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Assessing Water Resources Access of Nouhao Sub-Basin, Burkina Faso

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Abstract

Water resource access in the Nouhao sub-basin, assessed based on the availability of drinking water mobilization facilities, the availability of water for uses and the quality of drinking water, revealed that in 2017 the basin was covered by 1249 modern water point, main drinking water sources. On average, the sub-basin shows a ratio of 271 users per drinking water point. Communal level shows some disparity with Bittou recording the highest number of people per drinking water point, *i.e.*, around 537. Water that can be captured in the entire sub-basin meets only 42% of the total water needs from the three mains uses: irrigation, domestic consumption and livestock. The highest demander among these uses is Irrigation with 75% of the need, *i.e.*, approximately 12,859,995 m^3. Water in 33% drinking sources of this sub basin is of poor quality. Arsenic, one of the quality parameters studied, is found in some communes of the sub-basin. 11% of the water points in Bissiga are arsenic polluted making this commune the most arsenic contaminated location. The vulnerability maps deducted from lack of water for uses; lack of drinking water works and poor water quality shows so, the exposure level of the sub-basin' communes to some potential risks related to low water resources access.

Keywords

Water Resources, Nouhao Sub-Basin, Access to Water, Modern Water Points, Vulnerability

1. Introduction

Globally, water access in the 21st century remains a challenge. Indeed, out of the 771 million people without access to safe water worldwide in 2020, more than half live in Africa [1] [2] [3]. Sub-Saharan Africa has one of the highest rates of non-access to water in the world [4]. And yet, the African continent has the necessary water resources to meet its needs [5]. According to FAO [6] water is very abundant in Africa. In fact, African continent has more than 17 large rivers and a hundred lakes. It has significant groundwater and its rainfall is evaluated at 20,360 km^3 or an average of 678 mm of rain per year. Although with all this potential, the difficulty of water resources access remains. Some authors justify this fact by many causes such as climate change, increase of domestic water needs generated by population growth. There is also, the increase of agricultural water needs due to the development of irrigated agriculture [7]. The major challenge is how to secure these resources for various uses including water for consumption, agriculture, livestock breeding and energy [8]. This gap of suitable water mobilization, retention or storage infrastructures is quoted by Sokona [9] as the main cause of poor access to water resources in sub-Saharan Africa. It is also the key root to water stress which is increasingly worsened by climate variability [10] [11]. Water stress puts this portion of Africa to many risks such as waterborne diseases, social conflicts and poor social and economic development [12] [13]. According to Veyret and Reghezza [14], vulnerability is exposure to a risk; as a result, rural sub-Saharan Africa communities are vulnerable to risks due to water resources access.

The assessment of water resource access level by the different uses in an area allows a better organization of its availability [15]. It is also a way to highlight water resources constraints and identify the risk factors worth targeting and monitoring in order to limit vulnerability [16]. This study, that general objective is assessing water resources access level in Nouhao basin, thus provides an overview of access to water in quantity and quality for the various uses, while identifying the areas of risk. Specifically, it's including assessing: 1) the availability of water mobilization infrastructures; 2) the water demand for various uses; and 3) the quality of the water for drinking.

2. Materials and Methods Used

2.1. Study Location

Nouhao sub-basin (NSB) illustrated in **Figure 1** is a tributary of Nakanbe basin and is in the Central-East of Burkina Faso. It spreads between 0˚10' West longitude, 0˚38' East longitude and between 12˚00' and 11˚08' North latitude on a surface area of 4261 km^2. NSB river system includes the main river itself, *i.e.*, the Nouhao flowing North-East to South-West and covering the communes of Gounghin and Diabo towards the commune of Bittou. NSB has no sustainable rivers as most of its rivers are temporary with floods occurring between August and September. NSB is equipped with a hydrometric station located in Bittou

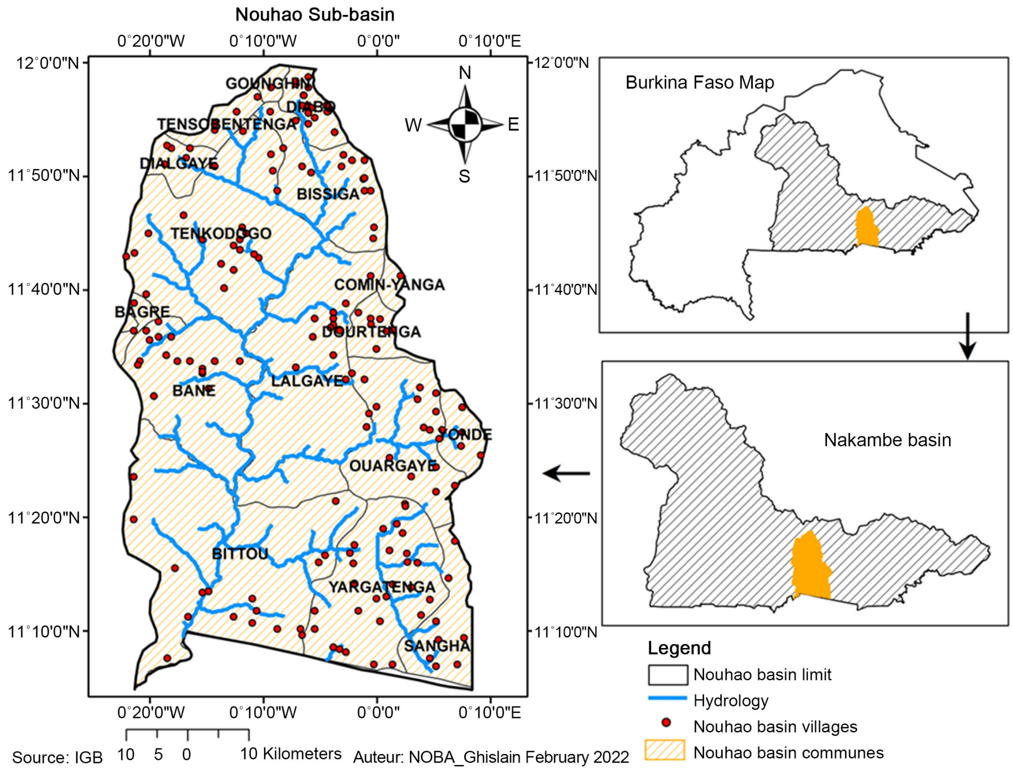

Figure 1. Map of study area.

with an average annual water inflow of 375.28 million m³. NSB also has some swampy areas [17]. NSB covers a total of 16 communes and nearly 180 villages with a population estimated to 340,000 persons [18] and has two climate categories: a Sudano-Sahelian climate in the North with an average annual rainfall ranging from 600 to 900 mm and lasting 6 months at most. The southern part of NSB displays a Sudanian climate with average annual rainfall beyond 900 mm and a rainy season lasting more than 6 months [19]. The forest formations are mainly wooded lands and to a lesser extent riverbank woods. Examples of plant species found include: Acacia Seyal, Acacia Gourmaensis, Acacia Dudgeoni, Anogeissus Leiocarpus, Diospyros Mespiliformis, Combretum Sp, Balanites Aegyptiaca, and Ziziphus Mucronata, etc. [20].

2.2. Data Collection and Assessment Method

❖ Assessing the available modern water points (MWPs)

To assess the existing MWPs which include boreholes and modern wells in the basin, we have used the 2018 national database on water facilities, INOH-2018, to number in each village and commune the successful boreholes and modern wells. According to the CIEH (Comité Interafricain d'Etudes Hydrauliques) [21] successful boreholes are those with a minimum flow rate of 0.7 m³/h. Equation (1) Thereafter, permetted to estimate the 2017 population in the basin using the 2006 population census. Equation (2) provides the average number of user per borehole.

$$N_a = N_{a-1} \times (1+T)^n . \quad (1)$$

N_a = Population of given year (say "*a*").

N_{a-1} = Previous year population (*a* – 1).

n = Number of projection years.

T = Population growth rate.

$$\overline{X_p} = \frac{N_a}{Q_p} . \quad (2)$$

$\overline{X_p}$: Average person per water point.

N_a : Population of year a.

Q_p : Quantity of MWP.

❖ Assessing the water demand in the sub-basin

Based on the [22] report of and the field surveys, we have limited the assessment to three main water uses in the basin area: irrigation, domestic use and livestock breeding.

Water for irrigation was calculated using "CropWat" software 8.0. CropWat was designed by the Land and Water Development Division (LWD) of the UN Food and Agriculture Organization to assess water needed for irrigation. This software-based assessment integrates the area climate data, the crop coefficients, the crop cycle and the root depth [23]. The results from CropWat provide the amount of water needed for a crop in one hectare. Equation (3) shows so, the total water demand in the basin.

$$D_a = \sum_{i=a}^{z} X_i \times N_i . \quad (3)$$

D_a = water for irrigation.

X_i = Water requirement per hectare of the crop calculated by CropWat.

N_i = Number of arable hectares of the crop planted.

Equation (4) permitted to calculated domestic water demand by using national water supply standard for urban and rural areas which are respectively 40 liters/person/day in urban areas and 20 liters/person/day in rural areas [17] [24].

$$CD = \left[(N_{a.ub} \times 40) + (N_{a.ru} \times 20) \right] \times 365 . \quad (4)$$

$N_{a.ub}$ = Urban population.

$N_{a.ru}$ = Rural population.

To assess the water needed for livestock in NSB, we used the method of CIEH [21], which defines a Tropical Livestock Unit (TLU) by species and a standard daily water demand per TLU. Here, the quantity of water required applies only to the needs of sedentary animals during dry season [17]. Equation (5) applied by using the livestock data base of DGESS-Direction Générale des Etudes et des Statistiques Sectorielles-permitted so, to assess the livestock water requirements.

$$D_e = N_t \times UBT \times D_j \times N_s . \quad (5)$$

D_e = Annual water demand for livestock.

N_t = Number of livestock species.

UBT = Tropical livestock unit.

D_j = Daily demand per UBT.

N_s = number of dry season days.

❖ Assessing water availability in the Nouhao river basin

To do this, we first identified the area water sources (dams and MWP) using the national water facility database. Then, we looked at not only the maximum amount of water produced by an adult through mechanical pumping, which is 0.7 m^3/h but also, the helpful water from lasting dams in our area, which is 60% of the total volume of the dam [17] [21]. The Equation 6 was used to know the available volume.

$$Q_d = \left(Q_{\max} \times T \times N_c \times N_j\right) + 0.6V_t \quad (6)$$

Q_d = Quantities available.

$Q_{\max}$ = Maximum hourly water produced through pumping by an adult.

T = Maximum time of use of the borehole per day.

N_c = Number of MWPs.

N_j = Number of days per year.

V_t = Maximum volume of the dam.

❖ Drinking water quality assessment in the Nouhao river basin

MWPs are the main supply source of drinking water in the Nouhao basin. The quality of this drinking water was assessed using about 25 MWPs per commune in Bissiga, Dialgaye, Tenkodogo, Lalgaye, Bittou and Yargatenga. The MWPs were selected randomly. The main parameters analyzed were pH, temperature, conductivity, nitrite and nitrate content, bacteriological content (*E. coli*) and arsenic content. The equipment used in situ included, a pH meter, quantofix test strips for nitrites and nitrates, a bacteriological analysis kit and an arsenator kit to monitor arsenic. We then compared the results of these analyses with OMS [25] water quality guideline.

❖ Vulnerability mapping

Vulnerability is not a measurable characteristic of a system. It's a concept which shows through a factor the sensivity of a system opposite to a risk. There are no rules predefine to define the factors or methods to be consider for vulnerability quantification [26]. Vulnerability being an exposure to a risk, the risk of bad water quality and lack of water in quantity is therefore a source of vulnerability. This is being said, three types of vulnerability were highlighted through three mains factors or indicators in this study: 1) the lack of MWP, 2) lack of water for uses (domestic, livestock and irrigation) and 3) the poor water quality. These factors can be quantified for vulnerability mapping through indexes. Theses indexes call indexes of vulnerability influence the exposure level to risks [27]. In this study, indexes defined are:

$I_p = \overline{X_p}$: average number of people per MWP.

I_u : Rate of water uses demand satisfaction.

I_q : Rate of poor-quality water points.

The highlighting of the different vulnerability level in maps needs a prioritization. This prioritization is done of index interval classes [28]. The choice of these interval is based on [29] report which mention national norm in term of MWP access in Burkina Faso, the stress level due to the lack of water for uses and the water quality level and its consequences.

Table 1 shows so, the interval classes for indexes defined. The software Arcgis 10.3.1 through this classification has permitted to create the vulnerability maps according to the availability of MWPs, the lack of water for uses and the poor quality of water from MWPs.

3. Results and Discussions

3.1. Availability of MWP in the Nouhao Sub-Basin

In late 2017, the NSB numbered 1249 functional modern water points, *i.e.* an average of 1 MWP for 271 users. Overall, the number of people per MWP in the basin is in line with the national standard of 300 people per MWP. Figure 2 shows that the municipality of Bittou is particular with a ration beyond the national standard, on average 537 people per MWP. This is due to the lack of MWP in the commune given the total number of 167 MWP to supply approximately 90,000 people.

Table 1. Table of vulnerability classification.

	Indexes		
Vulnerability classes	**Vulnerability related to PEM availability**	**Vulnerability related to Water for uses**	**Vulnerability related to PEM water quality.**
Low or zero	$I_p \leq 300$	$I_u \geq 100\%$	$I_q \leq 25\%$
Medium	$300 < I_p \leq 600$	$75\% < I_u \leq 100\%$	$25\% < I_q \leq 50\%$
High	$600 < I_p \leq 900$	$50\% < I_u \leq 75\%$	$50\% < I_q \leq 75\%$
Very high	$I_p \geq 901$	$I_u \leq 50\%$	$I_q > 75\%$

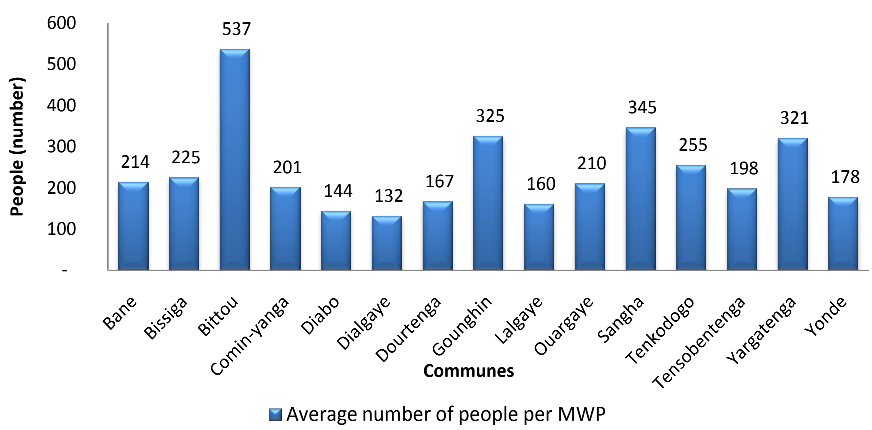

Figure 2. Average people per MWP.

In Gounghin, Sangha and Yargatenga, the average number of people per borehole is slightly above the national standard, whilst the remaining communes align with the national norm. Communes where the average number of people per borehole exceeds the norms are those at risk in terms of access to water.

Indeed, the inadequate water supply facilities brings about an overuse of water points, rapid dry up of aquifers as well as rapid deterioration of pumping facilities [30]. Also, to address the lack of drinking water facilities, people generally resort to other sources of water such as traditional wells and ponds for their needs. Use of water from unconventional sources is the cause of many diarrhea diseases with death likelihood [31].

For Barry and Ouédraogo [32], the insufficient MWPs limit the development of economic activities, given the important time/role in collecting water daily. Similarly Kibi and al [33] states that the lack of MWPs is the source of many conflicts among people, bringing both women and young children to be the most exposed groups.

3.2. Uses and Availability of Water Resources

The investigations in the Nouhao sub-basin helped us to identify three (03) major uses of water, namely for domestic use, irrigation, and livestock farming. **Figure 3** presents the assessment of water needed for these three major uses which amount to 17,215,549 m^3. Irrigation is the largest water user with an estimated need of 12,859,995 m3 (75%), followed by domestic consumption and livestock farming, 2,770,111 m^3 (16%) and 1,585,442 m^3 (9%) respectively. Differences exist within the study area. Bittou and Yargatenga are the highest demand for water. In most communes, irrigation uses water the most and Bittou and Yargatenga are the biggest users. Report on the 2016-2017 dry season agricultural season says that Bittou and Yargatenga have more sown lands during the dry season, hence, their high water demand for irrigation [34]. Other communes in the basin such as Comin-yanga, Diabo, Dialgaye, Dourtenga, Gounghin, Tenkodogo and Tensobentenga do not host irrigated areas, meaning they do not need water for irrigation. Regarding water for domestic use in the SBN, Bittou comes first, followed by Ouargaye and Yarghatenga. This is because Bittou and Ouargaye are urban. For Yargatenga, the population flow between Togo and Burkina could explain their high-water demand.

The need for water for livestock is predominant in Bittou and Lalgaye and this reflects the size of livestock population in these two areas. Indeed, Bittou and Lalgaye have respectively 116,080 heads and 101,314 heads, *i.e.* about 19% and 16% of the livestock in the Nouhao sub-basin.

When we compare the water needed for various uses to the water availability, see **Figure 4**, we can o observe an overall need in the basin of 17,215,549 m^3 against 7,274,525 m^3 available. That is a gap of 9,941,024 m^3 which indicates that only 42% of the water needed for different uses are covered in the basin. This comparison at the communal level shows that only Tenkodogo, Tensobentenga, Lalgaye and Dourtenga have water available to meet their water demands.

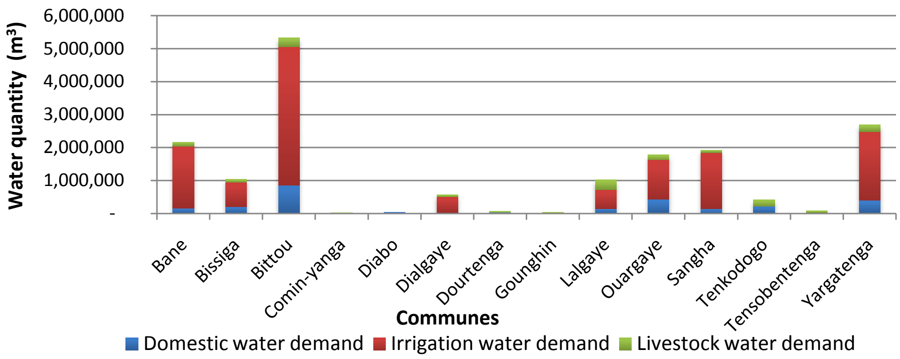

Figure 3. Water requirements for uses.

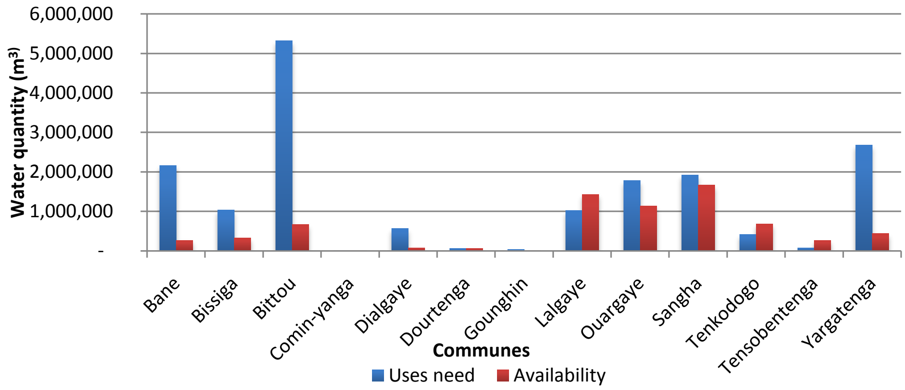

Figure 4. Comparison of water demand to availability.

Unmet water needs in the NSB could be the source of many negative consequences. Indeed, in homes, the lack of water leads to poor hygiene practices, causing "dirty hands disease" or fecal disease [35] [36]. In addition, lack of water for domestic use leads to unsafe water use, which is the source of many deadly waterborne diseases [37] [38]. The lack of water for domestic activities is closely linked to the lack of sanitation in households. Indeed, the use of toilets in rural areas, especially in Africa, generally requires water for personal hygiene such as hand washing and ablutions. The inadequate availability of water increases some unhygienic practices such as not using the toilet, using hands and inappropriate objects in toilets [39] [40] [41].

In the Nouhao basin, the total availability of useful water (surface water and groundwater) is estimated at 7,274,525 m^3. The mobilizable part of MWP is estimated at 3,191,195 m^3. If we consider domestic and animal consumption, which are the main users of water from the MWP, the need is estimated at 4,355,553 m^3. This volume is only 73% satisfied by the production of the MWP. The deficit is therefore 1,164,358 m^3. The fact that 73% of the water requirement for domestic and animal consumption is met is indicative of a high level of coverage of the area by MWP. This can be explained by the fact that the Centre-East region containing the NSB has benefited from major drinking water supply programs, PIHVES I and II (Integrated Village Hydraulics and Education for Health Project) from 1993 to 2005, which created numerous boreholes [42].

The quantity of surface water that can be mobilized in the SBN is 4,083,330 m^3 for a total irrigation need estimated at 12,859,995 m^3. The deficit is estimated at 8,776,665 m^3 or 68%. This deficit is due to insufficient surface water mobilization in the basin [43]. This insufficiency of surface water resources is a limiting factor for the development of off-season agriculture [44]. It leads to an increase in groundwater pumping and pressure on waterworks. This results in the risk of groundwater depletion, groundwater contamination and frequent pump breakdowns [45] [46]. Similarly, this difficulty in accessing surface water also leads to an annual transhumance [47] [48]. This transhumance is at the root of many conflicts between farmers and herders [49] [50] [51].

3.3. MWP Water Quality

The analysis of the water from the MWP has made it possible to summarize in **Figure 5** the percentage of MWP that do not provide water of acceptable quality according to 2017 WHO standards. This summary shows that Bissiga is the commune with the highest percentage of MWP that do not meet the WHO standard in terms of arsenic concentration. More than 11% of the water points in this commune are contaminated with arsenic. In the whole basin, 2% of the MWPs have an abnormal arsenic concentration. For the concentration of nitrate in the water, the commune of Bittou stands out as having more water points with abnormal concentration *i.e.* 12%. The water points contaminated with nitrates represent only 5% in the basin. For the nitrite concentration, no water point in the basin has an abnormal concentration. Bacteriological contamination in the sub-basin is most evident in the commune of Dialgaye with 44% of its MWPs contaminated. Over the whole basin 28% of the MWP have a poor bacteriological concentration.

The results show that 33% of the water points in the whole basin do not meet the WHO standard for water quality. The high concentration of arsenic in the water of some NSB water points may have several causes. According to SMEDLEY and al [52], certain human activities such as mining, coal burning, pesticide use, leather tanning can lead to arsenic pollution of groundwater. This pollution can also be natural as arsenic is a compound present in eruptive and metamorphic rocks which are geological formations covering more than ¼ of the Burkinabe territory [53]. Consumption of arsenic-polluted water is not immediately dangerous, but in the long term it can cause cancer, abdominal pain, vomiting, diarrhea, weakness and loss of feeling in certain parts of the body. In the worst case, it can lead to death [54] [55] [56]. The presence of arsenic in water should not be taken lightly, the causes should be detected, and certain precautions should be taken to avoid health problems for the population that depends on this water [57]. The high concentration of nitrate in the water off MWP in the Nouhao basin can be explained by the presence of organic matter, soil leaching, the use of chemical fertilizers, the use of pesticides and the presence of wastewater [58] [59]. Drinking water polluted with nitrates can cause blood diseases to babies even death. If water from a borehole is found to have a

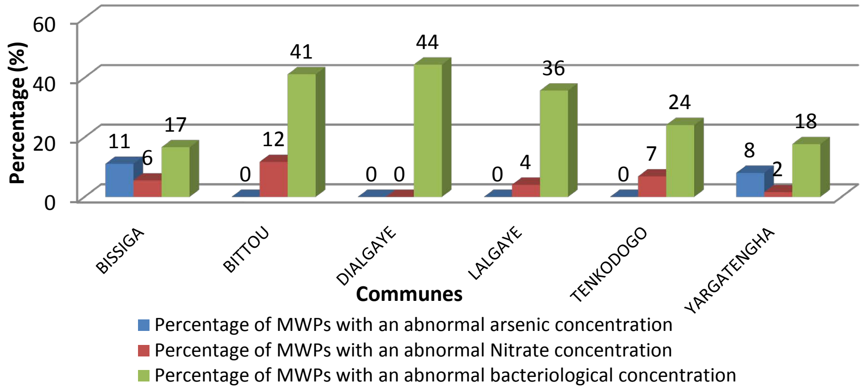

Figure 5. Percentage of NSB's MWP not meeting WHO standards.

high concentration of nitrates, it is best to prevent babies from drinking water from these boreholes [25] [60] [61]. This also applies to water with high bacteriological concentrations. According to DEGBEY *et al.* [62] the high bacteriological concentration in water is one of the major health risk factors. Consumption of water contaminated with faecal coliforms (*E. coli*) which is the main bacteriological indicator causes waterborne diseases (enteritis, gastroenteritis, amoebiasis, bacterial dysentery, typhoid fever, intestinal parasitosis, digestive mycosis, cutaneous staphylococcal disease, etc.), which can lead to death if not treated in time [62] [63].

High bacteriological concentration in water can be caused by the presence of septic tanks in shallow water areas [64]. It can also be caused by poorly treated sewage discharges into the environment or by infiltration of runoff and flooding [65] [66]. When an MWP produces water of poor bacteriological quality, its water should not be drunk. In addition, the source of the pollution should be detected, and actions such as the population awareness to not drink this water and even the closing of the water point should be adopted to limit the risk [67].

3.4. Vulnerability Mapping of the Nouhao Sub-Basin

In this study we have identified 3 types of vulnerability, namely: Vulnerability linked to the lack of MWP, vulnerability linked to the lack of water for uses and vulnerability linked to the poor quality of the water from MWPs. For these three types of vulnerabilities four levels of competitive vulnerability have been observed.

Regarding vulnerability linked to the lack of MWPs, the communes of Bittou, Gounghin, Sangha and Yargatenga show average vulnerability while the remaining communes show a low vulnerability nill (**Figure 6(a)**).

Looking at **Figure 6(b)**, which shows the vulnerability linked to the lack of water for uses, four levels of vulnerability emerge: low or nill, medium, high, and very high. The communes of Bané, Bissiga, Bittou, Dialgaye and Yargatenga show very high vulnerability. The parts of Comin-yanga, Ouargaye and Gounghin have a high vulnerability. The commune of Sangha, on the other hand, has a medium vulnerability. Low vulnerability or vulnerability nill is observed in the communes of Dourtenga, Lalgaye, Tenkodogo and Tensobtenga.

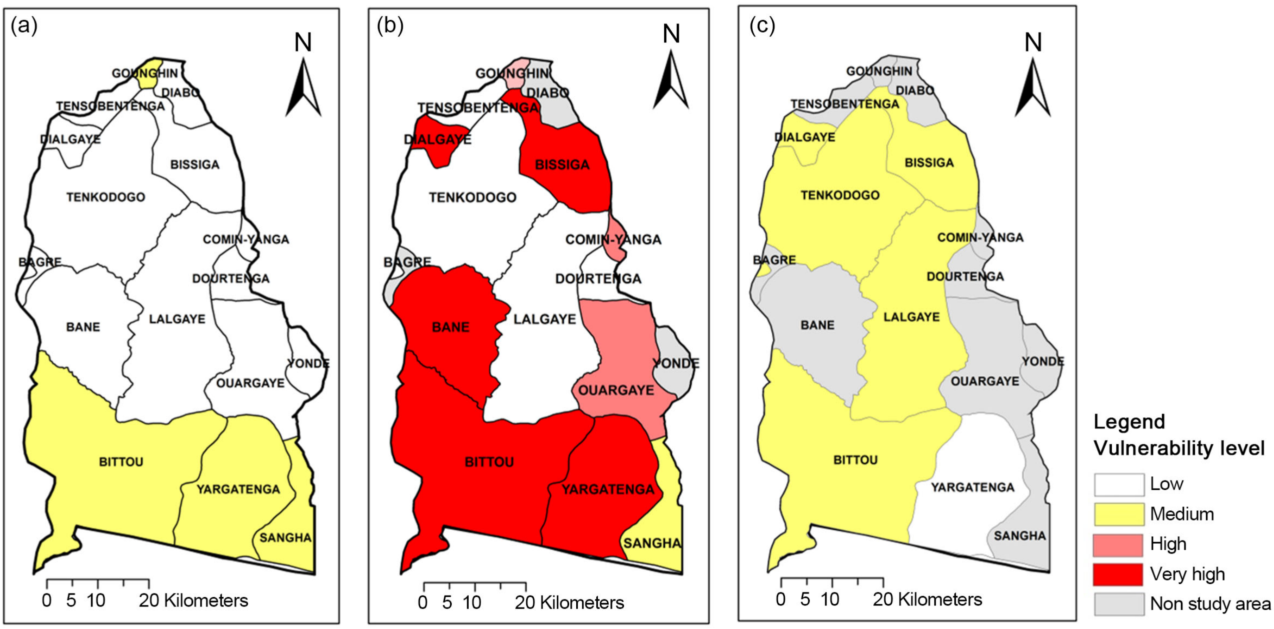

Figure 6. (a) Vulnerability map linked to access to the MWP; (b) Vulnerability map related to access to water for uses; (c) Vulnerability map related to water quality.

Figure 6(c) which is a representation of vulnerability related to the quality of drinking water show only one level which is the medium one in all the 6 assesses communes.

In view of these results and based on the definition of vulnerability by DEGBEY and al [62] as the exposure of an entity to a risk, it is obvious that the communes of the Nouhao basin are exposed to many risks but at different levels. The risk that emerges in most of the high, very high and medium vulnerability areas is essentially the low supply of drinking water for the population, the expansion of water-borne diseases and the slowdown of economic activities [68] [69] [70] .

In low-vulnerability or vulnerability nill areas in general, water fetching times are reduced, off-season agricultural activities are more profitable and water-borne diseases have a low occurrence [71] [72] [73]. This facilitates economic development and generates income generating activities [74]. Areas of medium, high and very high vulnerabilities are parts of NSB which need particulars attentions from leaders. These areas need more actions which will strengthen population resilience and minimize the risk.

4. Conclusion

Access to water resources of Nouhao basin assessed in this study clearly shows that the whole basin is exposed to various risks, including risks related to the lack of MWP, risks related to insufficient water for uses and risks related to the poor quality of drinking water. These risks are generally water-borne diseases, conflicts, and the slowing down of economic activities. It is therefore necessary that the medium, high, and very high vulnerability communes mapped in this study receive special attention from decision makers to strengthen the populations' resilience of the Nouhao basin. This study should serve as a basis of intervention for development actors. Indeed, it should allow to optimize water supply planning in the study area and to avoid public health water-related problems. It can also be a basis of modeling future water allocations and hydrological situation prediction. To sum up, this study has particularly identified the communes in the basin for which actions to prevent risks linked to water resources access in quality and quantity would be highly effective. Its consideration will therefore contribute to the achievement of the Sustainable Development Goals 06 in Burkina Faso.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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