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Use of GIS as a Tool for Integrated Water Resources Management in the City of Parakou, Benin

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Abstract:

Water, a source of life, is the habitat, food, means of production and transportation and is threatened by irregular rainfall and evaporation. The objective of this study is to contribute with the help of GIS to a better management of water resources in the city of Parakou. To achieve this objective, the methodological approach was based on the collection, processing and analysis of data through the SWOT model. The sample consisted of 109 individuals distributed in the three districts of the city of Parakou. The study revealed that the water resources available in the city of Parakou are of three types (rainwater, surface water and groundwater). These resources are constantly decreasing due to the downward trend in rainfall with a slope of -3.99mm. In addition, the growing population with a growth rate (4.9%) from 2002 to 2013 and the poor use of these resources influence its availability. The unequal distribution of waterworks (58.94%) for the first

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arrondissement and 41.06% for the other two coupled arrondissements, as well as the unequal distribution of water from the Société Nationale des Eaux du Bénin (SONEB) lead to difficulty in accessing water. Under these conditions, the populations are developing various measures to adapt to the situation. These measures are related to the subscription of households to public water services, the purchase of drinking water, water treatment and water conservation. Given the effectiveness of the measures identified and their limitations, it is important that decision-makers develop a sectoral policy encompassing the construction of water supply infrastructure, better management of structures and support for the reorganization of the drinking water sector.

Keywords : Water, Resources Management, supply, GIS, Parakou

1. Introduction

In a world increasingly subject to urbanization, thus exposed to increasing risks with a galloping population over the years; water occupies a primordial place; water needs are thus becoming increasingly vital (R. Abdoulaye, 2017, p. 526). This observation requires all its importance in West Africa in general and in the city of Parakou in particular. Indeed, several international events mark the evolution of ideas in the management of water resources. At the conference in Dublin (Ireland) in 1992, a number of key principles were adopted by the international community with regard to the sustainable use of water resources. These principles are now recognized internationally and form the basis of debates on the management of water resources. They offer a framework for analyzing and then managing the different uses of a polluted resource, in a context of competitiveness and increasingly harsh conflicts (P. Moriarty et al., 2007, p. 7). Today, water resources in general are facing major constraints such as climate variability and change, increased demand, degradation of water quality, conflicts of use and national tensions (upstream/downstream) or international (shared rivers) for the sharing of the resource. To address these concerns better management of water resources should be considered. The city of Parakou located in the North of Benin has a poorly diversified hydrographic network. This study aims to contribute with the help of GIS to better management of water resources in the city of Parakou.

2. Materials and Methods

2.1 Presentation of the study environment

The City of Parakou extends over approximately 60 Km². It is located between 9°18'25" and 9°23'55" north latitude and between 2°31'48" and 2°39'55" east longitude. It is bounded to the north by the third arrondissement of the commune, to the south by the first arrondissement, and to the east by

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the second arrondissement. It is practically halfway to the north-south axis (RINE 2) of the country and has a road link with neighboring countries (Togo, Burkina-Faso, Niger, and Nigeria). There is also a rail link from Cotonou. The city of Parakou stands out as the real capital of the northern region thanks to its administrative, banking, and industrial functions and ranks third in the hierarchy of the main cities of Benin after Cotonou and Porto-Novo (R. Abdoulaye, 2006, p. 6). Figure 1 presents the geographical location of the city of Parakou.

The city is in the domain of the humid tropical climate of the Sudanian type, characterized by the alternation of a rainy season (May to October) and a dry season (November to April) (Akognongbé et al., quoted by AD Chabi, 2017, p. 12). The average annual rainfall is estimated at 1151.5 mm. Maximum precipitation is often observed between the months of August (214.6 mm) and September (212.5 mm). The hydrographic network is essentially made up of streams and backwaters.

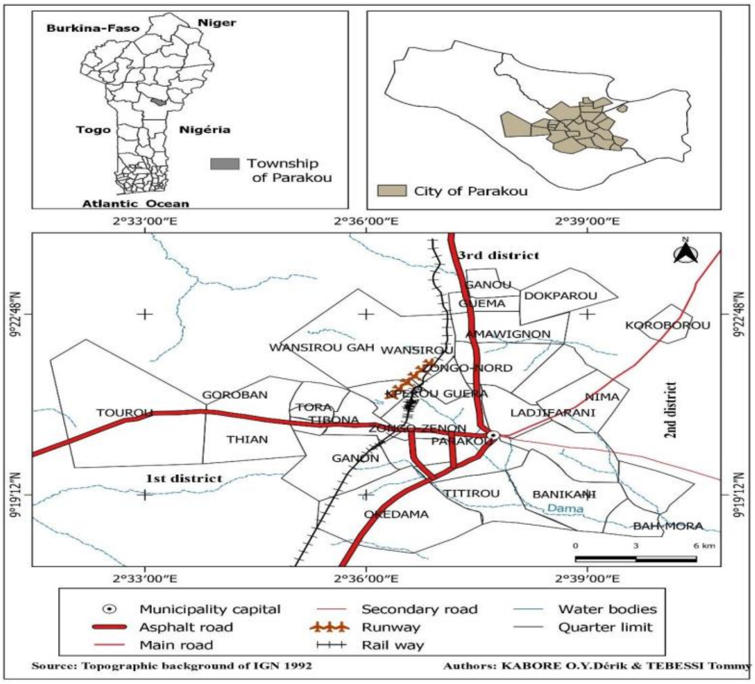

Figure 1: Geographical location of the city of Parakou

The soils are generally tropical ferruginous or ferritic types on a crystalline basement (A. Akognongbé et al., 2012). The plant cover is dominated by wooded savannah. It is characterized by the presence of néré (Parkia biglobosa), false mahogany (Blighia sapinda), ebony (Diospyros mespilifounis), and shea (Butyrosperum paradoxum). The urban economy is characterized by: an industrial fabric making the city an industrial pole; the development of large aircraft transport activities; a predominant informal

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sector; a booming banking sector; a thriving commercial sector; a developed artisanal sector. (C. Hougbegnon, 2019, p. 21).

2.2. Data and methods

The methodological approach used revolves around: data collection and data processing, the analytical framework was made through the SWOT model

2.2.1. Data

The data used for this study are rainfall data from 1988 to 2020 downloaded at https://power.larc.nasa.gov/; socio-anthropological data collected in the field; data on the spatial distribution of hydraulic infrastructure obtained from the city's hydraulic service and finally demographic data from INSAE.

2.2.2. Methods

The tools used for data collection are, among others, the observation grid which made it possible to discover the field of study beforehand, the interview guide for obtaining information from officials of the town hall, SONEB, authorities local and municipal, a digital camera for taking pictures, a GPS to geo-reference the units of the various hydraulic structures.

To carry out this research, a sample was chosen in a reasoned way and made up of: one (01) manager of the water and sanitation services of the town hall, three (03) managers of the technical services of the districts, two (02) SONEB, one (01) from the city's water supply service, i.e. a total of 116 respondents. The choice of this sampling was made using the probabilistic theory of Schwartz (1995).

The method of processing the data collected takes into account the classification and distribution of the data, the control of their quality, the counting, and then the analysis.

The survey questionnaire used in the field was read and then codified. This data is then entered into Excel sheets under Windows. This database made it possible to process the data and carry out a quantitative and qualitative analysis.

To assess the climatic variability in the municipality of Parakou, the arithmetic mean was used; The average rainfall height was used over a period of 1988-2020. It is obtained by summing the distinct values that have been observed, each of them being assigned a weight equal to its frequency.

Its formula is $\bar{X} = 1/n \sum xi \; n \; i=1$; with n: the number of observations; $\bar{X}$: the average and xi: the value of the annual rainfall in the year i.

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3. Results

3.1. Types of water resources in the city of Parakou

The main water resources used in the city of Parakou are, among others, rainwater, surface water, and groundwater.

3.1.1. Rainwater

The rainwater available in Benin varies from region to region. Northern Benin is characterized by a two-season climate (a rainy season and a dry season). In Benin, the average rainfall varies between 750 and 1500 mm per year. Figure 2 presents the average annual rainfall regime of the city of Parakou over the period from 1988 to 2020.

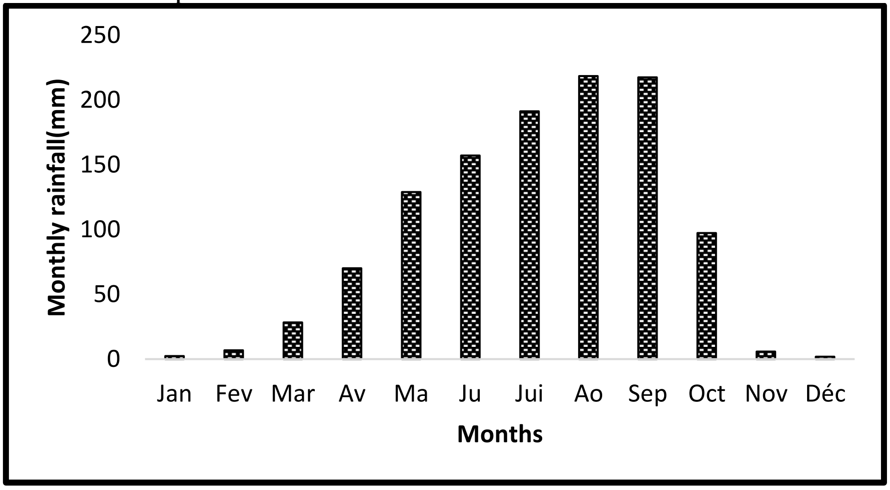

Figure 2 : Average monthly rainfall regime of Parakou 1988 to 2020
Source: NASA, 2021 (Parakou station)

The maximum rainfall is recorded in July, August, and September which are respectively 191.34 mm; 218.47mm, and 217.45mm.

The amount of rainfall varies from year to year. Figure 3 presents the interannual variation of rainfall in Parakou from 1988 to 2020.

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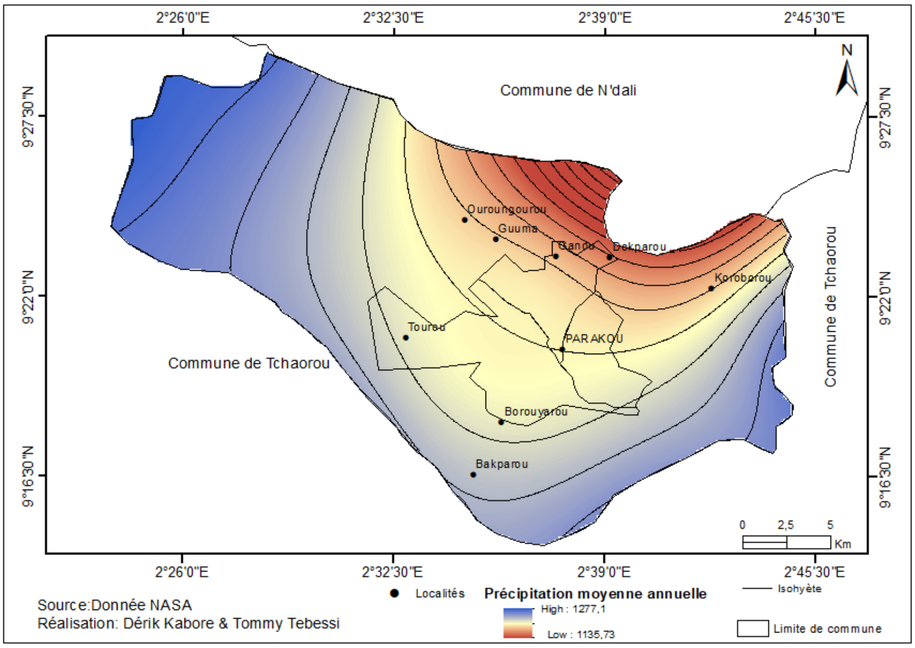

Figure 3: Interannual variation in rainfall in Parakou from 1988 to 2020
Source: NASA, 2021 (Parakou station)

The average rainfall over the period 1988-2020 varies between 1135.73 and 1277.1 mm.

3.1.2. Surface water

The city of Parakou has various courses and water points. The Okpara River is the city's largest source of surface water. This river covers an area of 190 ha, with a maximum length of 15 km and an average depth of 7.50 m. The reservoir of the Okpara dam is built in impermeable lateritic earth placed in a North-South direction over a length of approximately 480 m. The dam is centered on three spillways, namely the south spillway, the north or regulation spillway, and the lateral or flood spillway.

3.1.3. Groundwater

The geological substratum of the city of Parakou essentially consists of formations such as migmatites and granitoid migmatites. Figure 4 illustrates the hydrogeological context (groundwater potential) of the city of Parakou.

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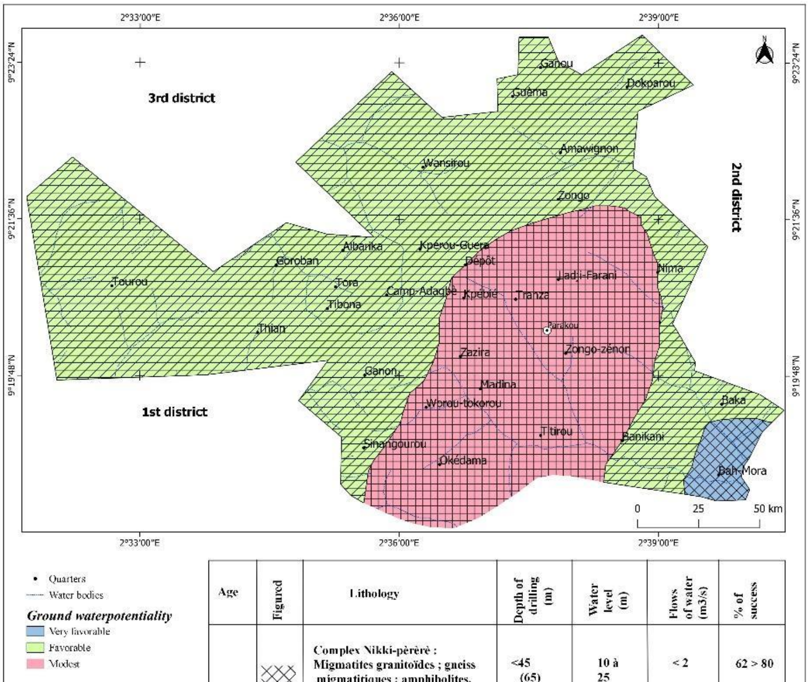

Age	Figured	Lithology	Depth of drilling (m)	Water level (m)	Flows of water (m3/s)	% of success
Dahomeyen		Complex Nikki-pèrèrè : Migmatites granitoïdes ; gneiss migmatitiques ; amphibolites, diorites, quartz in intercalations	<45 (65)	10 à 25	< 2	62 > 80
		Syntectonic granite calco-alcalins, granitoïdes, lephlbolites, migmatites, gneiss migmatiques whith biotite	<45 (65)	10 à 25	< 2	62
Late Instruisons		Massive intrusive-granites-prophyroid granite-grano-diorite	<45 (65)	10 à 25	2 à 5	52

Source:Hydrogéological Map of Bénin 1/500000, May 1985 & Topographic background of IGN 1992
Author: Dérik Kabore

Figure 4: Groundwater potential of the city of Parakou

In terms of groundwater potential, the soil of Parakou is favorable even though there is a relative disparity in hydrogeological formations. In fact, the groundwater level varies between 10 and 25 meters.

There are several types of hydraulic infrastructure: traditional wells, improved wells, boreholes equipped with hand pumps, autonomous water stations, and a SONEB network. The following plate illustrates these different structures.

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Plate 1: Hydraulic infrastructures of the city, a: traditional well; b: modern well; c: manual drilling; d: an autonomous water station.

3.2 Aspects of water resource management in the city of Parakou

Figure 5 presents the different sources of water supply in the city of Parakou.

Analysis of Figure 5 reveals that the majority of the population surveyed uses wells as a source of water supply.

The access of the population of Parakou to drinking water is provided by SONEB according to the majority of respondents. The outlying districts of the city have difficulty accessing running water, the distribution network not yet being sufficiently extensive. In these neighborhoods, people get their water from wells and boreholes.

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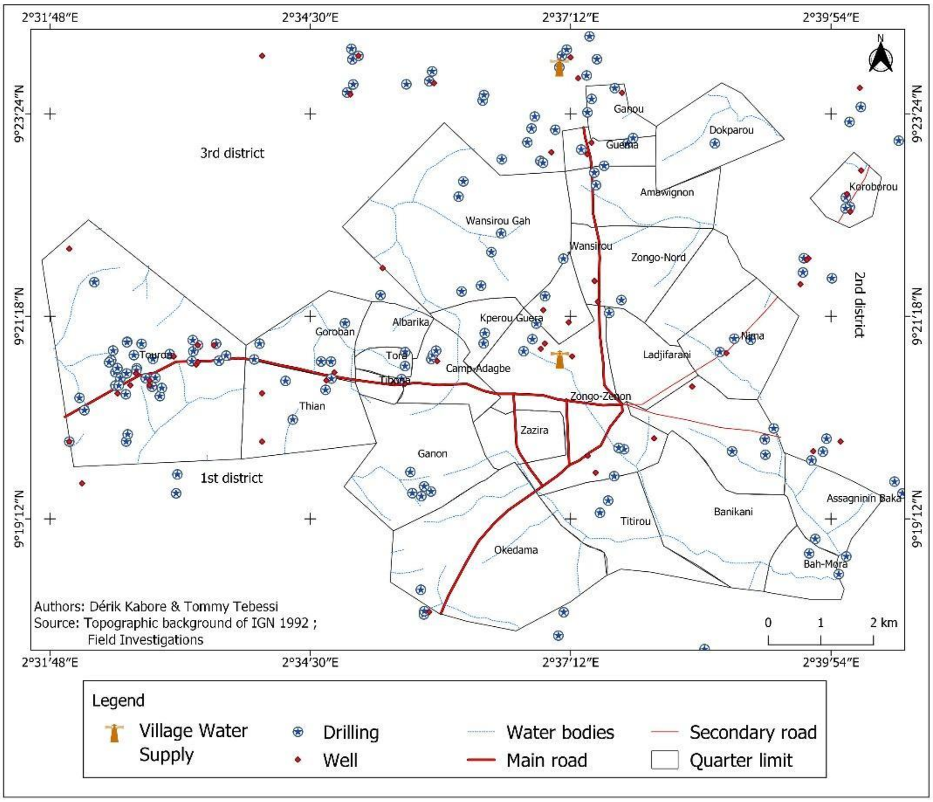

Figure 5: Water supply source for the city of Parakou
Source: Fieldwork July 2021

Figure 6 shows the different drinking water supply sources according to respondents.

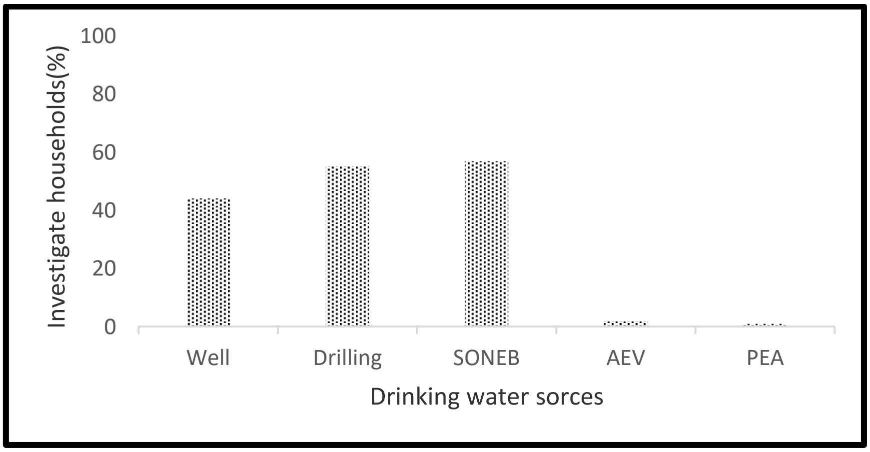

Figure 6: Drinking water source
Source: Fieldwork July 2021

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Analysis of Figure 6 reveals that 46.78% of respondents use SONEB water as drinking water and respectively 33.94% and 17.43% use water from boreholes and wells as drinking water. . PEAs and AEVs are virtually unused by respondents as drinking water. Thus the majority of respondents use water from SONEB.

This mobilized water allows some households to meet their drinking water needs. The water from the wells is used for domestic needs. These households use water from different sources for drinking, domestic use, sale, watering animals, etc. Figure 7 shows how respondents use water.

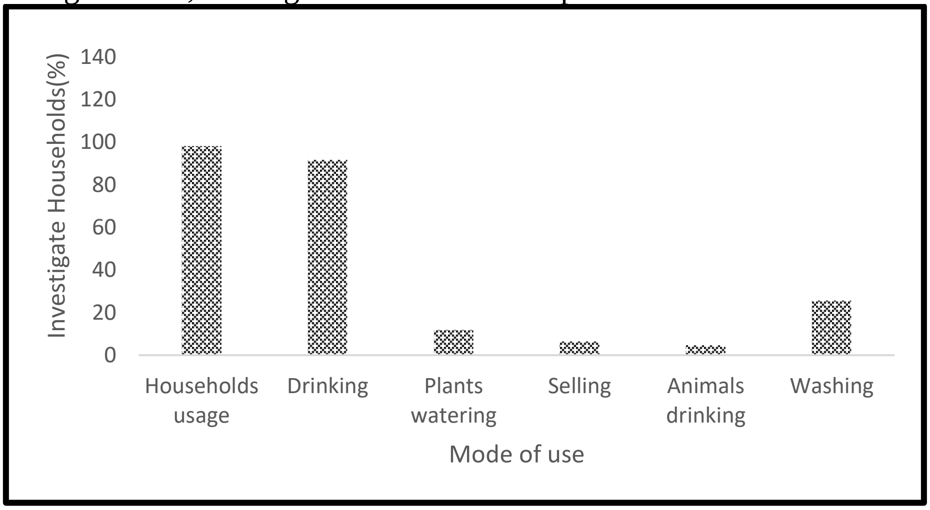

Figure 7: Mode of use of water resources
Source: Fieldwork July 2021

Analysis of Figure 7 shows that water is used more for domestic use (98.16%) and drinking (91.74%) than for other activities.
To guarantee good water quality, several efforts are made by households. This is water treatment. Figure 8 presents the different modes of treatment of water resources.

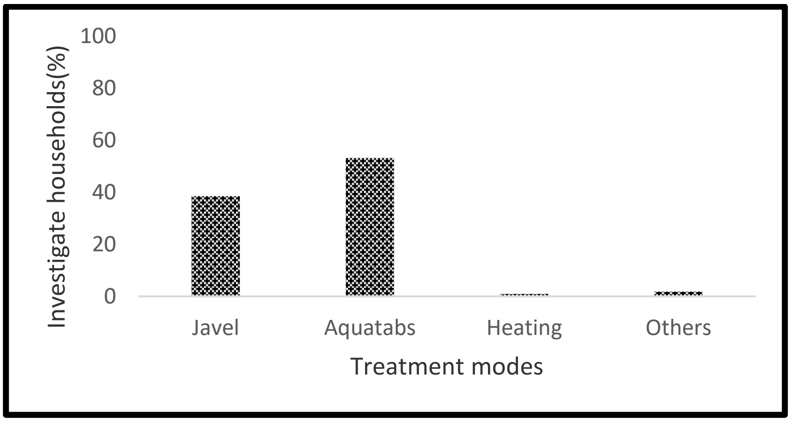

Figure 8: Domestic water treatment mode
Source: Fieldwork July 2021

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The analysis of Figure 8 shows that Aquatabs tablets (53.21%) are the most used for water treatment, followed by bleach (38.53%) and then the heating technique (0.91%). Aquatabs are made from chlorine for the treatment of water before consumption. It disinfects water of questionable quality in order to make it drinkable.

GIS and planning of SONEB water points in the city of Parakou

For a better spatial analysis of the distribution of water resources, thematic maps were produced, in particular, that of the spatial distribution of hydraulic infrastructures, that of the water coverage of the SONEB of the people surveyed and the summary map of the distribution of infrastructures. hydraulics depending on the water coverage of SONEB in the city.

Figure 9 shows the spatial distribution of these hydraulic structures. From the analysis of Figure 9, it appears that the density of hydraulic structures is higher in the first arrondissement than in the others. The works are unevenly distributed in the districts. This is the case, for example, of Tourou (First arrondissement) which has about 15 boreholes to the detriment of Albarika (4 Boreholes), a district of the first arrondissement. This disparity can be explained by the social works of politicians and others. This figure also reveals the state of the boreholes; thus, structures that are not very functional: boreholes lacking equipment (5.4%) and broken boreholes (8.1%) are fewer in number compared to functional structures.

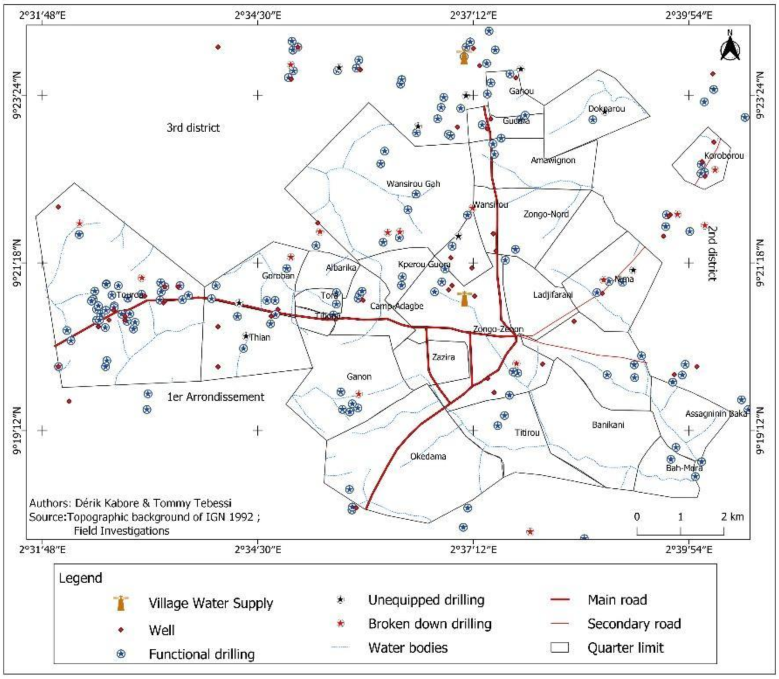

Figure 9: Spatial distribution of hydraulic structures in the city of Parakou

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Figure 10 shows the coverage of the neighborhoods surveyed by the SONEB water distribution network.

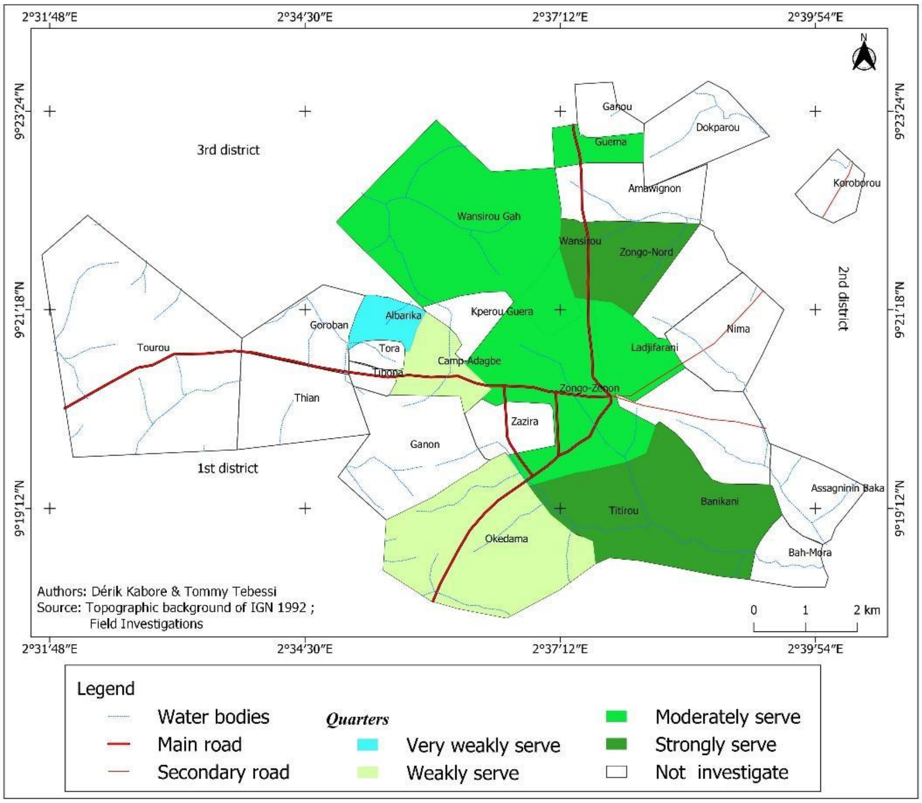

Figure 10 : SONEB water supply coverage

The analysis reveals that SONEB's water coverage is unevenly distributed in the city from one district to another. This is the case of the Banikani, Titirou, Zongo districts which are strongly served by SONEB to the detriment of the Okédama, Camp Adagbe districts, which are poorly served, and Albarika which does not benefit from SONEB services. This unequal distribution may be due to the non-opening of roads in certain districts on the one hand and the relief (the city of Parakou is at an average altitude of 350 m). It presents a hilly aspect where one observes a succession of hilltops generally having a rounded top. This relief divides the city into low areas and high areas. High areas have an altitude greater than or equal to 359 m; they impede the distribution of water because they reduce the discharge flow) on the other hand.

Figure 11 shows the spatial distribution of SONEB hydraulic infrastructure and water coverage in the city of Parakou.

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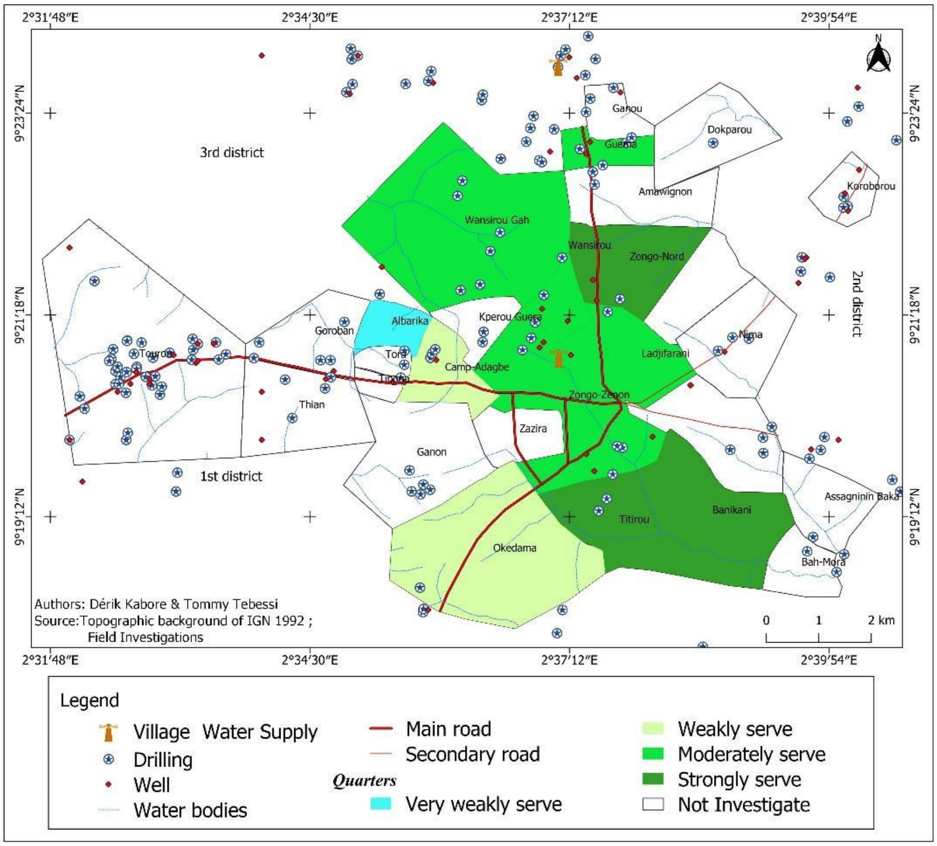

Figure 11: Spatial distribution of SONEB infrastructure and water coverage

From the analysis of this figure 11, it appears that the hydraulic works are unequally distributed in the city as well as the water coverage of the National Water Company of Benin (SONEB). The districts of Camp Adagbe and Okédama are poorly served by the SONEB network and have few hydraulic structures (1 at Camp Adagbè and 0 at Okédama); the Albarika district is very poorly served by the SONEB network and has only three (3) hydraulic structures for a population of around 18,000 inhabitants.

The populations of these neighborhoods, therefore, do not have access to drinking water in sufficient quantity and are forced to obtain water from wells which sometimes dry up, thus causing a water shortage.

Discussion

The results of the research showed that the water resources available in the city are of three kinds, namely rainwater, groundwater, and surface water. This result is similar to that of L. Odoulami, (2000, p. 3) who stipulates that the water resources available in the towns of Parakou, Cotonou, and Porto-Novo are of three types, namely rainwater, groundwater and surface ones.

The quality of this water is sometimes questionable and to deal with it, households use Aquatabs tablets for water treatment; these results are in line with the work of Gildas Louis Djohy, (2018, p. 45-51) who states that the treatment of collected water the majority of the population uses Aquatabs tablets to treat in thirty minutes (30min) twenty liters of water (20 litres) of water and for the minority they use bleach.

In this study, the GIS provided an idea of the spatial distribution of hydraulic structures and the water coverage of SONEB in the city of Parakou. These results are in line with the work of R. Abdoulaye, (2017 p.539) who states that GIS has provided an idea of the typology, distribution, and operating status of water points throughout the territory of the municipality of Nikki.

Conclusion

The present study aims to contribute with the help of GIS to better management of water resources in the city of Parakou. At the end of this study, it should be noted that the city's water supply sources are of three types, namely rainwater, groundwater, and surface water; a major part of the city's population has access to water and is developing methods of conserving and protecting this water for their well-being; the hydraulic works are unevenly distributed in the city as well as the water coverage of SONEB, which leads the population to use wells to obtain drinking water. The absence of a territorial information system as a spatial planning tool in the distribution of water points in the city of Parakou is a major factor limiting its development. This study highlights the multifunctional capabilities of (GIS) for decision-making support.

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