components and their correlation coefficients. *Source*: Pérez Foguet and Giné Garriga (2011)

2.2. Definition of priorities to support decision-making

In targeting and prioritization, the key issue is to correctly identify the most vulnerable populations. Indices and indicators proposed in Chapter 3 may be used as performance indicators for this purpose, and a straight comparison can be made when any population group is compared for example to the leader, the laggard or the average performance. Most importantly, however, index values might serve as the basis to rank and denote priorities, where the 'highest' priority is assigned to those communities with increased levels of poverty.

When defining priorities, a key issue is to guarantee reliability of the outcomes produced and thus avoid decisions based on false or misleading assumptions.. As mentioned in previous chapter, the sample of waterpoints in mapping campaigns is exhaustive - all waterpoints are included -, and no statistical analysis is thus required to meaningfully exploit the results at different geographical scales. This offers advantages over household data in terms of statistical precision and accuracy, since household estimates are computed on a sample by sample basis. Therefore, some basic statistics are needed in data analysis. To prioritize among various populations in relation to a given variable, a common approach is to consider the proportion p of households verifying a given variable with its respective confidence interval (p_L, p_U). However, at a local level with reduced populations, precision of estimates is often sacrificed due to sampling issues. Since large sample sizes would hinder in practice the implementation of local surveys, relative large lengths of confidence intervals are typically obtained. This presents a drawback from the viewpoint of

interpretability. Small area estimates (Ghosh and Rao, 1994; Rao, 2003) may be used to improve precision but only to a limited extent. In these contexts, the abovementioned approach is often underused or misused.

Alternatively, a simple algorithm may be employed to assign the estimates p to a specific category within a finite set of sorted options, as described for sample size design in Chapter 1. Let us consider the set of sorted categories covering the interval $C = [0,1]$ defined as $\bigcup_{i=1,\dots,m} C_i = C$, with null intersection between them. For instance, the intervals $C_i = [l_i, u_i)$, with $l_1 = 0$, including left boundary but not the right one, for $i = 1, \dots, m-1$, and the last interval $C_m = [l_{m-1}, 1]$, which includes both boundaries. Each category is characterized by its limit values l_i and u_i. To define the set of categories, the analysis focuses on checking the potential overlapping between the confidence interval (CI) of estimates from one category with the CI of the limit values of the other categories. Specifically, the criterion to accept the set of categories is that if an estimate lies in C_i, there is no reasonable chance for the real value to belong neither to C_{i-2} nor to C_{i+2}. Formally, the hypothesis test of the difference between proportions belonging to alternate categories being equal to zero is rejected in all cases. In practice, this criterion can be easily applied by comparing the CI of a given estimate p lying in C_i with those of limit estimates located in C_{i-2} and C_{i+2}; specifically, whether p_{U,C_i} is lower than $p_{L,C_{i+2}}$, and whether p_{L,C_i} is larger than $p_{U,C_{i-2}}$. If both conditions are confirmed for all estimates, the set of categories C_i may be considered adequate to discriminate proportions.

Table 32 Classification of bairros from Manhiça in relation to access to sanitation infrastructure. *Source*: Giné Garriga, R., Jiménez, A. and Pérez Foguet, A. (2015)

	Access to improved sanitation					**Open Defecation**				
	Rank	*pi*	*pli*	*pui*	*Prioritization Groups*	*Rank*	*pi*	*pli*	*pui*	*Prioritization Groups*
Balocuene	4	0,103	0,045	0,192	High Priority	7	0,051	0,014	0,126	No Priority
Cambeve	6	0,208	0,124	0,315	Priority	9	0,026	0,003	0,091	No Priority
Chibucutso	3	0,080	0,030	0,166	High Priority	5	0,067	0,022	0,149	No Priority
Chibututuine	5	0,115	0,054	0,208	High Priority	3	0,244	0,153	0,354	Low Priority
Maciana (+ Maragra)	13	0,533	0,450	0,615	No Priority	12	0,007	0,000	0,037	No Priority
Manhiça Sede	14	0,587	0,467	0,699	No Priority	10	0,013	0,000	0,072	No Priority
Matadouro	9	0,333	0,229	0,452	Low Priority	13	0,000	0,000	0,048	No Priority
Mitilene	2	0,067	0,022	0,149	High Priority	2	0,347	0,240	0,465	Priority
Mulembja	11	0,373	0,264	0,493	Low Priority	6	0,067	0,022	0,149	No Priority
Ribangue	10	0,372	0,265	0,489	Low Priority	14	0,000	0,000	0,046	No Priority
Ribjene	1	0,013	0,000	0,072	High Priority	1	0,613	0,494	0,724	High Priority
Timaquene	8	0,229	0,137	0,344	Priority	4	0,229	0,137	0,344	Low Priority
Tsá-Tsé	7	0,218	0,132	0,326	Priority	8	0,038	0,008	0,108	No Priority
Wenela	12	0,440	0,325	0,559	Low Priority	11	0,013	0,000	0,072	No Priority

Notes: a) a = 0.05 (95% confidence); b) Three bairros are excluded from the analysis since the sample of HHs is not adequate to achieve required statistical precision

To illustrate, we exploit the data from Manhiça (Mozambique) as a case study. Specifically, we set the priorities among the bairros of this municipality in relation to two planning indices described in Chapter 3: i) use of improved sanitation, and ii) practice of open defecation. It is gleaned from Table 32 that four categories may be defined in both indices by imposing the non-overlapping principle cited above. The first league table identifies those bairros with inadequate use of sanitation facilities, and for instance verifies that i) $(p_{u,i})$ Chibututuine is lower than $(p_{l,i})$ Matadouro (0,208 < 0,229); and ii) $(p_{u,i})$ Timaquene is lower than $(p_{l,i})$ Maciana (0,344 < 0,450). The second list aims to visualize the bairros that are free of open defecation and show, for example, that $p_{u,i})$ Mulembja is lower than $(p_{l,i})$ Mitilene (0,149 < 0,240); and ii) $(p_{u,i})$ Chibututuine is lower than $(p_{l,i})$ Ribjene (0,354 < 0,494). Different prioritization lists may be defined for different purposes following the same classification principle, and the previous examples only aim to show that despite low precision of estimates (large d values), the approach adopted herein is able to produce reliable inputs that may be exploited in targeting and prioritization processes. Finally, it is remarkable that previous league tables can be depicted in maps, which allows for an easy interpretation (see Figures 53 and 54).
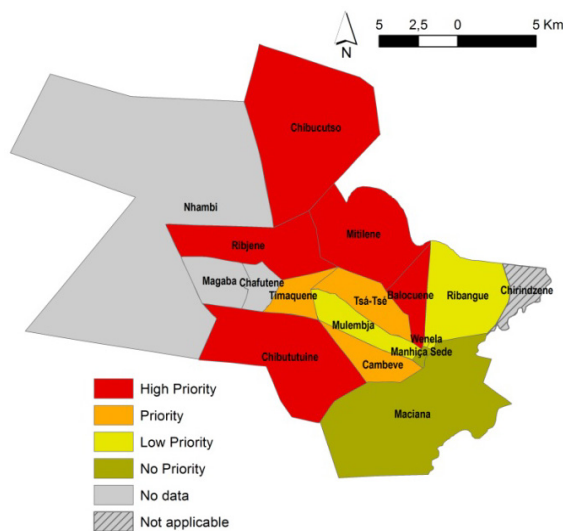

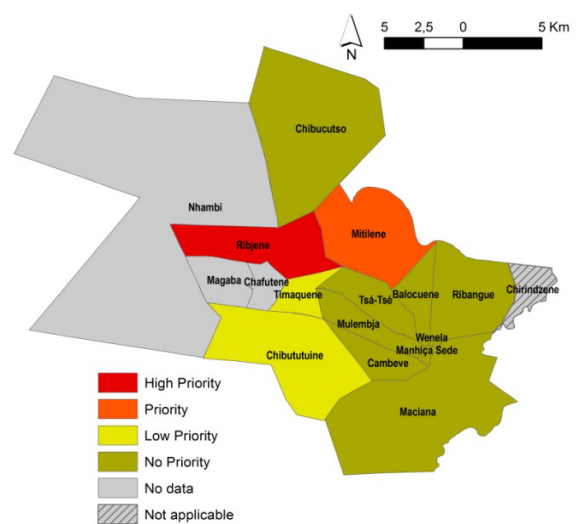**Figure 53** Improved Sanitation - Priorities (Manhiça)   **Figure 54** Open Defecation - Priorities (Manhiça)

2.3. Equity issues

In local planning, there is a growing concern in moving from coverage-based to pro-poor programming. Beyond average attainments, it is widely accepted that monitoring frameworks should identify the high-risk groups in which policy-makers may prioritize efforts and resources (Joint Monitoring Programme, 2012a). In addition, the recognition of the right to water and sanitation corroborates the need for mechanisms that address equity and non-discrimination (United Nations General Assembly, 2010a). Therefore, socio-economic disparities cannot be masked when planning through a pro-poor lens, as they are likely to determine different levels of service. An essential condition to prevent that the most vulnerable are overlooked in the process of increasing access is to disaggregate data by poverty levels, which provides the evidence base for equity-oriented planning.

To do this, the standard of living of the household is assessed. However, assessing household economic status poses considerable problems, and this raises the question of how best it can be done. The conventional approach is through 'direct' measures of living standards, such as household income or expenditure, but in low-income settings these data are often unreliable, unavailable or expensive and difficult to collect (Filmer and Pritchett, 2001). In the absence of accurate money-metric information, another approach is to use a 'proxy' measure of wealth. Assets that households have acquired, housing quality, water and sanitary facilities and other amenities are good indicators of 'long-run' welfare (Booysen et al., 2008; Cortinovis et al., 1993; Filmer and Pritchett, 2001; O'Donnell et al., 2007). Although this alternative also presents considerable limitations (Houweling et al., 2003), it has the merit of employing only data that can be easily collected in a single household interview (O'Donnell et al., 2007). In this research, a wealth index is developed for descriptive and monitoring purposes by assembling a long list of household durables (e.g. radio, television, bicycle, etc.) and various attributes of the household's dwelling (type of flooring; materials used for the roof and walls). Data on drinking water supply and type of sanitation are explicitly excluded from the measure for being direct determinants of the analysis. A Principal Component Analysis is performed to handle the vexing problem of weights, and it is assumed that the first component represents an adequate measure of welfare (Filmer and Pritchett, 2001; O'Donnell et al., 2007). When constructing the index, all asset items are summed and weighted by the elements of the first eigenvector.

In this section, the wealth index is used as a background characteristic to identify socio-economic groups at risk and observe whether gaps in service provision between the poor and the better off are remarkable. Specifically, households are stratified in quintiles according to their socioeconomic status, and the analysis explores the correlation between wealth and WaSH indicators. It employs the Pearson's chi-square test for this purpose[9], in which relationship between these variables are statistically assessed. The analysis is based on the data from the Kenyan case study.

To start with, statistics show that WPI, SPI and HPI are positively related to wealth, that is, water supply and sanitation infrastructures as well as hygiene knowledge are invariably worse among the poor (Figure 55). These figures confirm the urgent need for policymakers to focus on improving service delivery among the most vulnerable segments of the population, although complementary conclusions are reached when indicators are analysed separately.

As regards water supply, differences exist with wealth in relation to access to improved water sources; and it is noted for example that benefits of piped water on premises are enjoyed only by the wealthiest (Figure 56). In addition, time spent in fetching water considerably decreases with wealth; i.e. the proportion of households among the poorest spending more than half an hour is over two times that of the richest (Figure 57). When the analysis focuses on gender disparities in water collection, a slight improvement is observed in the richest quartiles. Finally, the per capita water consumption is also correlated with wealth, although in this case distance to the source might act as confounding variable.

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[9] In the Pearson's chi-square test, the null hypothesis is independence, and the value $p = 0.05$ is used as the cut-off for rejection or acceptance.
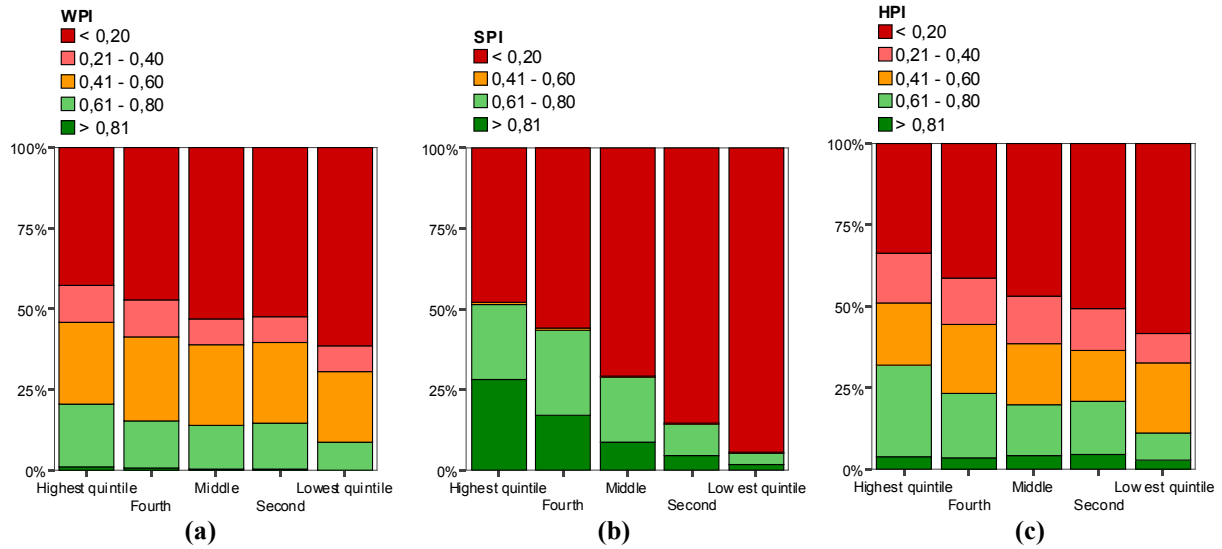
Figure 55 The WASH PI (% of HH), based on wealth. a) The Water Poverty Index. b) The Sanitation Poverty Index. c) The Hygiene Poverty Index. *Source*: Giné Garriga and Pérez Foguet (2013)
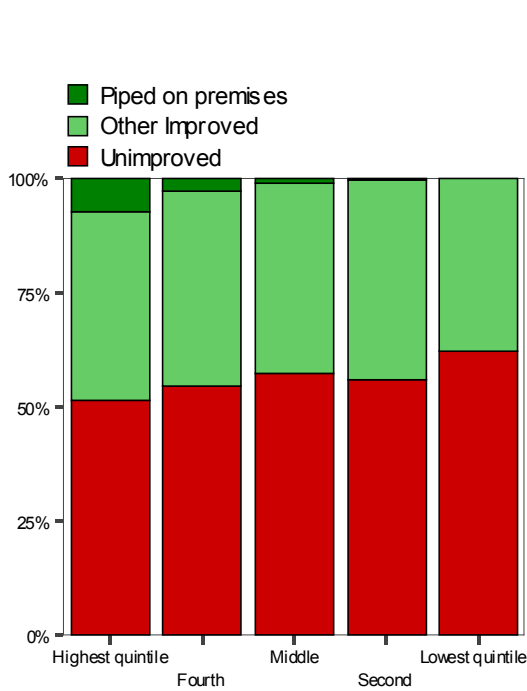

Figure 56 Access to improved drinking water sources (% of HH), based on wealth
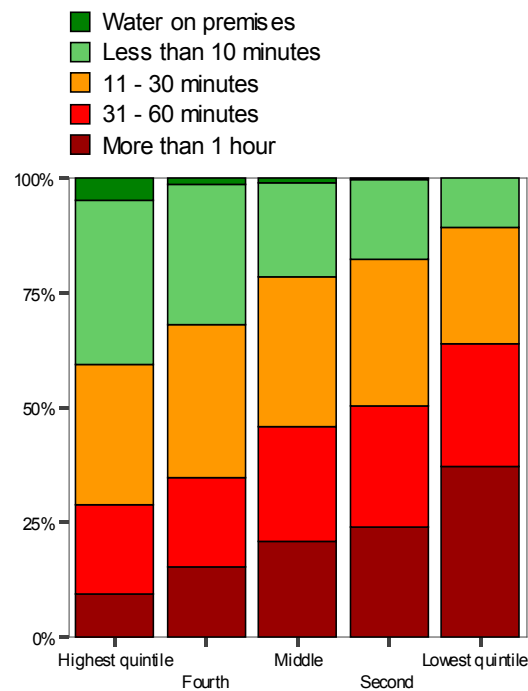
Figure 57 Time to fetch water (% of HH), based on wealth

It is also observed that use of basic sanitation shows strong association with wealth (Figure 58). The richest 20% of the population in the area of intervention is almost fourteen times as likely to use an improved facility as the poorest quintile. And the poorest 20% is around seven times more likely to practise open defecation than the richest quintile. Still, even among the richest, 10.9% practise open defecation. The variations in latrine conditions by wealth are also significant, although in this case the facilities of mid-wealth households are found in more risky sanitary conditions than that of the poorest (Figure 59). It is noted that a common sanitation practice within

the poor is open defecation, so sample size of latrines decreases as the level of wealth increases (877 households in the highest wealth quintile against 250 households in the poorest quintile).
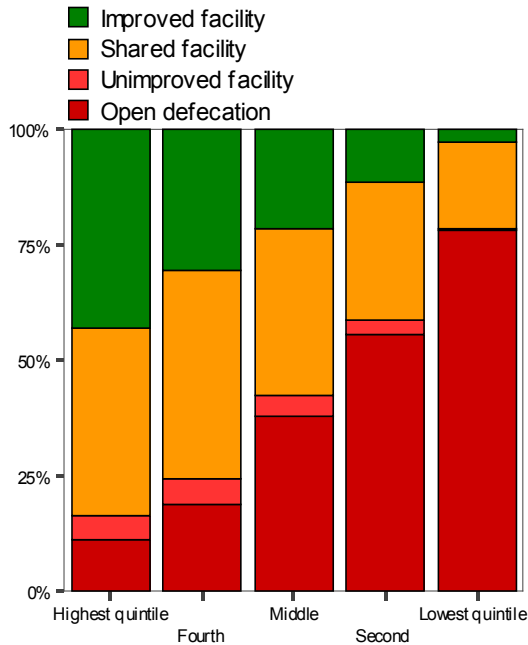
Figure 58 Access to improved sanitation (% of HH), based on wealth
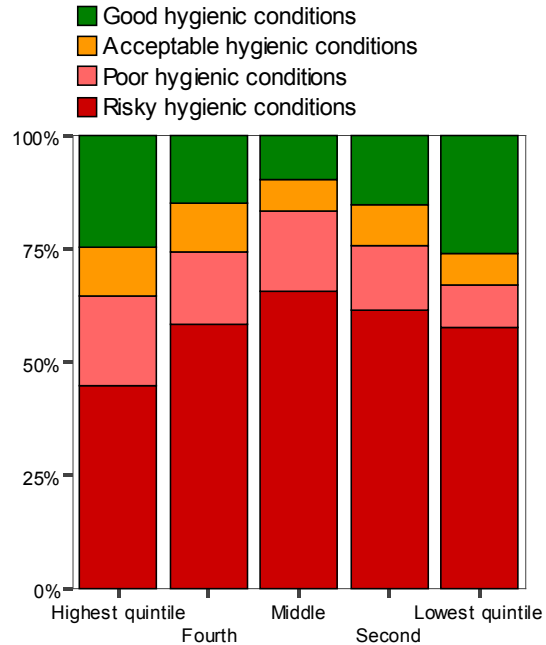
Figure 59 Sanitary conditions of latrines (% of latrines), based on wealth
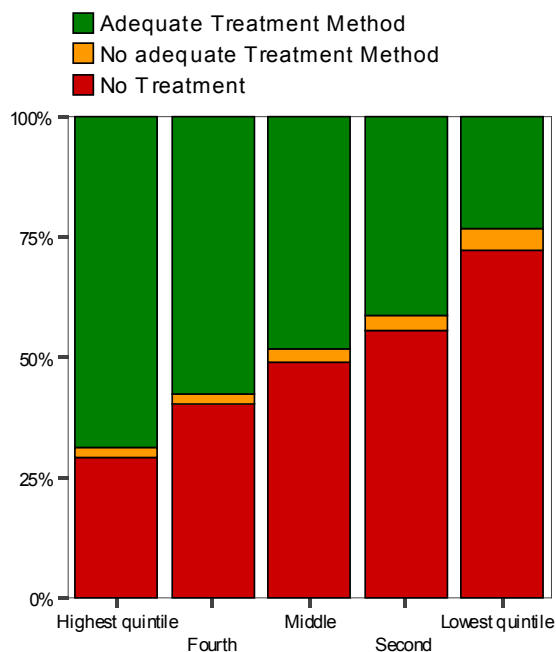
Figure 60 Adequacy of household water treatment (% of HH), based on wealth
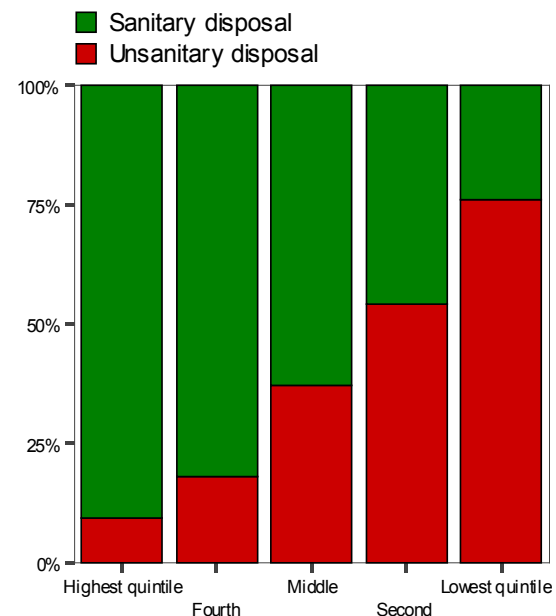
Figure 61 Disposal of children's stools, based on wealth

Regarding hygiene, it is gleaned from the statistics that percentage of households with adequate point-of-use treatment method significantly increases with wealth (Figure 60). And similar

conclusions might be drawn if the focus is on water handling / storage. It is also worth noting the correlation between safe disposal of children's stools with socio-economic status of the household (Figure 61). In this case, though, and contrary to what might be expected, access to improved sanitation does not produce a significant confounding effect.

In the end, results indicate that a focus on the neediest is required when addressing gaps in service delivery, which ultimately would promote more cost-effective and equality-based interventions.

2.4. The issue of scale

Water resources are often extremely variable, both on a spatial and temporal scale (Savenije, 2000; Sullivan and Meigh, 2007). Poverty is also a spatially heterogeneous phenomenon (Henninger and Snel, 2002). And intuitively, water poverty should represent a more obvious geographic variation than income poverty, as its incidence and magnitude owes to factors with spatial dimensions, such as water resource endowments, as well as to people's ability to access reliable water supplies (Cullis and O'Regan, 2004). In policymaking, it is thus essential that any assessment tool be applied at the appropriate scale to avoid misleading results, i.e. the extent to which indices accurately assess impact of development policies will partially depend on the scales at which they are applied (Cash et al., 2006; Lovell et al., 2002; Sullivan and Meigh, 2007). For example, national-level data may say nothing about regional variations; and inadequate provision of safe water at household level might be obscured by indices which operate at inappropriate scales (Sullivan and Meigh, 2007; Sullivan et al., 2006).

The spatial scale at which various types of knowledge are generated varies widely (Lovell et al., 2002; Sullivan and Meigh, 2007), since: i) climate models tend to be based on grids of about hundred kilometres; ii) assessment of water resources use smaller grids, typically covering areas of few thousands of km^2; iii) at the socio-economic and political levels, the scale relevant to policy making can range from the household to the nation; and iv) in terms of water quality, both spatial and temporal scales may vary depending on impacts of both point and diffuse sources of pollution. Similarly, natural water resources planning unit (watersheds) generally do not align themselves with jurisdictional boundaries and political governance. And despite the incongruence between water systems and national boundaries, the state is the basic unit for which most socio-economic data is collected, and it should be taken into account when defining suitable scales to apply monitoring tools. An attempt to integrate information that has been generated at different spatial scales consists on the use of geo-referenced datasets, which provide a means of linking data from different sources at any point on the globe (Cullis and O'Regan, 2004; Mlote et al., 2002; Sullivan, 2002). For instance, and by geo-referencing the various index variables, the link can be made between catchment-level hydrological data reflecting water availability, and micro-level data on household water stress. Within such a framework, for any specific point on the map, detailed and accurate information from both the social and physical sciences can be combined in an integrated way.

On the temporal scale, system change typically occurs at different rates, making it important to pay attention to the interactions among fast and slow changing variables (Lovell et al., 2002). On the one hand, slower changing variables might be undetectable because of the 'noise' created by monitoring fast changing variables. For instance, monitoring management decision making processes at monthly intervals versus government level policy changes regarding rights and

responsibilities annually (Cundill and Fabricius, 2009). On the other hand, while some variables change unpredictably (e.g. functionality of the water point), other variables are affected on a cyclical basis, such as seasonal changes in rainfall. Indeed, seasonality of water resources needs to be taken into consideration in any planning exercise, in order to storage sufficient water and ensure access to it when needed (Sullivan and Meigh, 2007). Likewise, appropriate knowledge of inter-annual variability is essential to mitigate vulnerability of water resources against the impact of climate change, and then foresee if water supplies will secure meeting future demands for water. Temporal variability of resources is subjected to high levels of uncertainty, and thus is more difficult to deal with than spatial variability (Sullivan and Meigh, 2007). One way to address this may be through single iteration (Sullivan et al., 2006), i.e. to regularly assess how the resources and conditions in a particular location have changed over time. This would provide a monitoring tool that enables trends to be revealed, as well as changes to be noted. Another approach to tackle temporal variability is to integrate cause-effect relationships, not only taking into account all existing pressures exerted on the environment but the policy responses that are implemented in a given place, in a given period (Walmsley, 2002).

In an attempt to bring all previous issues together, this section applies the enhanced Water Poverty Index - eWPI - (Pérez Foguet and Giné Garriga, 2011) at two different spatial scales: the community and the watershed.

Targeting the water poor at community scale

The eWPI has been piloted at local scale in Bolivia, in ten communities located at Tiraque Valley (Department of Cochabamba). In this region, water is seen as one of the most critically stressed resources, suffering from an increasing and competing demand, increased sources of pollution, inadequate management of water resources, low capacities to anticipate and mitigate against the impacts of flooding, and poor access to consistent information relating to water supplies. It seems evident that water sector development urgently requires the attention of policy makers. In this context, it is believed that the index might serve as a policy tool to support strategic and to target priority needs for interventions.

Table 33 lists all variables used to assess the eWPI at community scale. In this study, the selection of indicators has not been based on what is desirable to measure but on the need to use available data, avoiding further field data collection. According to the table, the set of identified variables has been found appropriate to describe at household level the essence of the five components of the index (Resources, Access, Capacity, Use, Environment) in all three different stages (Pressure - State - Response).

Table 33 WPI component variables and indicators used at community scale

Variables	Indicator – Pressure	Indicator - State	Indicator – Response
Resources			
Water resources availability	Annual Population Growth	Water Availability	Adequacy of water storage capacity
Rainfall	Rainfall variability	Rainfall	

Access

Access to safe water	Variation in safe water accessibility	Percent Population with access to safe water	Improvement in adequate water infrastructure (sector expenditure)
One way distance to water sources	Percent of HH who consider distance to water source an issue to solve	Distance to waterpoint	
Access to sanitation	Adequacy of hygienic practices	Percent Population with access to improved sanitation	Improvement in adequate sewage treatment (sector expenditure)
Access to water for irrigation purposes	Rights to water for irrigation	Percent Population with access to water for irrigation purposes	Improvement in adequate irrigation treatment (sector expenditure)

Capacity

Educational level	Variation in Educational Level	Educational level	Educational level of HH leader
Water sector institutional framework	Confidence in water institutions	Institutional control on water access	Percent of complaints regarding the water service level.
Operation and Maintenance	Adequacy of the maintenance programs		
Gender issues and the role of women	Variation in ratio of average female educational level to male educational level	Ratio of average female educational level to male educational level	
Financing strategies and cost-recovery	Cost of water	Percent of arrears on water fees	

Use

Domestic water consumption	Conflict over water sources (Human – Human)	Domestic water consumption	Domestic Water-use efficiency
Agricultural water use	Conflict over water sources (Human – Agriculture)	Agricultural water use	Agricultural Water-use efficiency
Livestock water demand	Conflict over water sources (Human – Livestock)		Livestock Water-use efficiency

Environment

Environmental regulation and management	Use of pesticides and fertilizers	Percent of area with natural vegetation	Adequacy of the environment sector-related institutional framework
Water quality	Percent of people suffering from Water-related diseases	Water Quality, for domestic use	Water source protection

The results shown in Figure 62 suggest that there are at least two communities which require special attention, with eWPI values of 0.528 and 0.568. In contrast, the least water poor community scores 0.718. A focus on the water-related dimensions highlights that "Environment" and "Resources" related issues require special policy attention, averaging 0.547 and 0.606 respectively. Similarly, a closer look at the three states provides valuable information to assess the impact of institutional and societal responses. It confirms that they are proving inadequate to address increasing pressures on water resources (0.583).
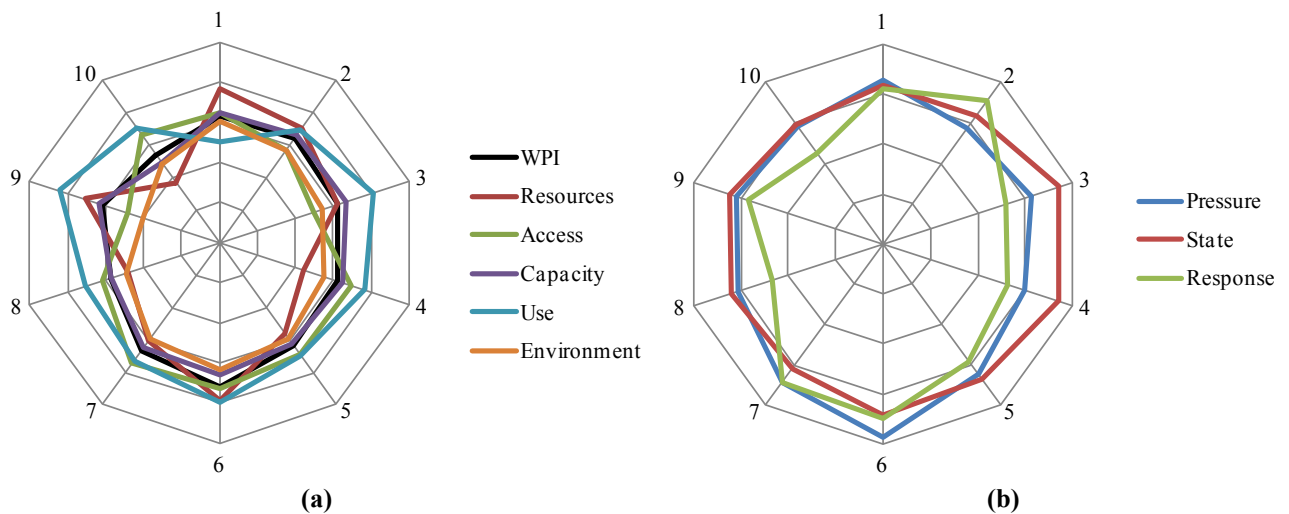

Figure 62 Final values of e-WPI at community scale. a) WPI values. b) PSR values.

Improving water resources management at basin scale

In Peru, the Government created the National System for Water Resource in 2008 (Law 1081). One year later, the National Water Policy (Law No. 29338) was launched. Under this new regulatory framework, the river basin becomes the territorial planning unit. However, one emerging challenge is related to the ability of basin authorities to effectively fulfil their management commitment. For this reason, a Peruvian watershed, the Jequetepeque River basin, has been purposively selected as initial case study to test the validity of the eWPI.

The choice of indicators to define index's dimensions has been driven by data availability. Multiple types of data have been obtained through consultation with a variety of stakeholders and literature review. The final list of indicators is presented in Table 34, though a more detailed description of variables employed to assess the causal relations is given in Table 23 of Chapter 3.

To illustrate the complexity of water issues, various maps have been developed (see Figures 28 and 29, Chapter 3). It is observed that aspects needing primary attention are those related to institutional strengthening, as well as to water usage efficiency. Further, "societal response" seem to be a major concern, thus a worsening of current situation is foreseen in the near future. To reverse this trend, institutional response would be directed to (i) build up capacities of sector stakeholders, (ii) reduce agricultural water demand by improving respective water-use efficiency, (iii) increase domestic water consumption through adequate hygiene promotion, and to (iv) launch water quality surveillance campaigns to improve water quality.

Table 34 eWPI components and indicators used at watershed level

WPI Component	Indicators
Resources	Water availability
	Integrated Water Resources Management
Access	Access to safe water
	Access to sanitation
	Equity issues in access to water and sanitation
Capacity	Human Development
	Institutional Capacity
	Gender issues
Use	Hygiene promotion
	Agricultural water use
Environment	Environmental preservation
	Drinking water quality
	Agricultural water quality

Discussion

To address the question of scale adequately, the development of a consistent and reliable composite index may be an adequate solution. The conceptual framework of the index needs to capture the essence of water poverty at each scale. Then, if a core set of key variables can be identified and can be regularly collected, they may provide the basis for a monitoring tool on which water decisions can be based. Ideally, the data required to assess the index's components should come from existing sources. It is noted in this regard that much data exists, although it is vital to check its accuracy and consistency to avoid misleading results.

In terms of temporal variability, the PSR model accommodates the causal inter-relations between the variables of the index. It is a useful approach to detect and predict changes in systems over time. Also, with single iteration – by repeating the measure after an appropriate interval -, it is possible to reveal trends and identify qualitative changes.

3. Dissemination of the data

The second challenge is related to the issue of data dissemination. It is well known that the data must be clearly communicated to portray a realistic picture of the situation, and it is thus essential that available information be easily accessible and presented in a user-friendly format. On the contrary, decision makers will probably do without it. Also, the way the data is disseminated may influence its interpretation. In consequence, this section presents two alternatives that attempt to enhance visualization of the information and ultimately produce clear policy messages. First, water and sanitation poverty maps are developed as visual instruments for displaying information and enable non-specialists to easily understand a complex reality (Henninger and Snel, 2002). Second, clustering techniques are employed to determine groupings of relevant peer locations through a multidimensional approach. That is, a cluster analysis is performed to classify locations into manageable sets (clusters) by exploiting their similarity on WaSH issues.

3.1. Poverty maps

Poverty mapping may be defined as the representation and analysis of indicators of human wellbeing and poverty in a spatial context (Davis, 2002). It is thus becoming an increasingly important instrument for more integrated study of social, economic, and environmental problems (Henninger and Snel, 2002). Maps are powerful tools for displaying information to non-technical audiences, who are able to examine mapped data to identify clusters, patterns, and trends (Henninger and Snel, 2002). Moreover, poverty is highly heterogeneous phenomena, and its spatial distribution widely varies between and within different geographic and administrative units (Davis 2002). Mapping permits a clear visualization of such heterogeneity, and provides a common data-framework on which to integrate socio-economic, physical and environmental information (Henninger and Snel, 2002; Sullivan, 2002).

In the water-poverty context, maps are being employed to assist in the analysis of water-related issues, and provide a practical way for planners and managers to (i) target public priorities through the spatial identification of the neediest, (ii) improve transparency of decision making, and (iii) assess the impacts and tangible benefits of sector-related development policies (Cullis and O'Regan, 2004).
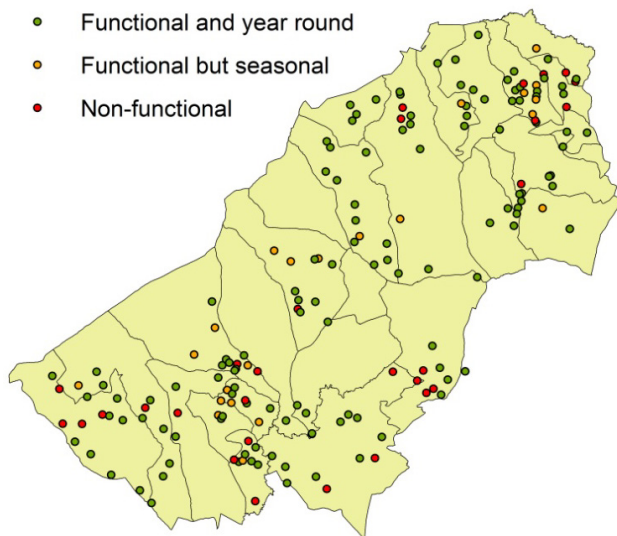
Figure 63 Distribution of functional improved water points, at location level
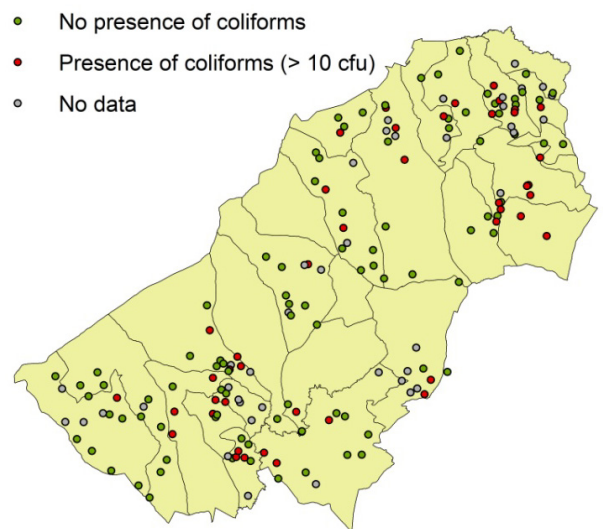
Figure 64 Distribution of safe improved water points, at location level

As an example, the map in Figure 63 shows the spatial distribution of improved water sources in Homa Bay (Kenya), and highlights the issues of functionality and seasonality. It is observed that the majority of audited sources were found operational and with no seasonality problems (71%), despite regional disparities. In Figure 64, it can be seen that three out of ten improved waterpoints (31.8%) showed microbiological contamination, and that polluted sources were to certain extent geographically clustered.

If such point-based information is combined with demographic data and the source:man ratio, coverage density maps can be developed (Figure 65) to show accessibility rather than availability

aspects, i.e. the percentage of population covered if it is assumed that each community tap only serves 250 people. By exploiting the planning criteria presented in Chapter 3, it may be gleaned from the maps that differences between coverage rates are marked (see also Table 35). On average, functionality issues "only" reduce access from 12.15% to 10.26%, but for instance water quality almost halves the initial coverage ratio, while management-related coverage stands at 3.7%. This coverage variability highlights the need of properly defining access to water, taking into account different perspectives to achieve a more realistic picture of sector challenges.
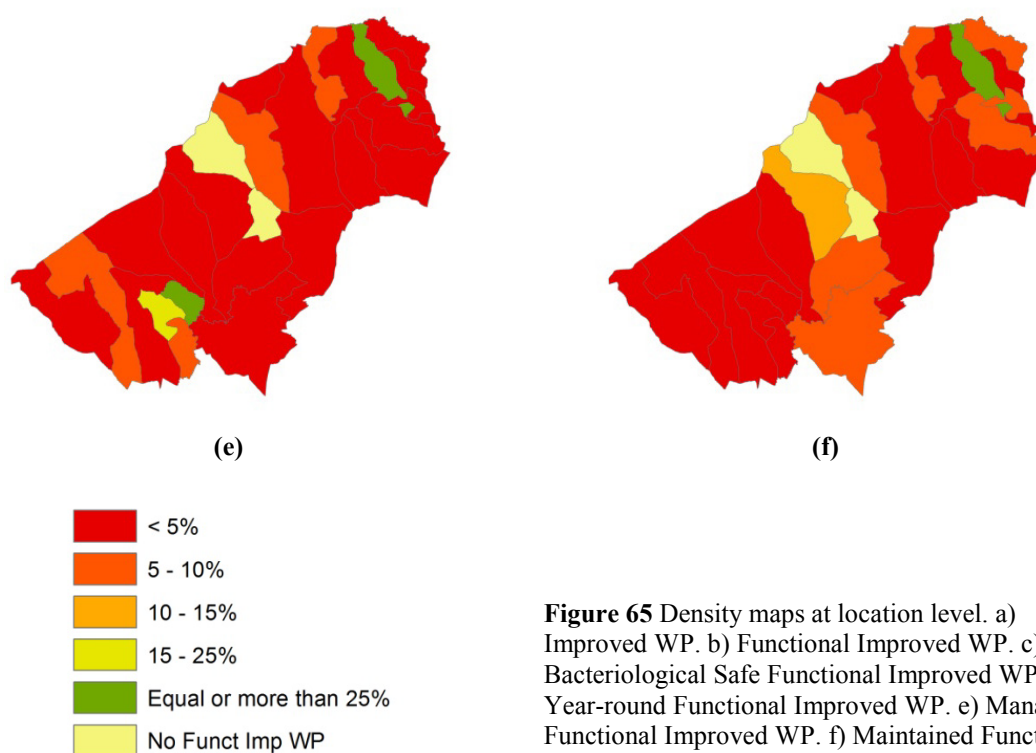

(a)

(b)

(c)

(d)

(e)   (f)

	< 5%
	5 - 10%
	10 - 15%
	15 - 25%
	Equal or more than 25%
	No Funct Imp WP
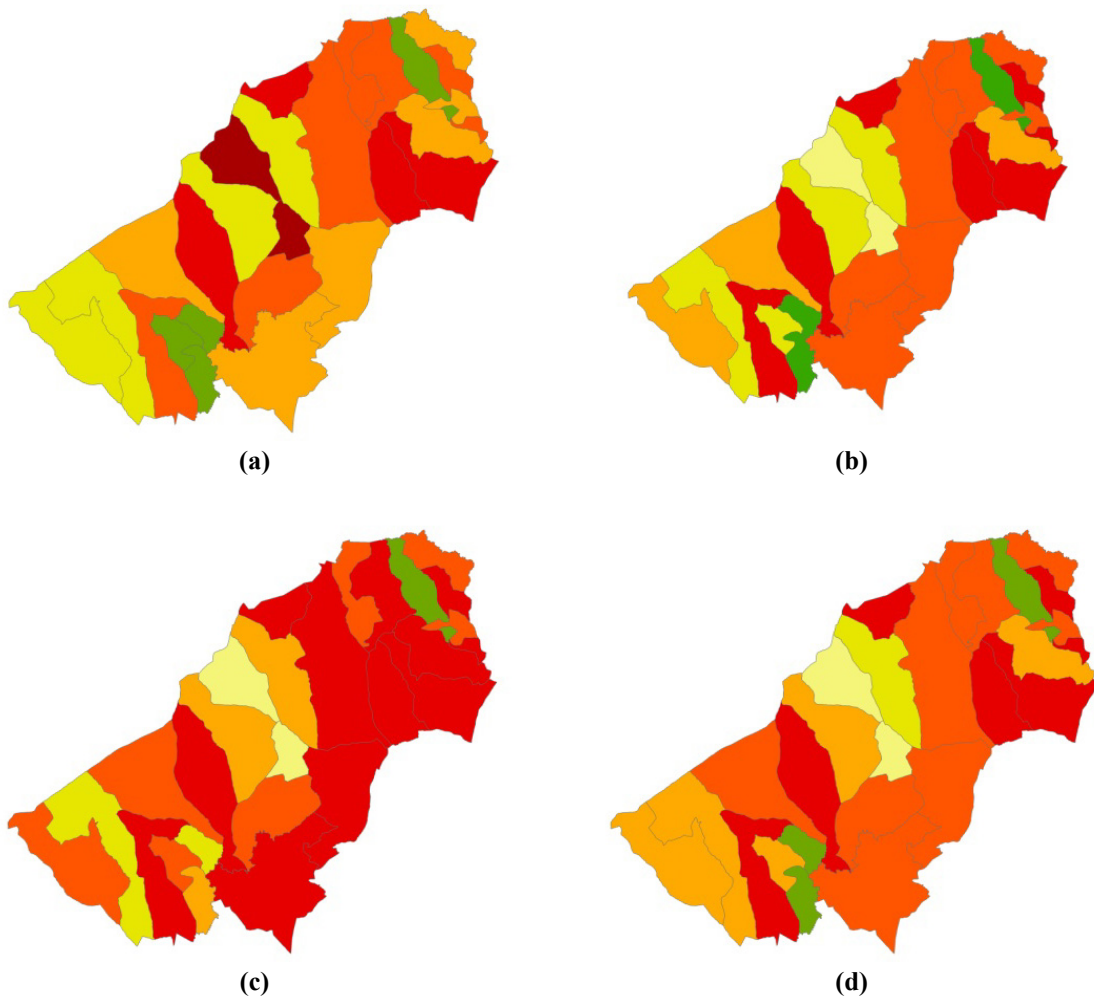
Figure 65 Density maps at location level. a) Improved WP. b) Functional Improved WP. c) Bacteriological Safe Functional Improved WP. d) Year-round Functional Improved WP. e) Managed Functional Improved WP. f) Maintained Functional Improved WP

Table 35 Water coverage and service level

	Improved WP Density	Functional IWP Density	Year-round FIWP Density	Bact. Safe FIWP Density	Managed FIWP Density	Maintained FIWP Density
% Served	12,15%	10,26%	8,83%	6,43%	3,70%	5,39%
% Unserved	87,85%	89,74%	91,17%	93,57%	96,30%	94,61%

3.2. Clusters of variables

From a policymaking point of view, the need to simultaneously manage large amount of data from a significant number of administrative units is becoming an increasing concern, particularly at the local level. One possible solution for dealing with this challenge is to perform a cluster analysis, as a tool that has been widely applied for classifying large amounts of information into manageable sets. Specifically, clustering techniques may be employed to group information on populations based on their similarity on different indicators. Among the various clustering algorithms available, the k-means clustering method is employed herein, which divides the sample in k clusters of greatest possible distinction. The algorithm computes the similarity between population groups in the dataset, with the aim of (i) minimize the variance of elements within the clusters, and (ii) maximize the variance of the elements outside the clusters (Nardo et al., 2005). Although this is a common method in development planning (Berlage and Terweduwe, 1988; Esty et al., 2005; Tang and Salvador, 1986), this does not mean that cluster analysis is a panacea. In terms of methodology, the arbitrary decision about the number of clusters employed is subject to criticism

(Gelbard et al., 2009). As the goal in this study is to provide a classification of administrative units that can be used as a basis for planning, key criteria to determine number of peer groups include the cluster size, in terms of number of units and total population, and also their relevance from a WaSH perspective.

For illustrative purposes, the data from the Turkana case study has been exploited. A spider diagram is displayed in Figure 66 to summarize the differences in the means between clusters, which are presented in Table 36. Figure 67 shows geographical distribution of sub-locations within clusters. To understand particularities of these five groups allows policy planners to identify target groups and determine specific and more coherent strategies, which in terms of poverty reduction and allocation of resources is more efficient and cost-effective than to launch an equally expensive universal distribution program (Cullis and O'Regan, 2004).
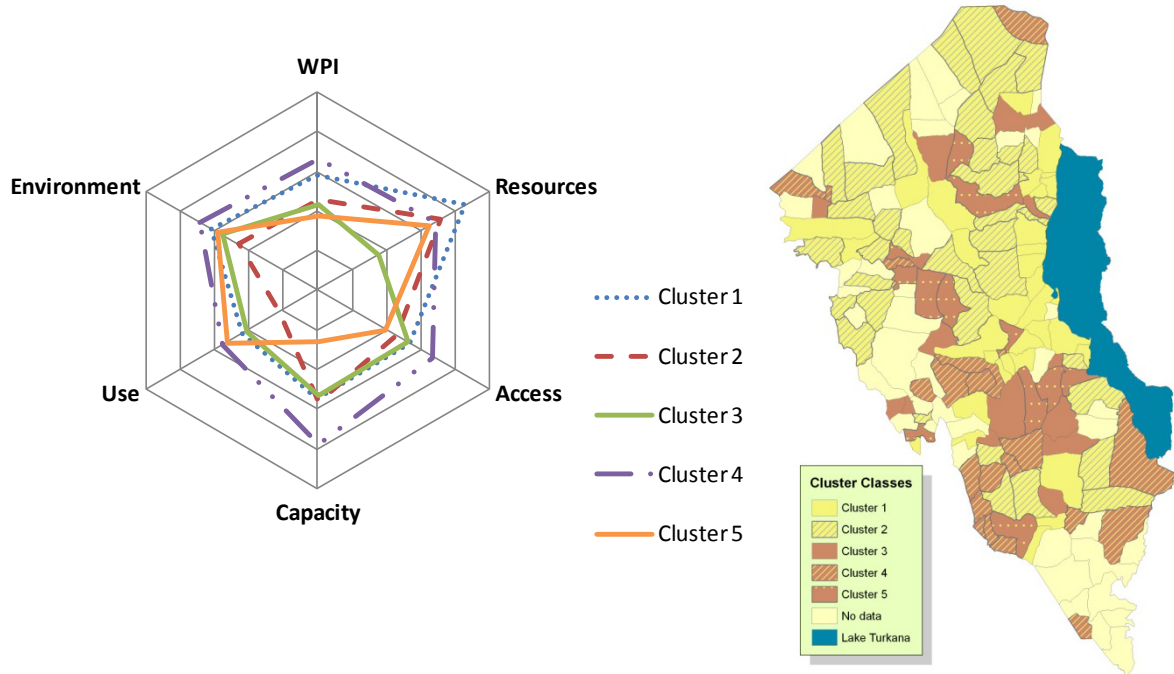
Figure 66 Diagram of WPI components for five cluster classes   **Figure 67** Map of Cluster Classes

It is shown for example that first cluster (which includes 33 sub-locations, 84.617 people) scores best in "Resources", and achieves good marks for the other four components. The level of water poverty is thus low. Cluster 2 corresponds to sub-locations (37; 72.299 people) in which usage of water is inadequate, access to basic services remains low, and water sources are not properly protected from potential pollutant sources. Sanitation campaigns should thus be first promoted to improve hygienic practices and to change behaviours, mainly aiming to raise awareness among the population of the importance to increase domestic water consumption. Furthermore, water sources need to be protected to prevent water from being contaminated, and programs to construct new infrastructure should be launched to improve coverage. Sub-locations included in Cluster 3 (14; 34.568 people) are characterized by facing acute water scarcity, though they lack capacities to manage water facilities, water use is poor and environmental impact on resources is considerable. Consequently, the level of water poverty is remarkable. First intervention should be directed to increase water reservoir availability. In parallel, capacity building of water entities need to be

ensured. And equal to Cluster 2, hygiene promotion should be fostered, while awareness of the importance to protect water sources increased in the communities. Cluster 4 (21 sub-locations; 126.481 people) performs notably better, being the least water poor. Only the "use" component needs to be improved, since water consumption remains inadequate, though scoring the highest. Finally, cluster 5 (12 sub-locations; 37.887 people) score the lowest WPI values and thus represent the highest degree of water poverty. This group scores badly with respect to "Capacity" and "Access". The direction to be adopted in sub-locations included in this group should be that all water sector actors at the local level conduct capacity building through appropriate training, so as to enable water entities to manage the schemes. Additionally, access to water and sanitation needs to be improved by increasing coverage.

Table 36 Final cluster centres

	1st Cluster	2nd Cluster	3rd Cluster	4th Cluster	5th Cluster
No. Sub-locations	33	37	14	21	12
Population	84.617	79.299	34.568	126.481	37.887
WPI	0,578	0,453	0,428	0,663	0,373
Resources	0,857	0,711	0,347	0,689	0,647
Access	0,531	0,460	0,523	0,673	0,392
Capacity	0,546	0,565	0,527	0,775	0,256
Use	0,440	0,223	0,419	0,555	0,528
Environment	0,618	0,463	0,559	0,690	0,587

From a policy maker's point of view, these statistics can be used for development planning, and amongst others, to identify most vulnerable areas and define coherent strategies for poverty alleviation.

4. Conclusions

In order to effectively improve decision-making on the basis of a reliable and sector-specific dataset, two elements are necessary (Grosh, 1997): the data must be analysed to produce outcomes that are relevant to the policy question, and the analysis must be disseminated and transmitted to policymakers.

It is increasingly obvious that data should be primarily analysed to respond to the informational needs of policymakers, and therefore feed into decisions on resource allocations, targeting of services, and prioritization of interventions. Also, to offer relevant guidance to the policy question, the analysis must be disseminated effectively to end users.

To begin with, transparent mechanisms need to be in place to set priorities and target the water poor. Monitoring data may otherwise degenerate into a rationale for inconsistent planning, undermining the imperative need for efficiency and effectiveness. Various alternatives are presented in this chapter for improved planning. A simple classification process is proposed to prioritise among population groups and identify those communities with increased levels of WaSH-related poverty. Also, since equity is a major driver of local policymaking, data are

disaggregated to show socio-economic inequalities. A wealth index is developed for this purpose, and results suggest a strong link between WaSH poverty and wealth status. The issue of scale is finally discussed, and the need to apply policy tools at a suitable scale is pointed out. In the WaSH sector the priority should be given to the local level, where decisions on service delivery are made.

The selection of suitable alternatives to present and disseminate the information is not trivial, and deserves special attention. The goal is to communicate at a glance an accurate picture of the problem at hand. This chapter first discusses about the suitability of water poverty maps to provide adequate guidance about where and which investments are most likely to have a positive impact. Water poverty is a highly heterogeneous phenomenon. Since mapping permits the spatial identification of the poor, poverty maps prove to be powerful instruments for targeting and prioritization support. Second, for comparative policy analysis and to handle the vexing problem of simultaneously managing different datasets, clustering techniques are introduced as an objective approach to classify a number of population groups into manageable sets (i.e. clusters), by exploiting their similarity on the index variables. An accurate focus on the particularities of each cluster allows decision-makers to identify target groups, thus providing a good place to start in the search for best practices to tackle those water sector needs that require urgent policy attention.

In all, various approaches can be employed to enhance data interpretation. This is crucial to promote evidence-based and equity-oriented planning.

CHAPTER 5

CONCLUSIONS AND WAYS FORWARD

1. Conclusions

Expanding access to safe drinking water, improving sanitation infrastructure and promoting household hygiene are essential for human development. In most low-income countries, the delivery of these basic services has shifted to decentralized approaches, where control over management and implementation activities devolves to local governments (Crook, 2003). It has come to be widely accepted that such decentralization process can help to reduce poverty because local governments are assumed to be more knowledgeable about and responsive to the needs of the poor (Steiner, 2007). However, the impact is today still modest and the links between decentralization and the development of pro-poor and gender-equitable outcomes are at best ambiguous (Crook, 2003; Devas and Grant, 2003). Any prospect for effective pro-poor policies mainly depends upon real efforts to strengthen the capacity of decentralized authorities to take informed decisions (Schouten and Smits, 2015). The sector is integrating other elements of public services reform. For example, the focus is on shifting from infrastructure construction - e.g. number of water schemes, as output - to providing water services in the sense of water provision of agreed quantities and quality at agreed times and sites for people's actual use - as outcome - (Schouten and Smits, 2015). The sector also calls for greater transparency and accountability (WaterAid, 2008; WWAP (United Nations World Water Assessment Programme), 2015). In an indicative example, the World Bank estimates that 20 to 70 per cent of resources invested in the sector could be saved if transparency were optimised and corruption eliminated (Plummer and Cross, 2006). In theory, with more checks and balances in place, the costs for unethical behaviour get higher. Monitoring and reporting are therefore cornerstones of accountability (Plummer and Cross, 2006; The World Bank, 2004), enabling decision-makers to give an informed and objective account of their decisions and actions.

It is well known that the lack of a monitoring and reporting system for the water sector is a major barrier to the development of transparent and accountable decision-making (Schouten and Smits, 2015). In recent years, many countries have put a lot of effort into the implementation of harmonised monitoring systems to report on the state of water, and the way in which monitoring is done has changed rapidly thanks to initiatives led by the United Nations and other international organizations (Bartram et al., 2014). However, further improvement is necessary in many areas, and particularly at the local level, monitoring and reporting structures remain weak. First, regular reporting is challenging because the sector rarely has - compared to other sectors such as health and education - dedicated extension workers based at the local level who can systematically report on the functionality of water supply schemes and related issues (Welle, 2010). In addition, high turnover of technical staff hinders the implementation of capacity development programs. Thus, the information management and monitoring capacities of local governments are typically inadequate to deal effectively with the demands placed upon them. For water officers, auditing water points on a regular basis is logistically challenging because of the number and geographical dispersion of water supplies, because of the poor road infrastructure, particularly during the wet

season, and because of very limited operational budgets and resources available to them (transport, equipment, etc.). And, last but not least, monitoring and reporting procedures on the status of water schemes and sanitation infrastructure are simply not in place in the majority of developing countries. This situation is partly related to an ambiguity of scope in defining who is doing what, when and with who (Welle, 2010). For instance, the principle of community management to operate rural water schemes applies in many developing countries. This means that the responsibility of the national governments extends primarily to the provision of improved facilities while it is the responsibility of the users to maintain the services. Welle (2010) suggests that, in a narrow sense, the state's reporting responsibilities relate only to the number of water supply schemes constructed, and not to the percentage of people with access to improved water supplies or the true figure of people enjoying an improved health status, time savings etc., based on access to basic services. This ambiguity may have contributed to weak reporting mechanisms from the government side. In consequence, and despite the importance of monitoring and regular reporting for informed decision-making, the data challenge - access to and availability of accurate and timely data on sector performance – remains largely unaddressed.

Against this background, the specific problems this research addresses range from improving the availability of reliable information, to improving access to information for all relevant stakeholders, and in part, to encouraging the use of this information in decision-making processes. The ultimate aim is to show that local strategic planning and decision-making can be greatly enhanced by accurate and accessible information, which synthesised further, can guide the drafting of effective development policies. This thesis has been divided into four constituent parts: i) data collection methodologies; ii) WaSH indicators and indices; iii) planning tools for improved decision-making; and iv) mechanisms to interpret and disseminate data for planning purposes. The conclusions follow a similar structure.

1.1. Methodologies for data collection

A variety of tools and techniques have been developed in recent years to collect primary data for the WaSH sector. Of particular interest are the household surveys, which exploit the household as the basic sampling unit, since this is the information source by which water and sanitation indicators are usually assessed (Bostoen, 2002; Joint Monitoring Programme, 2006). These methodologies prove reasonably precise and thus valuable in large scale assessments. However, methodological problems arise when they are implemented at local scale to produce reliable inputs for planning support. Specifically, the direct application of the standards commonly employed in large scale-surveys at the local level - where number of administrative subunits is large and population size in each administrative subunit is low - would produce too large a sample. There is little choice but to select a reduced sample size, albeit at the cost of less accuracy in the final estimates. A scientifically valid sampling methodology is also necessary to achieve reliable estimates. For national household surveys, a cluster sampling design has proved a practical solution (Bennett et al., 1991; United Nations Children's Fund, 2006a). However, if sub-national or local estimates are required to assess separately the performance of the lowest administrative subunits, such sampling approach is not valid; and alternatively one could opt for a stratified sampling. The type of data required to monitor the sector is another aspect that must be considered, since different information sources may be required (Joint Monitoring Programme, 2012d). Household surveys are the most commonly used instruments for collecting WaSH data, but a focus on households is not sufficient to inform about many relevant issues of service

delivery, and hence needs to be supplemented with data from other sources (e.g. schools, health centres, water points, etc.). Finally, the techniques employed for data acquisition play a key role in terms of data reliability and validity (United Nations Children's Fund, 2006a), and a combination of structured interviews and direct observation helps elicit a response that is accurate and avoid bias in survey's outcomes.

The approach adopted in this study for data collection combines two different information sources: the water point and the household, and thus provides a more complete picture of the context in which the service is delivered. It takes the WPM as starting point, as a method with increasing acceptance amongst governments and practitioners to inform the planning of investments when improving water supply coverage. Since mapping entails a complete geographic representation of the study area, a stratified household-based survey is undertaken in parallel, in which a sample of households is selected from each stratum. In this fashion, the risk of homogeneity within the strata remains relatively low, thus enabling the selection of smaller sample sizes. Indeed, an issue of concern with reduced populations is how large should the sample be in order to produce precise confidence intervals for the estimates obtained. This study adopts a simplified approach to sample size determination for local surveys. Specifically, it provides the formulas to select the minimum sample size on the basis of desired precision and the maximum permissible sampling error. The data analysis presents a practical method to categorize the survey estimates based on the criterion of non-overlapping between the confidence intervals of the estimates. The outputs produced, despite the low precision of the estimates, may be used in categorization processes. Therefore, they could be further exploited for local level policymaking support.

1.2. Review of indicators and aggregated indices in the WaSH sector

The lack of water and sanitation sector monitoring and reporting system in many low-income countries is widely recognised as one of the critical constraints towards making informed decisions on the development and use of WaSH services. In recent years, many countries have put a lot of effort into the development of harmonised national sector monitoring processes to report on the state of these basic services. Despite considerable progress, much still remains to be done. Whole groups of people are not being counted and important aspects of service delivery are still not being measured. Specifically, the recognition of access to safe drinking water and sanitation as a human right specifically spotlights new dimensions that monitoring and reporting systems should address. This study aims to contribute to the existing debate about strategies for improved sector monitoring, and specifically assesses the utility of their respective outcomes to support planning. Different approaches that are widely promoted in the sector are compared. The first one describes the situation in terms of health impact. The other alternatives, which include three types of integrated indicators, focus on inputs and behavioural changes, and thus encompass a variety of measures that not only influence health but consider many other aspects.
The results suggest that measuring the health impact of water and sanitation is unlikely to produce reliable estimates. Moreover, the interpretation of epidemiological studies is not straightforward; and in terms of policymaking, they hardly detect operational deficiencies or suggest improvements. Simply put, it appears that health impact evaluations are not useful tools for monitoring purposes. Alternatively, measurement of the changes in use of water and sanitation infrastructure and in hygiene behaviour may improve the ability to evaluate water, sanitation and hygiene education programmes to make them more effective. A significant step in this direction is the establishment of the JMP to report on WaSH sector status and trends. Indeed, the

questionnaires designed by the JMP have been widely applied for multiple uses at different scales (regional, national and local). Its major strength, and the root of its success, is the simplicity of having a few relatively well-defined and easy-to-measure indicators, which produce reasonable estimates of coverage across different contexts. However, JMP assesses access through technology-based proxies, and it does not provide a broad picture of the context in which the service is delivered. Therefore, the simplicity of the monitoring framework is also one of its core limitations, and it is necessary to gain an insight into wider issues that relate to sector performance. Another direct consequence of the harmonisation of monitoring questions promoted by the JMP is rigidity with respect to monitoring outcomes, which conflicts with the increasing need of the sector to adapt monitoring and reporting systems to local level conditions and particularities (United Nations General Assembly, 2010a). The index approach attempts to partially overcome these weaknesses. It combines data of different nature and then helps differentiate the local multifaceted situation at the dwelling in relation to water, sanitation and hygiene. In doing so, indices appeal to policymakers as a tool for planning and monitoring support, as well as targeting and prioritizing of interventions. From the viewpoint of practitioners at the local level, however, aggregated indicators also present some limitations, including inter alia the amount of data required in the assessment process, the techniques employed in index construction, and the validity of the composite itself to inform decisions. To balance simplicity and exhaustiveness, i.e. instruments that not only are easy to use but also provide an insight into the context in which the service is supplied, the use of simple planning indices might be an in-between solution. To be effective, they should be presented in a way (e.g. league tables, ranks, poverty maps, etc.) that provide clear and unambiguous messages to decision-makers. In addition, indices must reflect real needs (e.g. extended practice of open defecation), and be easily linked to efficient remedial actions (e.g. construction of basic sanitation infrastructure).

In sum, these three monitoring approaches (i.e. JMP, composite indices and planning indices) are complementary to meet different needs at different levels. Consistent reporting of coverage is essential, and a more comprehensive evaluation system would probably be too difficult to implement and therefore counter-productive. The JMP's indicators are adequate to harmonize the monitoring mechanisms and produce quality basic estimates of the type of drinking water sources and sanitation infrastructure people use. In this regard, the ongoing consultation process guided by the JMP around the post-2015 sector-related goals, targets and indicators is of primary importance, as it will produce a broader view of service level and take into account human rights criteria. The index approach proves especially useful for decision-makers and planners as a rapid appraisal instrument. It provides a better understanding of the interactions between WaSH and poverty. If routinely assessed, the composite sheds light on whether the intervention strategy needs fine-tuning and how it can be improved, which is precisely the aim of operational monitoring. Finally, simple and user-friendly (easy to assess, easy to use) planning indices are powerful tools for supporting decisions at the local level, where capacities of recipient institutional bodies are inadequate to correctly cover the information cycle, which includes data gathering, data processing, data analysis and data reporting.

1.3. Development of tools to support local level planning

Thanks to new technologies, the volume of information is increasing exponentially. In parallel, however, inequalities in access to data and information and in the ability to process and use it are growing. On the one hand, data remain too often unused because they are released too late or not at

all, they are not well documented and harmonized, or are not available at the level of detail needed for decision-making. On the other hand, particularly at the local scale, the limited capacity to analyse the data and to interpret the key messages of decision-makers widens the gap between access and use of data. This thesis seeks to assist managers and decision-makers in addressing this gap by developing various monitoring tools and improve access to available data. In brief, the tools are aimed at processing data to produce simple policy messages that support targeting and prioritization, and therefore allocate resources more efficiently.

First, an improved method for index construction is described, which may be summarized in the following steps: i) definition of the theoretical framework to provide the basis for the selection and combination of indicators, ii) selection of indicators on the basis of their analytical soundness and relevance to the phenomenon being measured, iii) exploratory analysis to investigate the overall structure of the indicators, iv) assignment of weights and aggregation of variables according to the underlying theoretical framework, and v) validation of the composite. Three different alternatives to select and combine indicators at subindex level have been proposed, two different weighting systems have been applied, and two aggregation forms have been used to construct the index. In all, six alternative methods are compared. It has been found that the weighted multiplicative function (selection of indicators based on PCA, and weighted geometric mean of subindices) is the most suitable aggregation method for assessment of water poverty at local scale.

Taking this methodology for index construction as a starting point, two composites are presented to unravel the linkages between water and poverty from different perspectives, namely the enhanced Water Poverty Index (eWPI) and the WASH Poverty Index (WASH PI). The eWPI approach combines the physical, environmental and social dimensions which are influencing sustainable development of water resources, and integrates within the indicator framework the existing pressures and policy responses to explicitly incorporate the cause-and-response logic. The WASH PI is aimed at offering an objective evaluation tool for assessment of rural poverty issues, with a focus on water supply, basic sanitation and household hygiene. The index is not presented in the aggregated form but as a thematic indicator, i.e. the three sub-indices are examined individually.

Second, in an effort to improve decentralized planning, a short battery of thematic indices is proposed to highlight which areas require policy attention and identify the most vulnerable populations. Specifically, six indices deal with water-related problems, and four indices describe the top sanitation and hygiene priorities. All of them have been disseminated through league tables and priority maps, which are easily understood by both policymakers and non-technical stakeholders. By linking sector priorities with specific remedial actions, the indices translate emerging problems into specific solutions that guide efforts and steer progress in the right direction.

Third, ooBns have proved to be effective tools when there is a need to make informed choices between alternative actions. Specifically, the study shows that they are powerful for combining the wide variety of information sources relevant to WaSH issues. Different sets of data from economic, environmental, physical and social domains are linked together in a way that allows integrated analysis. In addition, uncertainty of the data is explicitly represented in the output, which is particularly important in data-scarce contexts. The model also provides a holistic framework on which decisions can be based: designing a network ensures that all aspects of a

problem are taken into account, especially if the participation of sector stakeholders is encouraged. Finally, to assess the behaviour of the model when a number of potential actions are simulated is straightforward. Therefore, Bns enable policy planners to easily identify the type of intervention in which to direct their efforts for maximum impact. In contrast, a major drawback is that Bns are computed using software that needs to be used by highly qualified people. This clearly hinders its wider implementation in low-income regions, where resources are limited and stakeholders often lack capacities to profit from the model once developed.

Overall, achieved results reveal that aggregated indicators, planning indices and Bns have wide appeal due to their utility as policy tools for performance monitoring and resource allocation, as well as for guiding appropriate action towards better service delivery

1.4. Mechanisms to exploit and disseminate data for planning purposes

Regardless of data availability, their use in decision-making is limited, and much of what is labelled as monitoring stops at the level of reporting, with little action taken as a result of monitoring (Schouten and Smits, 2015; Welle, 2010). Indeed, data are often underutilised due to late release; lack of availability, documentation, harmonization; insufficient detail for effective decision-making; or simply because available data do not feed into planning and decision-making processes. Two elements are necessary to make information accessible (Grosh, 1997): the data must be analysed to produce outcomes that are relevant to the policy question, and the analysis must be disseminated and transmitted to policymakers. On the one hand, there is little doubt that data should be primarily analysed to respond to the informational needs of policymakers, and therefore feed into decisions on resource allocations, targeting of services, and prioritization of interventions. On the other hand, the outcomes should be disseminated effectively to end users to provide improved guidance to the policy question.

It is clear that transparent mechanisms need to be in place to set priorities and target the water poor. Monitoring data may otherwise degenerate into a rationale for inconsistent planning, undermining the imperative need for efficiency and effectiveness. First, this study proposes a simple classification process to prioritise among population groups and identify those communities with increased levels of WaSH-related poverty. Based on simple statistics, a criterion of non-overlapping between the confidence intervals (CI) of the estimates is applied for this purpose. Second, data are disaggregated to show socio-economic inequalities. A wealth index is developed to this end, and results reveal a strong link between WaSH poverty and wealth status. Finally, from a planning perspective, scale issues are discussed, and the need to apply policy tools at a suitable scale is pointed out. In the WaSH sector the priority should be given to the local level, where decisions are made.

The selection of suitable alternatives to visualize and disseminate the information is not trivial, and deserves special attention. The goal is to communicate at a glance an accurate picture of the problem in question. Water poverty is a highly heterogeneous phenomenon, and since mapping permits the spatial identification of the poor, poverty maps prove to be powerful instruments for allotting efforts and resources more equitably. Second, clustering techniques are introduced as an objective approach to classify a number of population groups into manageable sets (i.e. clusters). They provide useful means of identifying attribute groups by exploiting their similarity on the WaSH variables. An accurate focus on the particularities of each cluster allows decision-makers to

target vulnerable groups, thus providing a good place to start in the search for best practices to tackle those water sector needs that require urgent policy attention.

In all, various approaches can be employed to enhance data interpretation, which is crucial to promote evidence-based and equity-oriented planning.

2. Limitations of the research

In addressing the research questions initially formulated, one key issue have impacted the extent of the study, namely the practical integration of data into real-world local planning.

The thesis presents a comprehensive illustration of how water point mapping and household surveys may be adequately combined to produce sector data, and how these data may be post-processed and analysed to provide decision-makers with relevant instruments for local planning. The thesis falls short, however, of showing how the developed methodologies and tools may be applied in practice and integrated into existing monitoring and reporting structures at the local level. Indeed, despite the implementation of various case studies in distinctive different settings, they hardly suffice to give conclusive information on how WaSH sector-specific data is effectively used to improve decision-making.

The main reason for this relates to the lack of funding and possibilities to engage with local decision-makers after project completion and provide them with long-term support. This study has involved the local authority as the principal stakeholder, and has specifically engaged in various stages of the process with those government bodies with competences in WaSH. Moreover, all tools and processes have been applied at the administrative scale in which decisions are made; and principles guiding their design have included simplicity, functionality and transparency. As further discussed below, these measures are necessary and proved helpful, but probably become insufficient to promote continued use of these monitoring and reporting instruments in decision-making processes. This challenge has indeed remained elusive, and guides the way forward.

3. The way forward

The monitoring framework presented in this thesis deals with the development of prioritization and targeting mechanisms required to identify the sectors and the segments of the population in which to focus policy attention. It covers the monitoring cycle of data collection, data analysis and data dissemination; and provides reliable inputs for planning and informed decision-making. However, good access to data and information does not necessarily imply its proper use for sound decision-making. To effectively encourage planners and decision-makers in taking informed decisions, other specific challenges remain elusive, namely i) the improvement of systems and processes that support decision-making, and ii) the development of data updating mechanisms.

The effective implementation of processes that support planning, targeting and prioritization is challenging in different ways. First, the processes themselves need to be upgraded, simplified and systematized. It is evident that by and large decisions are driven by structured processes and regulations (e.g. district operational guidelines, strategic plans of water utilities, etc.), and that

decisions are supported by systems and processes that to a certain extent guide targeting, prioritization and resources allocation. However, these systems often lack transparency and accountability - can discriminate against particular population groups -, and they are typically fed by incomplete, inaccurate and outdated data - as previously discussed. In addition, they do not integrate in their basic configuration the various competing and often conflicting uses of water and sanitation services. Therefore, a step forward in the improvement of the decision-making process is the establishment of appropriate decision-support systems (DSS) for enhanced water services delivery. It should promote transparent, open and accountable decision making. Moreover, it should make best use of available data. A DSS should also guide decision-makers in evaluating decision options against multiple criteria and in choosing the most appropriate action. And eventually, it should help address water and sanitation problems through a holistic, common approach. Second, there is a need to strengthen the information management and monitoring capacities of decision-makers in the use of the developed instruments, systems and processes. Besides the urgent need to adapt DSS to local needs, conditions and capacities, continued support to final users – e.g. government technicians and practitioners - remains crucial. In the short term, multi-stakeholder alliances between governments, NGOs, academics and consultants may be well positioned to provide the necessary support. In the medium term, however, political will and commitment at all levels, i.e. from central government to local authorities, is imperative to enhance the process of turning monitoring data into valuable information, and in promoting the continued use of this information in decision-making. The ultimate goal should be to allow local governments to make informed decisions autonomously, which implies that they are able to negotiate the planning goals, to work together on an agreed strategy and to ultimately translate policy into action.

In parallel, the monitoring and reporting framework needs to be rethought so that it can be regularly updated by local stakeholders with their own resources. The reliability of the data decreases with time, and good systems and processes may lead to misleading results if they are based on outdated data sets.

It is noteworthy, on the one hand, that there is an exponential increase in the volume and types of data available due to developments in telecommunications and related technologies, creating unprecedented possibilities for improved quantification of water availability, water uses and their effect on freshwater-based ecosystems (Independent Expert Advisory Group on a Data Revolution for Sustainable Development, 2014). On the other hand, information and communication technologies (ICTs) i) have significantly reduced the cost and time needed for data collection, processing, and visualisation, ii) have provided opportunities for more stakeholders to collect and access data, and iii) have promoted confidence-building between stakeholders, which contributes to greater responsiveness, mutual accountability and trust (Pearce et al., 2014; Schaub-Jones, 2013). In addition, it is estimated that more Africans have mobile phone subscriptions than have access to improved water sources (Foster et al., 2012). In all, it is suggested that, if harnessed effectively, technologies such as mobile phones and online databases can - when allied with better monitoring - significantly boost the performance of water managers. However, there is a trade-off between the scope and quality of the data required for decision-making support and the complexity of updating mechanisms (WaterAid, 2010). The design of a cheap, simple and effective monitoring and reporting system is desirable, at least, initially, which in turn brings about the need for a detailed estimate of the costs associated with data update. By and large, despite successful initiatives of simple systems for data update based exclusively on local means, as one case study

reported in Tanzania (Jiménez and Pérez Foguet, 2010b), the limited resources and capacities of local stakeholders is a major barrier. In data collection, communities can contribute to the achievement of sustainable updating mechanisms, though this should not move attention away from the responsibilities of local governments (WaterAid, 2011). In data analysis, rankings and league tables can be easily computed through pre-programmed spreadsheets, but GIS-related skills are not be easily found at the local level. That being said, even despite the increased use of technologies in handling data and information, to ignore the need for external support may be counterproductive in the short run. From the government side, one alternative may be the establishment of regional units that provide support with data collection and data analysis. And since local capacities are unlikely to increase in the short term, capacity development programmes should be included in the national capacity development framework.

These two challenges suggest the way forward.

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