



# Determinants for water consumption from improved sources in rural villages of southern Mali



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## ARTICLE INFO

### Article history:

Received 11 October 2016

Received in revised form

26 May 2017

Accepted 5 June 2017

Available online 16 June 2017

### Keywords:

Improved water sources

Water supply

Indicators

Millennium Development Goals

GIS

Human rights

## ABSTRACT

Water supply must take into consideration a variety of factors, including consumer habits, options and needs. Little is known about water demands in rural areas of developing regions. Based on data from southern Mali, this paper banks on the hypothesis that water consumption in rural villages can be predicted by combining measurable variables with spatial analyses. A ten-day field campaign was carried out at the end of the dry season 2016. All improved water sources were checked for functionality, flow rate and water quality. Outcomes were coupled with those from over one-hundred household interviews and incorporated into a geographic database. Buffered network analyses were used to quantify the main spatial determinants for water use. Simple and multiple regression models were then developed to establish the main predictors for per capita and household water consumption. Multiple regression reveals that models based on the number of household members, travel time and total travel distance provide robust forecasts for water consumption ( $R^2 > 0.93$ ). Conversely, potentially relevant parameters such as affordability or water quality were not statistically significant. This could be attributed to the presence of free water sources and to the absence of quality-monitoring, respectively. Outcomes also suggest that having access to basic means of transportation, such as pushcarts, doubles water consumption at the household level. In terms of access to improved water sources, coverage was found to be lower in practice than on paper. These outcomes contribute to the growing body of literature that challenges the widely accepted assumption that 90% of the world population has access to safe drinking supplies.

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## 1. Introduction

Water is the world's most precious resource. Water is the life-blood of the planet, crucial for living beings and critical for the preservation of ecosystems. From the human standpoint, water is key to hydration, food-security, hygiene and health. It is also the essence of many economic activities, including hydropower, irrigation, navigation or fishing. Adequate water supplies enhance living standards and promote opportunities for development. Hence, having access to water is not only a human right in itself, but also an essential tool for the realization of all other human rights (United Nations, 2002, 2010). This becomes particularly obvious in developing regions, where water access remains limited and where shortages are all too frequent.

Water access is a manifold concept (Jiménez & Pérez-Foguet, 2008). A basic prerequisite for access is the existence of a physical

water source. Human beings may obtain water from nature in many ways, but only “improved water sources” are considered suitable for human consumption. An improved water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from fecal matter (UNICEF, 2014). This definition encompasses household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collection. Unprotected wells and springs, street vendors or surface waters are not considered improved water sources. The spectrum of improved sources is broad enough to cater for most water supply schemes across the world. For instance, household connections predominate in industrial societies, particularly in urban areas, while hand pumps and public standpipes are usually found in rural villages of developing regions.

The presence of a nearby source entails a physical opportunity to collect water. However, there are other important aspects that may constrain access (Obeng-Odoom, 2012; Zawahri, Sowers, &

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Weinthal, 2011). For one, water needs to be safe. In other words, it must comply with drinking standards for microbial and mineral content. Failures in meeting water quality criteria are responsible for millions of chronic illnesses and deaths around the world each year (UNEP, 2010, p. 88). Closely linked to quality is the issue of affordability. When water from improved sources is too expensive, users tend to look for other options, thus endangering their health and wellbeing (Smiley, 2013).

Quantity, reliability and sustainability are additional pieces of water access (RWSN, 2010). A suitable number of sources should be available for the population. These must provide enough water to supply basic needs while also optimizing waiting times. Sources need to remain functional in the long run, with no significant downtime on a regular basis. Functionality is subject to additional constraints. Management arrangements, user fees and social, cultural or environmental factors may play an important role in ensuring adequate operation and maintenance (Foster & Hope, 2016; Van den Broek & Brown, 2015).

Within this context, understanding consumer habits, options and needs can help practitioners such as governments or humanitarian organizations to predict demands. This provides a valuable aid in establishing how many water points need to be installed and where. Thus, the aim of this research is two-fold. First, it is hypothesized that water consumption from improved sources can be modelled based on relatively modest data requirements. Based on first-hand information from southern Mali, it is argued that a combination of geographic information systems with statistical approaches may lead to identify the main predictors for water consumption in remote rural regions. The second goal is to provide a systematic evaluation of the levels of service in the study area. This will contribute to the existing literature by showing that access to water across the world is probably not as high as currently assumed by international organizations.

## 2. Geographical setting

Data was collected in Beleko, southern Mali. This town, home to about 6000 people (AECID, 2017), is the capital of the rural commune of Djedougou (Fig. 1). Beleko is located in the Sahelian transition zone of West Africa, between the Saharan desert and the wet tropical regions of the Gulf of Guinea. The area presents a hot tropical climate. Temperatures are high throughout the year (average 26 °C), while rainfall amounts to 800 mm/yr. Rainfall patterns respond to the West African Monsoon. This implies that precipitation takes place almost exclusively between June and September (García-Castro & García-Rincón, 2017).

The landscape is predominantly flat and there are no surface water courses nearby. Thus, people rely on a shallow aquifer for water supply and irrigation (García-Castro & García-Rincón, 2017; Martínez-Santos, Cerván, Cano, & Díaz-Alcaide, 2017). The water table depth ranges between five and 15 m at the end of the dry season, but rises closer to the surface, i.e. one to 3 m, towards the end of the rainy months. There is no running water in the vast majority of the households. Most people obtain water to meet their everyday needs from public hand pumps and standpipes, as well as from shallow domestic wells (Martínez-Santos et al., 2017). Basic sanitation facilities, i.e. pit latrines, exist in most homes. These are generally located in close proximity to excavated wells, thus posing a direct risk to shallow groundwater and human health.

The town is theoretically well endowed with improved water sources. This field survey revealed the presence of six hand pumps and seven standpipes distributed across all seven neighborhoods. Hand pumps are installed directly above protected boreholes, while all faucets are supplied by a water tower connected to an additional borehole. Overall, there is one improved water source per 460

people. This is roughly consistent with the capacity of the system, as a hand pump or a faucet can be expected to serve between 250 and 500 people (Stoupy & Sugden, 2003, p. 27; WaterAid, 2013, p. 14). Hand pumps are public and free, while standpipe water is provided at a cost of around 10FCFA per 20-L container (1€ = 650FCFA).

## 3. Methods

### 3.1. Identification of water access indicators

Water is most direly needed in rural environments. Access to these regions is often constrained by logistic factors, which hampers the ability to collect reliable data. Thus, the challenge is to come up with a set of explanatory variables that are (1) quick to obtain, (2) sufficiently comprehensive, and (3) versatile enough to be used in other locations. Several indicators for water access were taken into consideration, including distance, travel time, quantity, quality, cost and reliability. These were defined as per several sources, including direct experience, the academic literature, technical reports or water supply guidelines and international standards.

There is no universally-accepted benchmark for water access. The Joint Monitoring Programme establishes reasonable access in terms of the availability of a given volume of water per capita (20 L) within 1 km of the users' dwelling (UNICEF/WHO, 2000). National policies are generally more stringent, but still place the emphasis on time, quantity and distance (Table 1). The World Health Organization reviewed water access indicators for forty-five countries in 1996. Forty-two were observed to use distance-based definitions, thirty-eight used water quantity-based definitions and two used time-based definitions (Kayaga, Fisher, & Franceys, 2009; WHO, 1996, pp. 13–14). These benchmarks remain in place in most countries. For instance, recent official reports of the Tanzanian government refer to the percentage of the population with access to improved sources of water within four-hundred meters or a 30-min travel time (URT, 2013), whilst in South Africa, public standpipes should be a maximum walking distance of 200 m from dwellings and the flow rate should be no less than 10 l/min (DWAF, 2004).

Howard and Bartram (2003) explain that water consumption is interlinked with distance and travel time. In theory, when collection takes longer than 5 min or the source is over one-hundred meters away, the volume of water can be expected to decrease (Fig. 2). Consumption hits a plateau between one-hundred and one-thousand meters (or between five and 30 min), and decreases again once these thresholds are overcome.

Water quantity may not only expressed in terms of demands, but also as a function of supplies. Stoupy and Sugden (2003, p. 27) presented an approach based on a suitable number of water points per number of people. These authors establish a rule of thumb whereby each source serves 250 people. While roughly appropriate, there are two important aspects associated to measuring water access in terms of density of water points. The first one has to do with the supply threshold. Hand pumps and standpipes usually present flow rates between 10 and 25 l/min (WaterAid, 2013, p. 14). Considering an operation time of 8 h per day, the amount of people supplied would vary depending of per capita water consumption (lpcd): between 320 and 800 people would be served by a single improved source at an average consumption of 15 lpcd, while only 96 to 240 would be served at 50 lpcd.

The second issue pertains to the need to contemplate the spatial distribution of water sources. Consider this: if the ratio of improved water sources to population were to be accepted in raw terms, a 1000-people village endowed with four improved water sources

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