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Mapping Ground Water Access in Two Rural Communes of Burkina Faso

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Abstract: Granting safe water access worldwide is a major objective of the Sustainable Development Goals. Water access is a manifold concept that encompasses collection time, distance from the household, water quality, affordability, and reliability of water sources, among other factors. GIS-based methods can be particularly useful in improving water access estimates, particularly in rural areas of developing countries. Based on an extensive water point database (n = 770), this paper explores the main challenges involved in mapping water access in two rural communes of Burkina Faso. Water access is estimated in terms of coverage per surface area. Coverage is filtered into four distinct categories of improved water sources, namely existing infrastructures, operational infrastructures, permanent infrastructures, and permanent infrastructures that provide safe water. The outcomes suggest that the study area is better endowed with water access than rural Burkina Faso and the remainder of the African continent, although there are important questions regarding groundwater quality. The outcomes highlight the conceptual differences between coverage and access, as well as some of the practical difficulties involved in estimating water access beyond standard ratios. The shortcomings include the absence of continuous monitoring of infrastructure functionality and water quality, as well as water affordability, among others. Enhancing national borehole databases with items aligned with the United Nations' definition of water access is recommended.

Keywords: water supply; human right to water; basement aquifers; SDG 6; drinking water

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1. Introduction

Water provision at the household level not only encompasses drinking water, but also water for cooking, personal hygiene, and other domestic uses. Because all of these activities are crucial to leading a life in human dignity, and because water is key to food security, poverty alleviation, and health, having access to water is not only recognized as a human right in itself, but also as a prerequisite for the realization of other human rights [1,2]. Although seemingly simple, water access is a manifold concept. Dimensions of water access include per capita availability, number of people using the facilities, distance to the household, and collection time. Affordability, reliability, and water quality also play a crucial role in ensuring that individuals have adequate access to water [3]. Monitoring these variables is time consuming and logistically complicated, particularly in the case of rural communities of non-industrialized countries [4]. As a result, simpler metrics are often relied upon. Distance to a public water source and collection time are perhaps the most common indicators in developing regions. A maximum distance of 500 m from the household to the nearest water point and a queueing time of no more than 30 min are typically recommended in humanitarian charters [3], although national water supply standards tend to be more stringent [5].

Target 7.C of the Millennium Development Goals used the availability of improved water sources as a proxy for water access. Improved water sources were defined as those that "by nature of construction or through active intervention, are protected from outside contamination, in particular from fecal matter" [6]. The concept of improved water sources is useful in as much as it allows for a basic evaluation of water availability. However, some authors contend that this approach is subject to major limitations, as improved water sources do not always provide safe water [7]. Additionally, the literature demonstrates that improved water sources in rural areas are often unreliable and prone to falling into disrepair [8]. Despite these shortcomings, the improved water sources proxy was the benchmark of choice for the Millennium Development Goals, which monitored global progress until 2015. The Sustainable Development Goals (SDGs) retained the idea of improved water sources, but made inroads towards enhancing water access metrics [9]. For instance, Target 6.1 of SDG 6 ("by 2030, achieve universal and equitable access to safe and affordable drinking water for all") represents an important step in recognizing the complexities of water access because water access is now categorized as per a "drinking water ladder", instead of by means of a binary classification (Table 1).

The ultimate goal is to grant access to "safely managed" water sources; that is, improved water sources located on premises, available when needed, and free from fecal and priority chemical contamination. The immediately lower level, termed "basic access", also implies access to an improved source. In this case, it is acceptable for the source to be located away from the household, but only if water collection takes 30 min or less. Further down the ladder, "limited access" refers to the presence of an improved water source from which collection takes longer than 30 min. Finally, the "unimproved" and "surface water" categories depict the reality of people who, in the absence of improved sources, resort to unsafe water from unprotected wells, rivers, lakes, or irrigation canals.

According to the United Nations, 71% of the world's population had access to "safely managed" drinking water services in 2017, whereas 88% had access to at least "basic" services. There are, however, important inequalities between urban and rural areas [10,11]. Out of the estimated 663 million people who do not have access to improved water sources, 78% live in rural environments. Furthermore, 85% of the people living in urban areas have access to safely managed sources, whereas only 55% of the rural population does. Causes can be found mostly in social, economic, and cultural factors. Geographical constrains, issues related to the absence of transport infrastructure, and limitations in management capacity also play important roles in many cases [10,12–14].

Table 1. The United Nation's "drinking water ladder" (after [11]).

Category	Description
Safely managed	Drinking water from an improved water source, which is located on premises, available when needed, and free from fecal and priority chemical contamination
Basic	Drinking water from an improved source, provided collection time is not more than 30 min for a roundtrip including queuing
Limited	Drinking water from an improved source for which collection time exceeds 30 min for a roundtrip, including queuing
Unimproved	Drinking water from an unprotected dug well or unprotected spring
Surface water	Drinking water directly from a river, dam, lake, pond, stream, canal, or irrigation canal

An additional challenge in rural areas is the absence of adequate approaches to compute water access. The following pages are concerned with this issue. Based on data from rural Burkina Faso, we explore the challenges involved in estimating safe water access in rural communities of developing countries, as well as the limitations involved with obtaining reliable field information. More specifically, the purpose of this work is to examine the relationships between infrastructure provision, population density, and water-related factors. Our analysis caters to elements such as the functionality of water sources, seasonality, and water quality in relation to the spatial distribution of the population, with the intent of providing both an objective snapshot of water access in the study region and a methodology that can be extrapolated to other geographical contexts.

2. Materials and Methods

2.1. Study Area

This work focuses on the Centre Nord region of Burkina Faso (Figure 1). The study area is located 80 km north of the country's capital, Ouagadougou, and comprises two rural communes of the Sanmatenga province, namely Kaya and Mané. The ensemble of both territories spans 1600 km^2 and is home to 160,000 people. The population density amounts to 63 inhabitants per km^2 in Mané and 129 inhabitants per km^2 in Kaya. This disparity is attributable to Kaya town, the administrative capital of the Centre Nord region. Kaya town accounts for 56,800 people; that is, 34% of the total population of both communes. The next largest settlement in the area is Mané, with 7000 residents (4%). The remainder of the population is scattered across 120 small villages. Only eight of these exceed 2000 inhabitants, whereas none exceeds 3000.

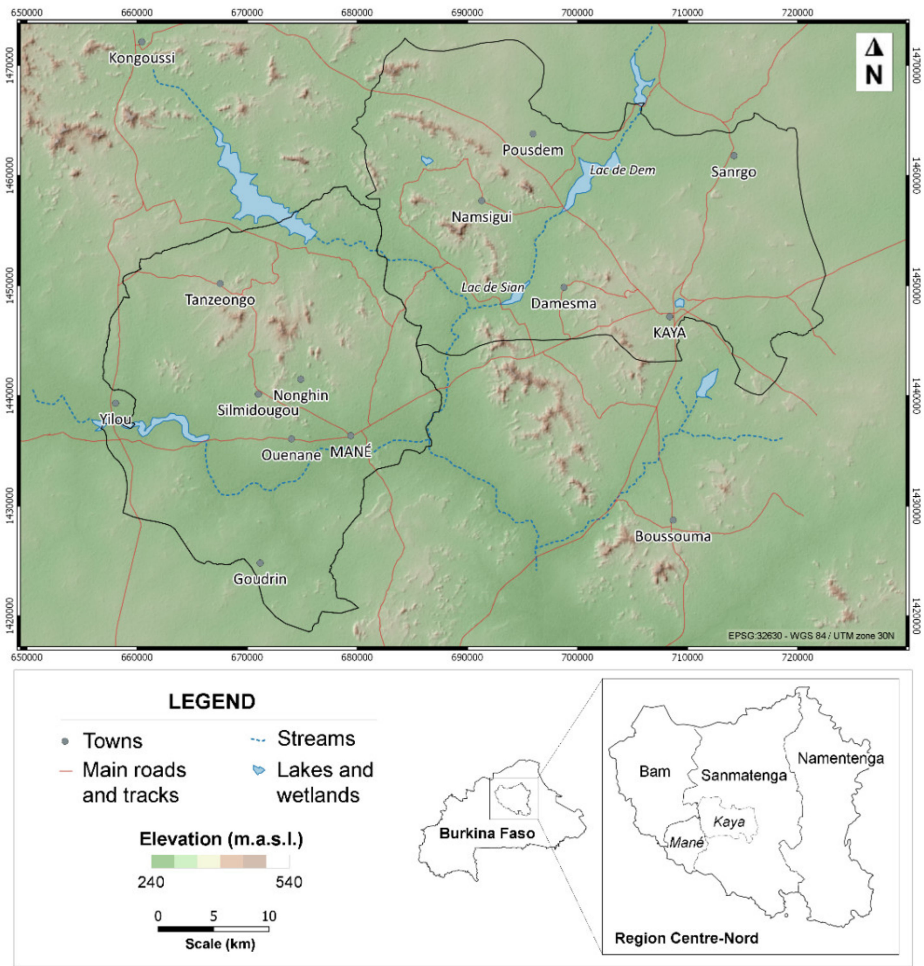

Figure 1. Geographical setting. The study area is located in the Centre Nord region of Burkina Faso, 80 km north of Ouagadougou.

From a geographical standpoint, the region belongs in the Nord Plateau Mossi domain [15]. The landscape is predominantly flat, with altitudes ranging between 200 and 300 m.a.s.l. The sole exception is a series of hills that run across the central part in the N–S direction. These reach up to 500 m.a.s.l. Climate conditions are typically Sahelian. Mean daily temperatures range from 24 °C in January to over 32 °C in April. Yearly rainfall amounts to 600 mm, however presents significant inter and intra-annual variability [16]. Rain takes place almost exclusively between May and September, and is close to zero for the rest of the year. Potential evapotranspiration is in the order of 1900 mm/y [17].

The region is located in the upper part of the Nakambé river basin (White Volta). Several natural wetlands, including the Lac de Dem and the Lac de Sian, have been reconverted into small-capacity dams to favor downstream irrigation during the dry season. Because surface water is unreliable for most of the year, the majority of the local population relies on groundwater for domestic supply.

Much like the rest of Burkina Faso, the Sanmatenga province is underlain by a Precambrian crystalline basement. Hard rock formations such as these are common in central Africa, and are characterized by the presence of water in fractures (mostly discontinuous) and weathered mantles (mostly continuous) [18,19]. Weathered mantles are typically clay-rich and capped by a layer of lateritic soil [20]. The saturated thickness in hard rock aquifers is frequently less than 100 m. Productivity is low, but generally sufficient to meet domestic demands [21,22]. Boreholes, particularly those that are drilled within the weathered zone and that reach down to the basement, are likely to yield enough groundwater to justify the installation of a hand pump (>0.5 m^3/h) [18,23].

In the study area there is a close association between landforms and groundwater occurrence. The hills are mostly unweathered outcrops of the crystalline basement, which are impervious for practical purposes. The flat areas feature a cover of weathered granite and schist that stores modest quantities of groundwater, both at the level of the weathered mantle and of the underlying fractures. The weathered thickness ranges between 10 and 50 m across the flats, while the saturated thickness ranges 10 to 30 m [17].

Alluvial deposits in river valleys and floodplains present high permeability and storage capacity when dominated by coarse-grained sand and gravel. Where alluvium is underlain by permeable rock, groundwater in the alluvial deposits can be expected to be connected with the bedrock aquifer. The water table in alluvium is often shallow, at less than 10 m below the ground surface [24,25]. Alluvial deposits are prone to groundwater pollution associated with percolation from the surface and flooding.

Relatively little is known about the natural processes that control groundwater composition and the anthropogenic factors that affect groundwater quality across Burkina Faso. Groundwater is generally suitable for drinking, although water quality is problematic in some cases. Shallow groundwater is exposed to nutrient and microbial contamination in many rural areas [26–28]. The study region is no exception; informal sanitation predominates, thus posing a risk to groundwater supplies [29–31]. Nitrate pollution from agriculture and domestic waste is common in shallow groundwater. The highest concentrations are often found in the vicinity of the more densely populated areas [20]. Values in excess of 500 mg/L have been found in rural contexts of the Kaya and Mané communes. Arsenic associated with zones of gold mineralization in Birrimian volcano–sedimentary rocks poses a threat to water supplies across various zones of the country, including a sector of the study area [32]. Salinity is known to be a problem in parts of northern Burkina Faso, but is tolerable in Kaya and Mané.

The Ministry for Water and Sanitation is ultimately in charge of developing and implementing water and sanitation policies and strategies. Water in Burkina Faso is managed at the catchment scale. Five river basin agencies have been set up in the country's four main basins (Comoé, Nakanbé, Mouhoun, and Niger). The Nakanbé, Comoé, and Mouhoun river basin agencies were created in 2010. The Gourma river basin agency, encompassing parts of Nakanbé and Niger river basins, and the Liptako agency, which is responsible for the remainder of the Niger basin, were created in 2011. Kaya and Mane belong in the Nakanbé catchment, whose river basin office is in the city of Ziniaré (about 30 km to the north east of Ouagadougou, outside the study area).

River basin agencies develop water management master plans in agreement with all stakeholders and then allocate water to users based on availability and use. The ministry is represented in all thirteen regions of the country by means of the Regional Offices of Water and Sanitation (Direction Regional de l'Eau et de l'Assainissement). Regional offices have commune-based technicians who are in charge of collecting and disseminating information on water. This includes collecting information on every borehole drilled at the village level, be it publicly or privately funded. Borehole data are incorporated to the national database, which will be described in the following section.

Most boreholes in the area are equipped with hand pumps. The responsibility for managing a water point rests with the local community. Newly endowed populations are invited to provide a team of two people to manage the pump. The first one is in charge of collecting fees, while the other is a mechanic. The mechanic is trained in hand pump maintenance and equipped with a toolbox, so that service downtimes can be minimized.

2.2. Borehole Database

The 2016 version of the national water point database was made available by the Regional Direction of Water and Sanitation in Kaya [33]. The database comprises information from all towns and villages of the Kaya and Mané rural communes. The data include information on the population, number of boreholes, borehole coordinates, operational status, use, seasonality, pump type, and groundwater quality, among other items.

The database refers to two types of drinking water structures, namely boreholes and modern wells, both of which fit in the category of improved water sources. The database includes 770 water points, 484 in the commune of Kaya and 286 in Mané. At the time the database was compiled, 19% of the water points in Mané and 11% of those in Kaya were out of service. A random sample of approximately 100 of these structures were visited during a verification campaign in November 2017. Over 95% of them were in similar condition to those described in the borehole database. Some of the pumps identified as functional presented different degrees of degradation, which is consistent with recent reports on borehole drilling in Burkina Faso [34].

The available database presents information on electric conductivity and nitrate concentration, but does not specifically cater to fecal contamination. Conditions within pits lead to nitrification of the contained waste, which also results in potential for contaminating shallow water tables [35]. In the absence of specific data, this research considers nitrate both a source of priority contamination in itself and an imperfect proxy for fecal pollution. A threshold of 50 mg/L of nitrate was established based on World Health Organization drinking water guidelines [36]. Practical implications will be discussed later on.

2.3. GIS Database

A geographic database was developed in QGIS 3.10. All towns and villages in the region were carefully delineated on a building-by-building basis, taking satellite images as a reference. A total of 8152 building polygons in Mané and 11,808 in Kaya were identified, spanning a total built-up area in excess of 2.5 km^2. Building delineation serves a double purpose. In the first place, it contributes to identification of the locations of households in relation to drinking water sources, and secondly, together with village population data, it can be used to obtain a reasonable estimate of the number of people served by each facility.

Water point data were subsequently added to the geographic database and filtered by operational status, seasonality, and groundwater quality. Here, 500 m buffers were generated for each of the resulting subsets. The 500 m buffer stems from widely accepted water access metrics [3], and roughly responds to the 30 min roundtrip standard outlined in Table 1 [9]. This assumes an average walking speed of about 4 km/h, with 15 min for queuing at the source and collecting water.

Data filtering led to four water provision levels from improved water sources: (1) theoretical drinking coverage, all existing water points considered; (2) population served by operational water points; (3) population served by permanently operational water points; and (4) population served by permanent operational water points that also provide safe drinking water.

The database does not specify flow rates, so per capita water availability could not be computed on a systematic basis. However, it is known that all populated places except for Kaya and Mané are supplied exclusively by dug wells or hand pumps (the latter with a clear predomination of India, ABI/DIAFA, and to a lesser extent, Kardia pumps). Each hand pump serves an average of 300 people [37].

3. Results

Table 2 presents the outcomes of filtering the borehole database as per the seasonality, operational status, and water quality criteria. In the case of Mané, 81% of the water points were operational, while 67% were worked on a permanent (non-seasonal) basis. Just 59% provided safe water. Kaya's figures are higher. About 89% of the boreholes and wells were operational, 79% were permanent, and 72% provided safe water. With both regions considered, 86% of the structures were operational, 74% were permanent, and 67% provided safe water. Figure 2 presents the spatial distribution of these results.

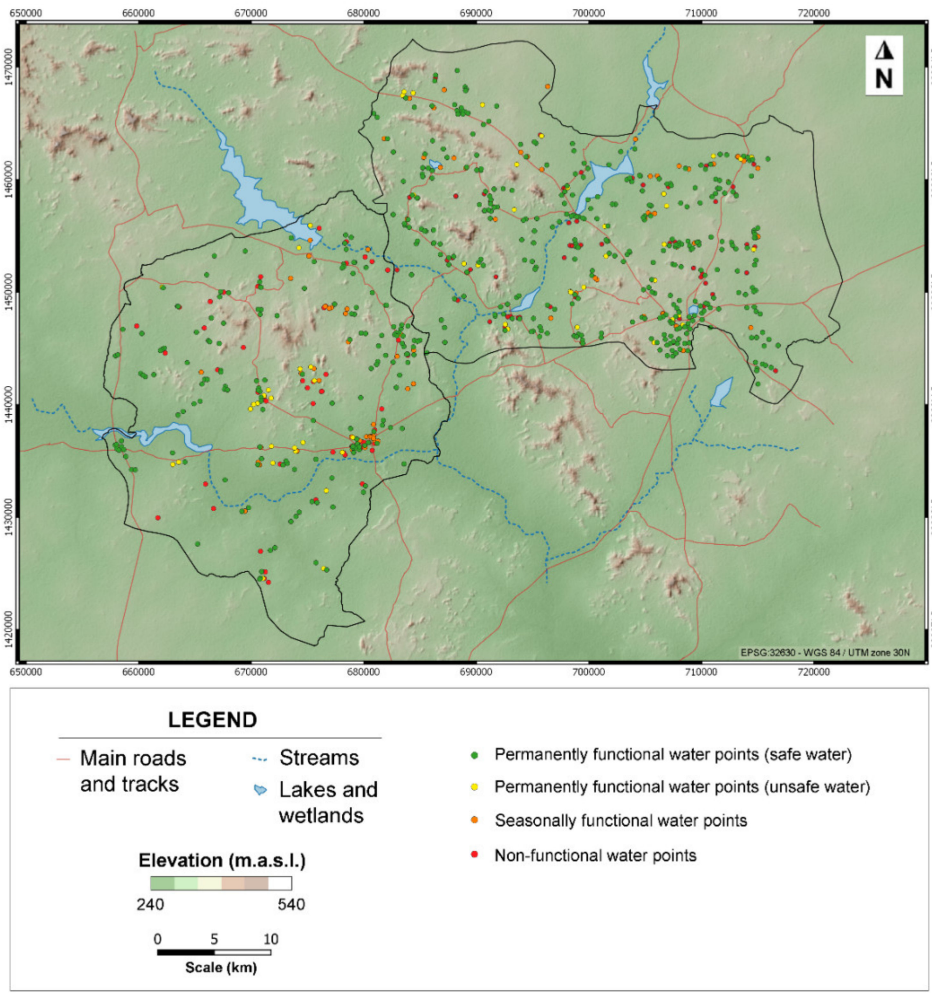

Figure 2. Spatial distribution of water infrastructure statuses across the rural communes of Kaya and Mané, Burkina Faso.

Coverage by surface area renders a more accurate picture of ground conditions (Table 3). Coverage is calculated as the percentage of built-up areas within 500 m of an improved water source. In turn, water access is calculated as the ratio between the village population and the surface of built-up areas within the buffer. Each of the four provision levels (infrastructures, operational, permanent, safe water) renders a different picture. Computing the coverage by surface area reverses the proportions found in Table 2. Theoretical coverage amounts to over 97% in Mané and 80% in Kaya. Once seasonal and non-working infrastructures are removed, actual coverage rates drop to 81% and 75%, respectively. Coverage by area is higher than coverage by functional infrastructure because the network of water points is redundant. In other words, when two structures are sufficiently close to one another, downtime for one of them is partially offset if the other one remains operational (Figure 3).

Table 2. Outcomes of the borehole database analysis filtered by categories. "Water points" represents the number of existing wells and boreholes; "functional" is the number of serviceable water points; "permanent" refers to serviceable water points that work all year round; "safe water" represents all serviceable water points that work all year round and provide safe water. Percentages are computed in relation to the infrastructures column.

Rural Commune	Water Points	Functional	Permanent	Safe Water
Mané	286 (100%)	233 (81%)	192 (67%)	169 (59%)
Kaya	484 (100%)	430 (89%)	381 (79%)	348 (72%)
Total	770 (100%)	663 (86%)	573 (74%)	517 (67%)

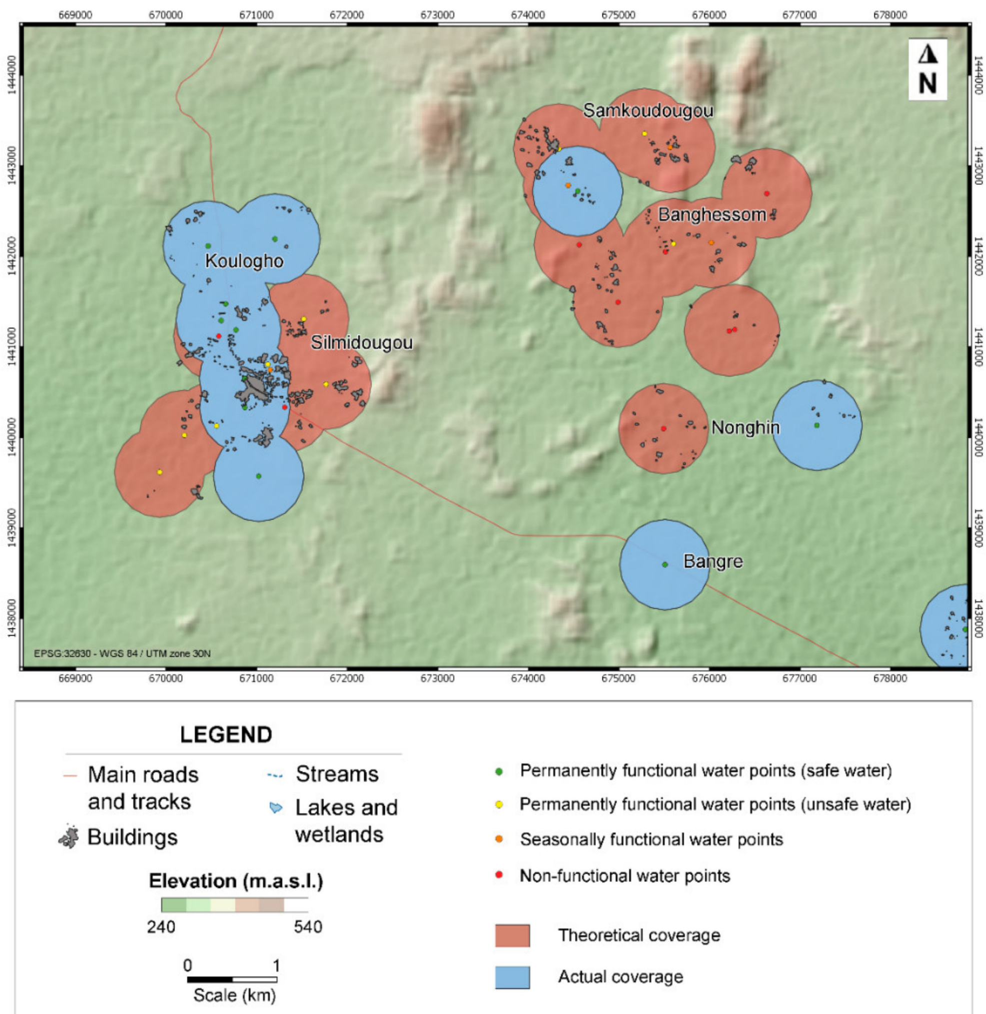

Figure 3. Water infrastructure coverage around the villages of Silmidougou and Banghessom. Both villages, together with their outskirts, present similar numbers of infrastructures and a theoretical coverage close to 100%. Once seasonal, non-functional, and unsafe sources are removed, coverage in Banghessom is significantly lower than in Silmidougou.

Table 3. Water access computed by surface area. "Infrastructure" represents the percentage of built-up surface within 500 m of all existing wells and boreholes; "operational" is the percentage within 500 m of serviceable infrastructures; "permanent" refers to serviceable infrastructures that work all year round; "safe water" represents the percentage of built-up areas within 5000 m of all serviceable infrastructures that work all year round and provide safe water.

Commune	Water Points	Functional	Permanent	Safe Water
Mané	97.7%	93.3%	89.3%	81.2%
Kaya	80.2%	78.6%	77.0%	75.1%
Total	85.2%	82.8%	80.6%	76.9%

Differences in levels of service are also clear when appraised in terms of population. Figure 4 shows that the larger towns (population >1500) maintain coverage per surface area above 70% once all service filters are applied. The variability in small villages is greater. Indeed, these were found to be more sensitive to filtering criteria. This can be attributed to reliance on a small number of water points, which means that failure to comply with any of the filtering criteria causes coverage to drop dramatically. Take for instance the villages of Pousdem (population 195), Ouenane (751), and Nonghin (541), where safe water coverage rates per surface area were observed to be 96%, 91%, and 74% lower than the theoretical coverage level, respectively.

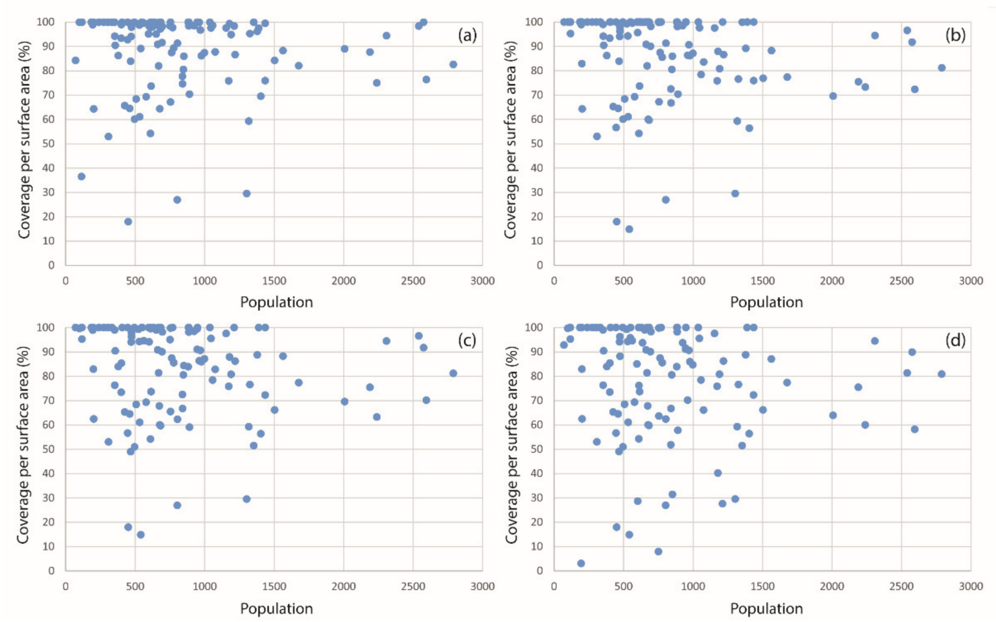

Figure 4. Water access coverage per surface area versus population, with the towns of Kaya and Mané (population >3000) omitted to facilitate readability: (**a**) theoretical coverage, all infrastructures considered; (**b**) coverage considering only operational infrastructures, (**c**) coverage considering operational, non-seasonal infrastructures; (**d**) coverage considering operational, non-seasonal infrastructures that provide safe water.

Figure 5 provides a frequency analysis for water access. The horizontal axis represents the frequency of each level of coverage expressed in terms of the surface area, whereas the vertical axis represents the number of villages that fall within each coverage interval. Theoretical coverage was found to be 100% in 80 villages, but only 50 villages maintained full coverage when appraised in terms of safe water from non-seasonal sources.

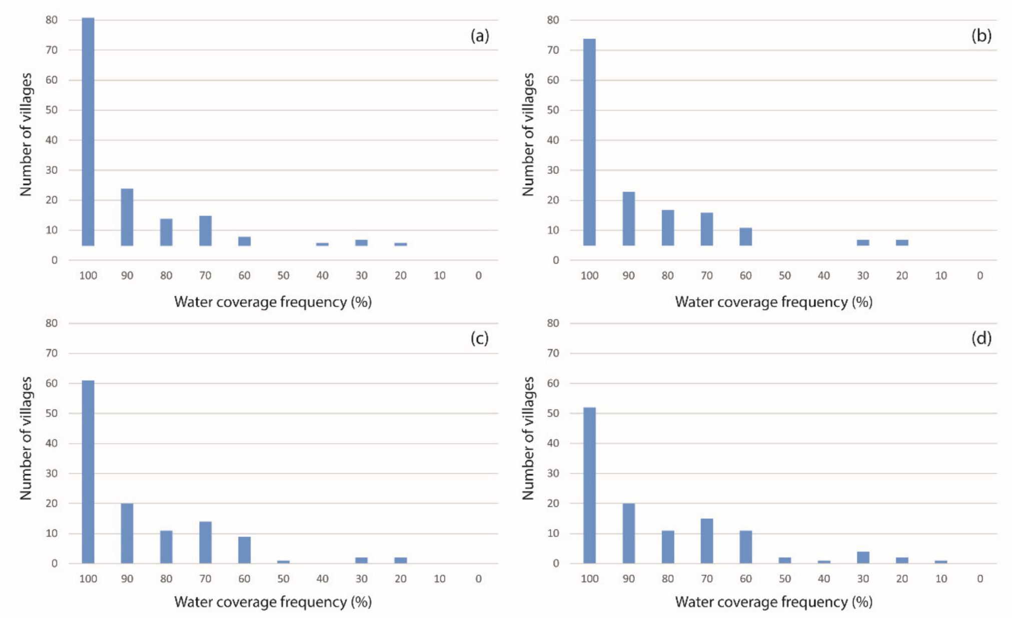

Figure 5. Frequency analysis of water access coverage per surface area. (**a**) theoretical coverage, all infrastructures considered; (**b**) coverage considering only operational infrastructures; (**c**) coverage considering operational, non-seasonal infrastructures; (**d**) coverage considering operational, non-seasonal infrastructures that provide safe water.

4. Discussion

Aquifers provide crucial sources of drinking water across sub-Saharan Africa [21,38], where the majority of the population depends on groundwater for domestic supplies and three-quarters of all the groundwater pumped from boreholes or taken from springs is used for domestic purposes [39]. It is estimated that the continent's shallow aquifers underpin the daily existence of 200 million people [40]. In countries such as Burkina Faso, the Central African Republic, Chad, Ethiopia, Nigeria, South Sudan, Uganda, and Somalia, groundwater is the main drinking water source for 70–90% of the population [41]. The study area is no exception, as close to 100% of the population relies on groundwater.

Our study cannot be compared on strict terms with other examples in the literature due to differences in scope, spatial scale, and the points in time at which they were carried out. It is, however, possible to draw some analogies. The only known benchmark at the national scale is the set of baseline figures reported by Burkina Faso to the Joint Monitoring Programme of the United Nations (Table 4). These state that only 43% of the population in rural areas of the country had at least basic water access at the time of reporting. Since the "permanent" and "safe water" columns in Table 3 resemble two different degrees of "at least basic" water access, the outcomes of our work suggest that Kaya and Mané are better endowed than the national average.

Table 4. Baseline water access in Burkina Faso as per the United Nation's Joint Monitoring Programme [11].

Category/Service Level	At Least Basic	Limited	Unimproved	Surface Water
National	54%	22%	22%	2%
Rural	43%	24%	30%	3%
Urban	79%	16%	4%	1%

A potential explanation is the high degree of functionality of the water points in the area. Data from Kaya and Mané show 88% of the hand pumps in Kaya and 81% in Mané to be functional. This represents an improvement in relation to the outcomes of the only known systematic survey of pump functionality carried out in northern Burkina Faso [42]. According to this, approximately 79% of the pumps installed by UNICEF in selected provinces of the Centre Nord, Sahel, and Nord regions were functional in the early 1990s. The report also noted that this was probably an overestimate, because pumps were considered functional so long as "water was still coming out", with no specific provision for working pumps in need of repairs.

Our results may also be placed in the broader context of continent and regional-scale studies. The Rural Water Supply Network highlighted pump functionality as a major water supply problem across rural sub-Saharan Africa [43]. Based on a detailed analysis of 25,000 hand pumps in Liberia, Sierra Leone, and Uganda, this report found that over one-third of hand pumps were non-functional just over a decade ago. Pump non-functionality was correlated with system age, distance from the district or country capital, and absence of fee collection [12]. Other key variables included water point type, hand pump type, funding organization, implementing organization, spare part proximity, availability of a mechanic, regular servicing, regular water committee meetings, women in key water committee positions, rainfall season, and perceived water quality. Corrosion associated with different factors, including acidic groundwater, has also been identified as a key predictor for pump non-functionality in West Africa [44].

While our work does not specifically deal with causes for pump non-functionality, some of the highlighted variables appear relevant. For instance, Figure 2 shows that a significant number of non-functional pumps are located in those areas of Mané where access is most problematic (central and southern parts of the commune). These zones are also among the furthest from Kaya, where repair services are located. System age could be partially related with pump functionality. The mean age of non-working infrastructures in the region is 30 years, with a standard deviation of ± 8 years, while the mean age of functional infrastructures 24 years, with a standard deviation of ± 10. It is, however, difficult to draw further conclusions because there is no systematic information as to the conservation status of the boreholes, how often hand pumps are fixed, or when the most recent repairs took place.

Water access has been computed under two basic assumptions. The first one is that people will get their water from improved water sources located within 500 m of their households so long as these are available; if not, they would either walk longer distances ("limited" water access, as per Table 2) or resort to unimproved sources or surface water (less than "limited" water access). Without a detailed field survey, there is no way to know whether people actually use alternative sources despite having an improved one nearby. Anecdotal evidence suggests this could be case in some instances, as children were occasionally spotted collecting surface water in carriages during fieldwork.

The fact that results are computed in terms of "coverage", rather than actual "access", emphasizes crucial differences between these two concepts. In our case, coverage represents the presence of an improved water source nearby. The notion of access is more complex. Access implies additional action, purpose, and means on the part of the users. This implies that coverage is a prerequisite for access, whereas the opposite is not true [44]. In other words, the physical availability of improved water sources does not mean that people will use them. People may choose not to collect water from improved sources if they perceive it to be too expensive or if the pump is located too far away from home. Conversely, some people may walk longer than 500 m if there are no other water points nearby or if they dislike the taste of the water from the nearest source.

The second assumption is uniform population density at the village scale, with an underlying hypothesis being that every building in the area is inhabited. Based on direct observation, this assumption seems reasonable in the case of small settlements (<2000 people). It is, however, recognized that it can be problematic in larger towns, where the proportion of administrative and commercial buildings is much greater.

Previous work shows that the street layout can distort 500 m buffers to a significant extent [45]. This may have implications in the case of larger settlements, such as Kaya town, where streets constrain mobility. However, including this in the calculations would be largely pointless in the case at hand, as the uncertainties involved in computing population density offset the advantages associated with taking the street layout into account.

A shortcoming of the database is the absence of flow rates. This is a relatively minor issue when referring to hand pumps, as these typically yield between 0.5 and 1.5 m^3/hour. However, the flow rates of protected wells can vary much more widely and are unknown in all cases. We were, therefore, unable to compute per capita water availability as the ratio between flow rate and the number of people served per source. While this represents a limitation in commune-scale results, it is possible to see how water availability could be important in some cases. Consider for instance the case of Tanzeogo, in Mané. Tanzeogo is a medium-sized village (population 1038) served by a single hand pump. The pump provides safe water throughout the year as per the defined threshold and is in functional condition. According to the 500 m buffer approach, coverage in Tanzeongo would be 100%. However, because a hand pump serves a maximum of about 500 people, computing access in terms of water availability allows us to identify deficiencies in domestic supply. In methodological terms, this flaw could be easily overcome with more complete information on flow rates.

Rural habitats in central Burkina Faso are characterized by disperse population. This presents practical implications in terms of water coverage. Insights may be drawn by comparing our findings with those from a survey carried out in Djedougou, a rural commune of Mali located 550 km to the west of the study area [31,44]. Djedougou is roughly similar to the two rural communes featured in this research in terms of size (630 km^2), population density (57 inhabitants/km^2), climatic conditions, and typology of water provision systems. When considering only the raw number of water points, the density in Mané is 6.2 water points per 1000 inhabitants, while this amounts to 4.3 in Kaya and just 2.1 in Djedougou. Theoretical coverage rates per surface area amount to 98%, 80%, and 82%, respectively.

These figures clearly reflect differences in land property structure and present major implications in terms of water access. Coverage in tight-knit villages such as those found in rural Mali can be achieved with a relatively low number of water points (around 80 in the entire commune of Djedougou, versus 286 in Mané and 484 in Kaya). Water provision, thus, becomes more efficient in economic terms. The distance and collection time are also reduced so long as enough water points are available. In contrast, a major trade off associated with a higher population density at the local scale is the risk of groundwater contamination arising from pit latrines and informal sanitation systems. The findings of these studies show that water access in the Djedougou rural commune dropped to 39% when considering only serviceable and contamination-free sources, while in Mané and Kaya the figures were 81% and 75%, respectively.

Since contamination in the case of Djedougou was analyzed in terms of fecal coliforms instead of nitrate content, further work would be needed to examine the argument of population density in relation to typologies of groundwater contamination in greater detail. This raises the issue of water quality, which is perhaps the most important limitation of the input data. Indeed, it is well known that nitrate content in groundwater can be associated with sources other than fecal matter [36], and that water sources with less than 50 mg/L of nitrate may incorporate unacceptable loads of fecal microorganisms. Hence, the "safe water" descriptions in Tables 2 and 3 do not strictly meet the requirement of "free from fecal contamination" that defines safe water access per international standards.

In the past, groundwater nitrate in rural Burkina Faso has been linked to housing density, as well as to certain ethnocultural factors [26]. No correlation between nitrate concentration and those variables was found in the study region. It is, however, recognized that data are limited to a single reading per water point, with no reference to the moment each was taken. Additionally, there is little or no information on the natural background concentration of nitrate in groundwater. This presents implications not only in terms of nitrate contamination itself, but also when using it as a proxy for fecal content. Furthermore, nitrate concentration is known to fluctuate seasonally [27]. This also means that the available information is insufficient for trend-wise evaluation. We, therefore, identify uneven data collection and a limited groundwater quality monitoring network as major problems of rural water supplies [46]. Continuous monitoring would be needed to attain more realistic estimates, as well as to evaluate progress.

In addition, the database does not cater to other sources of priority contamination known to be a problem in parts of Burkina Faso, such as lead and arsenic [20,28,47], nor does it provide for incipient forms of contamination such as those derived from informal gold mining. Geogenic arsenic in Burkina Faso stems from the oxidation of sulfide minerals (e.g., arsenian pyrite, arsenopyrite) often associated with gold mineralization, and occurs as As(V) under oxic conditions [32,47]. In the context of rural supplies, removing arsenic at the local scale is often the only option to meet the WHO and national acceptance thresholds (10 µg/L) [48]. This hints at the need to develop methods that can be implemented on the ground [48–50]. Priority chemical contamination remains a major challenge for the future.

On a final note, it is recognized that this work was carried out in a changing environment. Burkina Faso's national water strategy is expected to improve the landscape of rural water access in the coming years. In particular, low-productivity boreholes and hand-pump-based supply will gradually be superseded by high-yield boreholes (minimum flow rates of 5 to 10 m^3/h). These are to be equipped with solar pumps and water towers (600 m^3 storage capacity), so that safe water can be delivered to individual households and public fountains [51]. This is likely to minimize the risks involved with groundwater pollution, and in practice should make it easier to obtain more reliable estimates of water access across the country.

5. Conclusions

Despite being well into the 21st century, obtaining safe water for domestic use remains a major challenge for millions of people around the globe. While inroads towards universal water access have been made in recent decades, there is still a long way to go. The practical value of improved water sources has been overemphasized, disregarding the fact that improved water sources are frequently subject to downtime, that flow rates can be insufficient, and that many improved water sources are actually unsafe in terms of water quality. Continuous monitoring of all these aspects is often lacking, which hampers attempts to compute water access figures over time. By highlighting the conceptual differences between coverage and access, this research also shows that estimating water access in terms of the presence of improved water sources is of limited interest, even under a service ladder approach.

Official figures tend to overestimate the number of people who actually have reliable access to safe water. This is particularly true for rural environments in developing countries, where infrastructure maintenance and water quality monitoring still pose major challenges. The experiences of central Burkina Faso suggest that better estimates of water access might be attained through the very process of improving rural water supplies overall, as well as by replacing village-scale systems with more centralized water infrastructure whenever possible. Similarly to other national borehole databases in sub-Saharan Africa, Burkina Faso's caters to important aspects of water access, including functionality, population served, and seasonality. However, it would be desirable to include additional information on flow rates and water quality (fecal and priority chemical contamination). This would facilitate the task of obtaining more accurate estimates of water access in the future.

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