



(RESEARCH ARTICLE)



MAPPING THE GROUNDWATER AVAILABILITY INDICATOR FOR ALTERITE AQUIFERS IN THE GBOKORA NEIGHBORHOOD OF DALOA (CENTRAL-WESTERN CÔTE D'IVOIRE)

Yiwa Monique Kamenan Espse Mangoua ^{1,*}, Yaraba Tuo ¹ and Pehegninon Junior Orphelie Djade ²

¹ Jean Lorougnon Guédé University, Department of Earth Sciences, BP 150 Daloa, Côte d'Ivoire.

² Félix Houphouët Boigny University, Faculty of Earth Sciences and Mining Resources, 22 B.P. 582 Abidjan 22, Côte d'Ivoire.

* Corresponding Author

ORCID Details

Yiwa Monique Kamenan Espse Mangoua: <https://orcid.org/0009-0008-7684-701X>

Yaraba Tuo: <https://orcid.org/0009-0001-3078-1827>

Pehegninon Junior Orphelie Djade: <https://orcid.org/0009-0007-0969-9726>

GSC Advanced Research and Reviews, 2026, 29(01), 080–089

Publication history: Received on 21 August 2026; revised on 01 October 2026; accepted on 03 October 2026

Article DOI: <https://doi.org/10.30574/gscarr.2026.29.1.0256>

Copyright © 2026 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0

ABSTRACT

The scarcity and unpleasant taste of tap water in the city of Daloa have led to heavy reliance on water from traditional wells, without any clear understanding of this resource's availability. The objective of this study was to assess the water availability of the alterite aquifers in this neighborhood. To this end, in addition to a digital elevation model, two field surveys were conducted to determine, respectively, the piezometric level and the permeability of the neighborhood's alterite aquifers. Using a multi-criteria analysis methodology, the groundwater availability of the alterite aquifers in the Gbokora neighborhood was mapped. The results showed that groundwater availability in the Gbokora neighborhood is generally poor, as 65.68% of the area is classified as having poor or very poor availability. Good groundwater availability is observed in the south and southeast of the district, covering only 7.34% of the area. This study therefore suggests the use of tap water (surface water) to supplement the alterite aquifer.

Keywords: Water Availability, Alterite Aquifers, Gbokora Neighborhood, Daloa, Côte d'Ivoire

1 INTRODUCTION

Given the pollution problems affecting surface water, the issue of groundwater availability to address the shortage of drinking water for populations is becoming increasingly relevant (UNESCO, 2022; Eblin et al., 2022; Zrébré et al., 2025). Indeed, access to drinking water has become a major issue in most sub-Saharan African countries, where access to drinking water services remains significantly lower than global averages (UNICEF, 2025).

In Côte d'Ivoire, nearly half of the population currently faces difficulties accessing safe drinking water (Kouadio et al., 2025). This situation is all the more concerning given the rise of illegal gold mining, which is degrading the quality of water in rivers across the country (Ahoussi & Yapo, 2021).

In the city of Daloa, specifically in the Gbokora neighborhood, due to the poor organoleptic quality of tap water, residents are turning to water from boreholes and, above all, traditional wells (Kablan et al. 2023). This is why, in recent decades, studies have focused more on the potential of aquifers with the aim of identifying suitable areas for drilling. This resource is one of the most affordable sources of water supply due to its proximity to the point of consumption, its quality generally meets international standards and its low treatment cost.

These new water sources particularly water from traditional wells are needed to meet the needs of a rapidly growing population, raising concerns about the availability of groundwater in the alterite aquifer of the aforementioned neighborhood (Kouassi, 2021). For this reason, the present study, titled "Assessment of Water Availability in the Alterite Aquifers of the Gbokora Neighborhood in the City of Daloa," was initiated. The primary objective of this study is to assess the water availability of the alterite aquifers in the Gbokora neighborhood in order to evaluate their potential as groundwater resources for supplying the population. Specifically, the study aimed to: (i) develop thematic maps of availability parameters and (ii) map the water availability of the district's alterite aquifers.

This study is structured as follows: following the introduction, which presents the context, the research question, and the study's objectives, Section 2 presents the data and methodology; Section 3 outlines the main results; and the key lessons learned are summarized in the conclusion.

2 METHODOLOGY

2.1 Overview of the Study Area

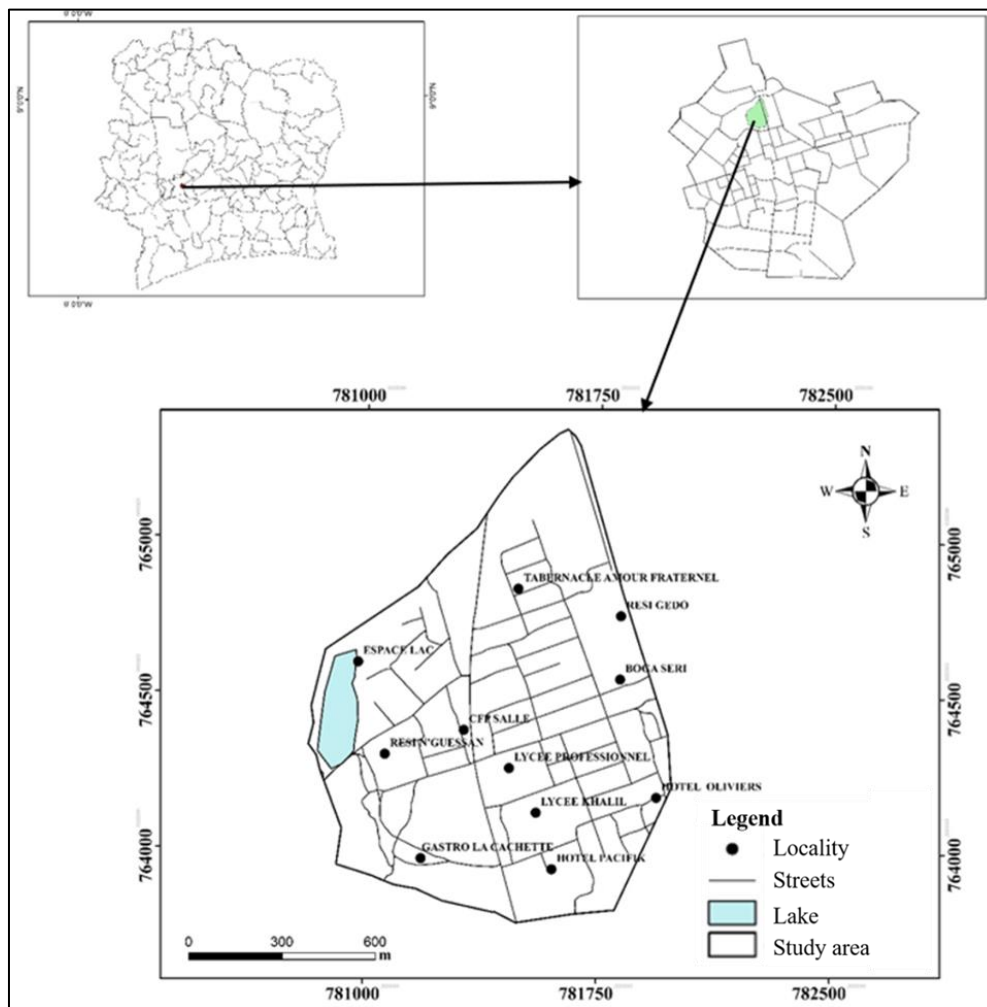


Figure 1: Map showing the location of the Gbokora neighborhood

The Gbokora neighborhood is located in the northwest of the city of Daloa, a city situated in central-western Côte d'Ivoire between longitudes 6°24' and 6°29' West and latitudes 6°50' and 6°55' North (Figure 1). Incorporated into the city of Daloa around the year 2000, Gbokora lies between 6°51' north latitude and 6°25' west longitude, with an estimated population of 1,087 inhabitants (2014 National Population Census).

2.2 Data

The data used in this study include the Digital Elevation Model (DEM), groundwater depths, and the permeability of the altuerite layer.

2.3 Data Collection

A survey campaign identified 31 traditional wells throughout the Gbokora neighborhood of the city of Daloa (Figure 2). The water levels in these wells were measured using a piezometric probe. At 10 sites evenly distributed throughout the district, a double-ring infiltrometer was used to determine the volumes required to saturate the soil at these sites, as well as the infiltration times, which were then used to calculate the permeability of the altierite layer.

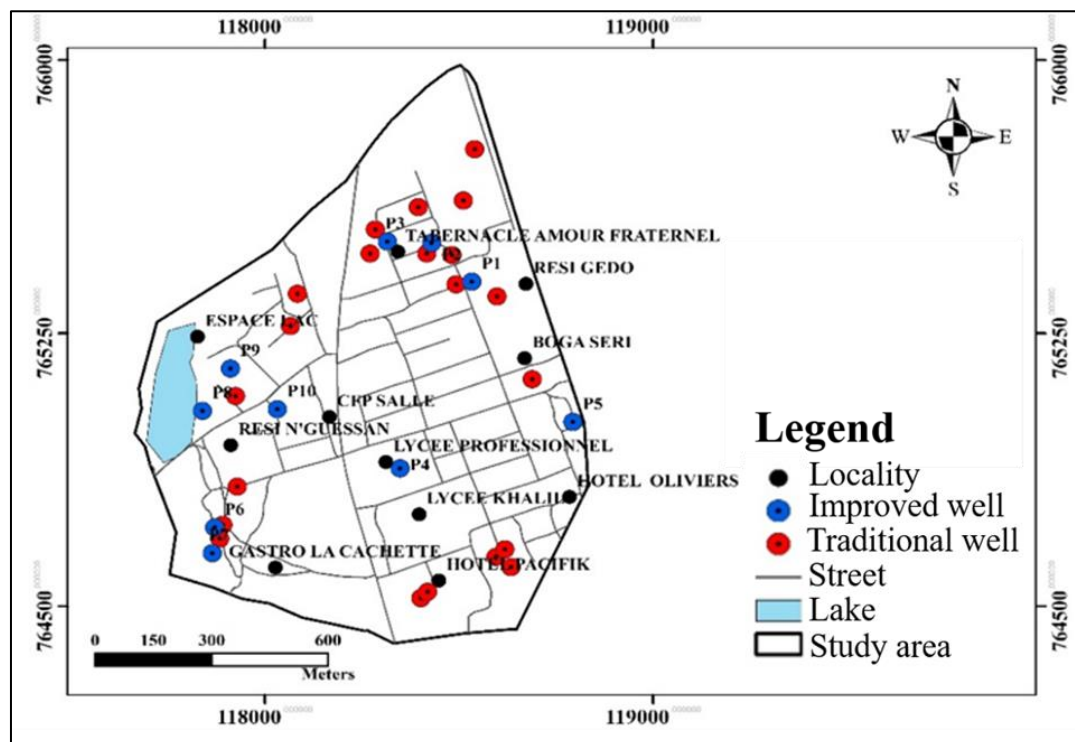


Figure 2: Map showing the locations of sampling points

2.4 Map Preparation

The methodology of this study pertains to determining the groundwater availability indicator for the altérites aquifers in the Gbokora neighborhood of the city of Daloa. The availability indicator is one of the three parameters used to assess an aquifer's potential. According to Mangoua (2013), it is the most essential parameter in assessing the potential of bedrock aquifers. The availability indicator reflects the existence of an aquifer in a given area (Yao et al., 2014). It does not provide information on the accessibility or exploitability of the aquifer.

Its determination follows these steps:

- Development of availability parameters;
- Classification and standardization of the parameters;
- Aggregation of the parameters.

In this study, the selected availability parameters include slope, drainage density, weathered layer depth, and permeability.

2.5 Development of Availability Parameters

The slope map was developed using the Digital Elevation Model (DEM) in the ArcGIS environment.

For the drainage density map, the hydrographic network was first generated. Next, it was interpolated using the “Kernel Density” tool in ArcGIS to produce the drainage density map.

The water depths of the 31 wells were interpolated to obtain the map of altérites aquifer depths.

Before being spatialized, permeability was calculated as a point function at the 10 sites using the formula proposed by Porchet in 1904:

$$k = \frac{\pi h'}{t(2h + r)}$$

k : permeability; h : height of the water column; h' : height of the percolated water layer; t : elapsed time; r : radius of the inner ring

2.6 Classification and Standardization of Maps

After each availability parameter is developed, it is classified, and weights are assigned to each interval of the parameter based on its importance in the water supply to the altérites aquifer. This classification follows that adopted by Mangoua et al. (2019), and the assigned weights range from 1 to 10. A weight of 10 indicates that the parameter promotes groundwater availability, while a weight of 1 applies to parameter classes that do so to a lesser extent (Table I).

Table 1: Classification and standardization of parameters

Parameters	Class Assessment	Classes	Weight
Slope (%)	Very low	< 1	9
	Low	1–2	7
	Medium	2–3	5
	High	3–4	3
	Very strong	> 4	1
Drainage density (km/km ²)	Very low	< 5	9
	Low	5–10	7
	Medium	10–15	5
	High	15–20	3
	Very strong	> 20	1
Induced permeability (X10 ⁻⁶ m/s)	Very low	< 3.5	1
	Low	3.5–5	3
	Medium	5–6.5	5
	High	6.5–8	7
	Very strong	> 8	9
Depth (m)	Very low	1–5	10
	Low	5–15	8
	Medium	15–25	6
	High	25–40	3
	Very strong	40–45	1

2.7 Aggregation of Parameters

There are various methods for evaluating multi-criteria analysis or aggregating factors. In this study, the choice was made to use the complete weighted aggregation method employed by Joerin (1995), Saley (2003), and Jourda (2005).

This method involves multiplying each factor or indicator by its respective weighting coefficient and then summing these results to produce a suitability index according to the following equation :

$$S = \sum_{i=1}^n w_i x_i$$

S : final result; w_i : weight of criterion i; x_i : standardized value of criterion i.

Table 2: Eigenvalues and Weighting Coefficients of the Parameters

Parameters	Eigenvectors	Weighting Coefficients
Slope	1.8	0.44
Drainage density	0.66	0.16
Permeability	1.2	0.30
Depth	0.4	0.1
Availability	4.06	1

3 RESULTS

3.1 Slope Map

Figure 3 shows the slope map of the Gbokora neighborhood in the city of Daloa. Based on the classification used, five classes were identified: very gentle, gentle, moderate, steep, and very steep. Gentle slopes are the most common (60%) and run primarily in a north-south direction through the center. Gentle and moderate slopes account for only 17% of the neighborhood's area and are unevenly distributed throughout the neighborhood. Steep and very steep slopes (23%) are more pronounced in the eastern part and less common in the rest of the neighborhood. The lake is located downstream from the gentle slopes.

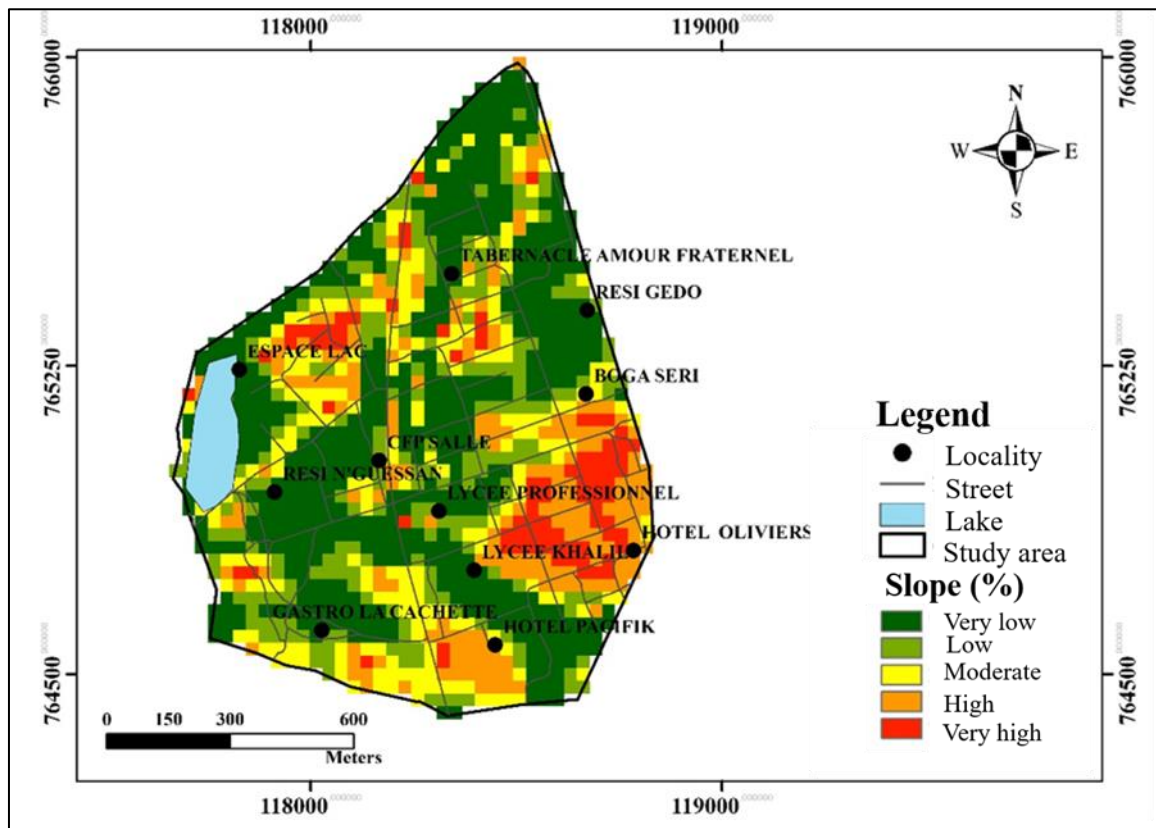


Figure 3: Slope map

3.2 Depth Map

Figure 4 shows the water depth map of the Gbokora neighborhood in the city of Daloa. Depths vary along a southwest-to-east gradient. The shallow depth class accounts for 28.05% of the area of our study zone. It extends from Lake Gbokora to the Pacific Hotel, covering the entire southern strip of the neighborhood. Intermediate depths are distributed in a curvilinear pattern, extending across the entire northern part, passing through the center, and emerging at the southeast. They account for 65% of the study area. The deepest areas are located in the far east, in the Boga Seri sector, with a coverage rate of 7.42%.

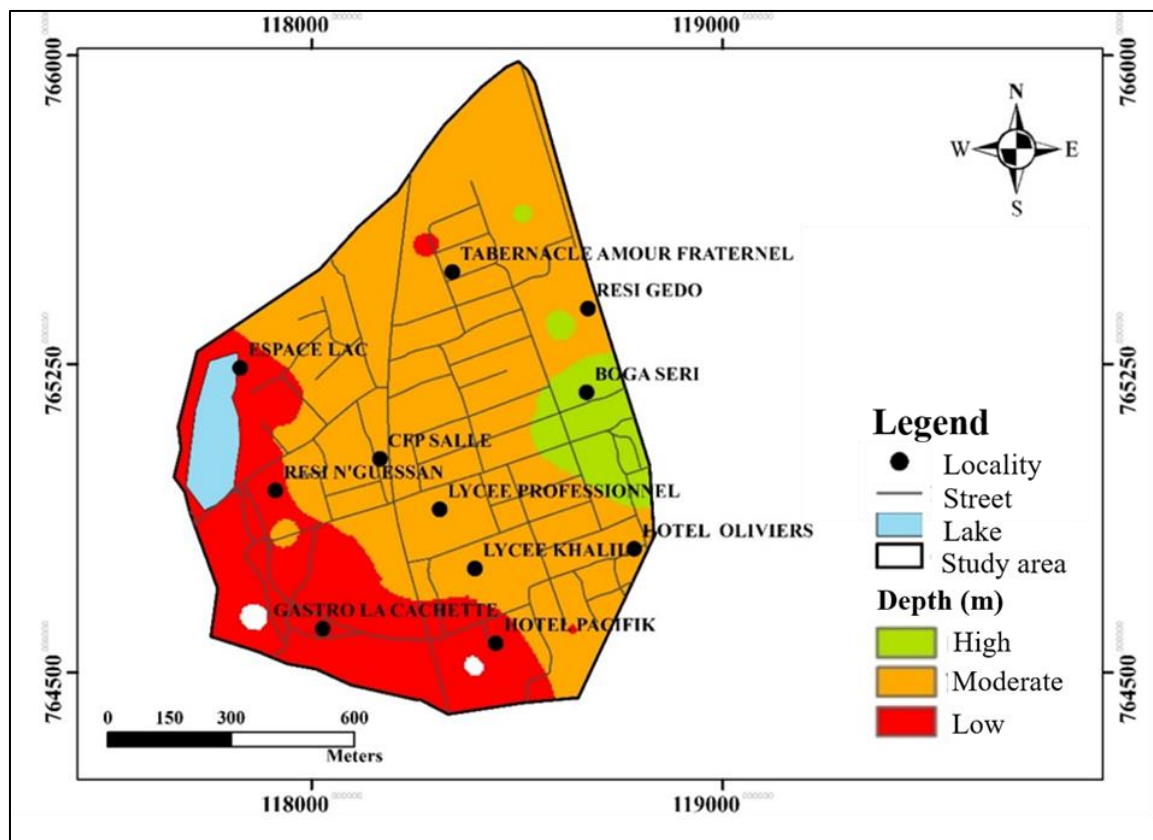


Figure 4: Depth Map

3.3 Drainage Density Map

Figure 5 presents the drainage density map of the Gbokora neighborhood in the city of Daloa. This parameter shows heterogeneity, with a drainage density gradient running from west to east, from low to high drainage densities. Statistically, low drainage densities cover 44% of the area and are more prevalent in the western and southern parts. Intermediate densities classified as poor and mediocre account for 24% and encompass the area stretching from the Tabernacle in the north to the southeast of the neighborhood. High drainage densities (32%) are more prominent in the east and southeast but less prevalent in the rest of the neighborhood.

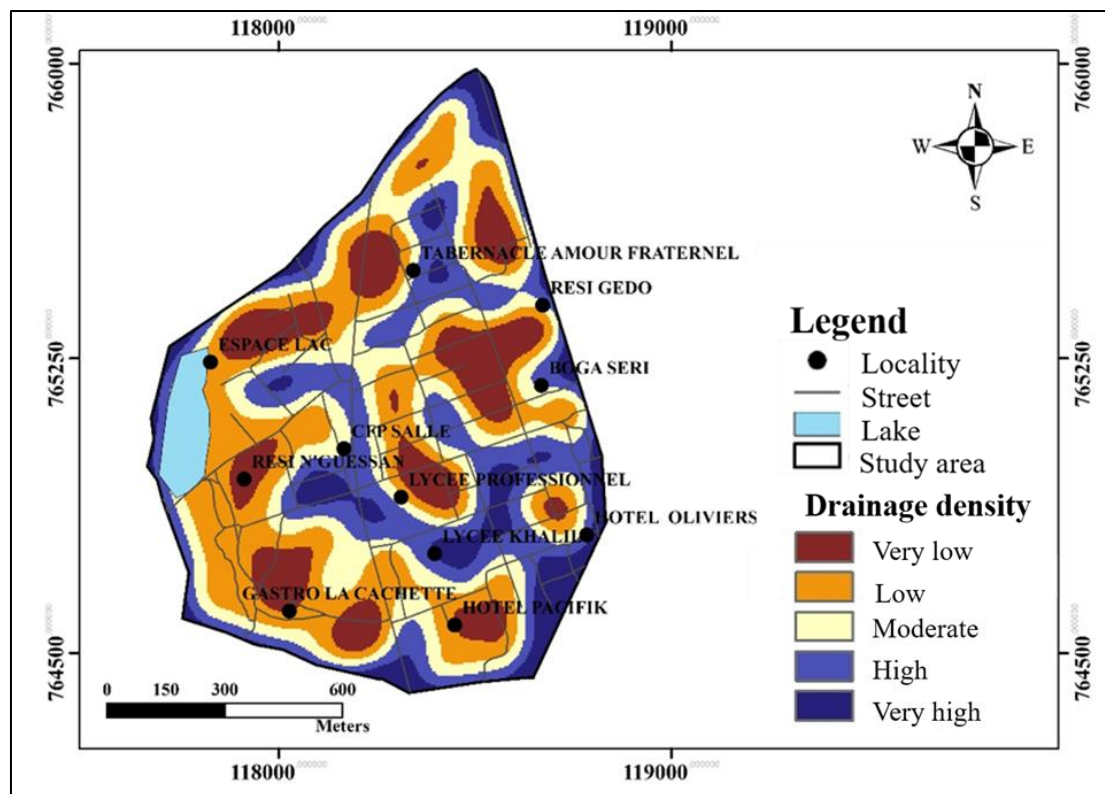


Figure 5: Drainage Density Map

3.4 Permeability Map

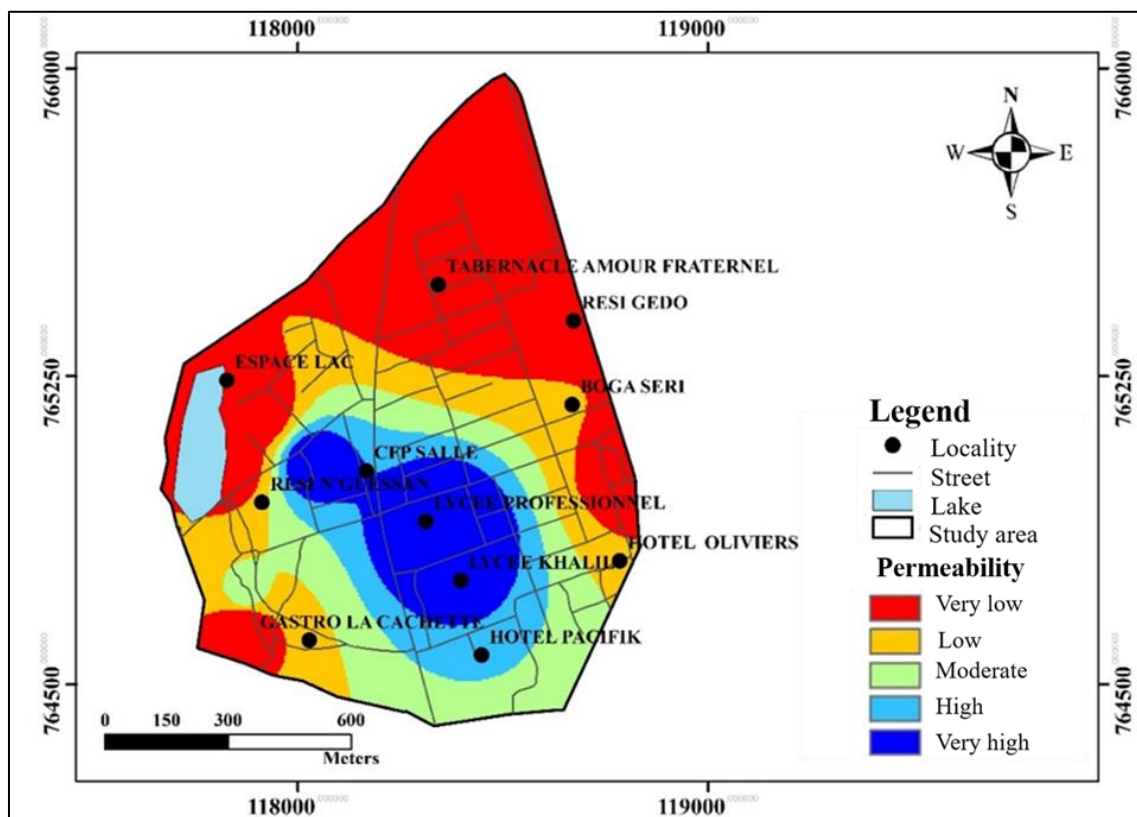


Figure 6: Permeability Map

Figure 6 below shows the permeability map of the Gbokora neighborhood in the city of Daloa. The results reveal that high, medium, and low permeability account for 24%, 18%, and 58% of the study area, respectively. The northern part

is less permeable than the southern part. The most permeable area is the center, which includes the CFP Technical High School, the Vocational High School, and Khalil High School.

3.5 Groundwater Availability Map

Figure 7 below shows the groundwater availability map for the Gbokora neighborhood of the city of Daloa. This map reveals five availability classes, including very poor, poor, fair, good, and excellent. The poor availability class is predominant and is distributed across the central and southeastern parts of the neighborhood, with a few isolated areas identified in the north. The “very poor” class is located primarily in the north and west, surrounding the district’s lake. The “poor” class is more pronounced in the east and south of the study area. The “fair,” “good,” and “excellent” availability classes overlap in the eastern and southeastern parts of the neighborhood. The “excellent” availability class is less prevalent than the other classes and appears only sporadically in the central-eastern part of the neighborhood.

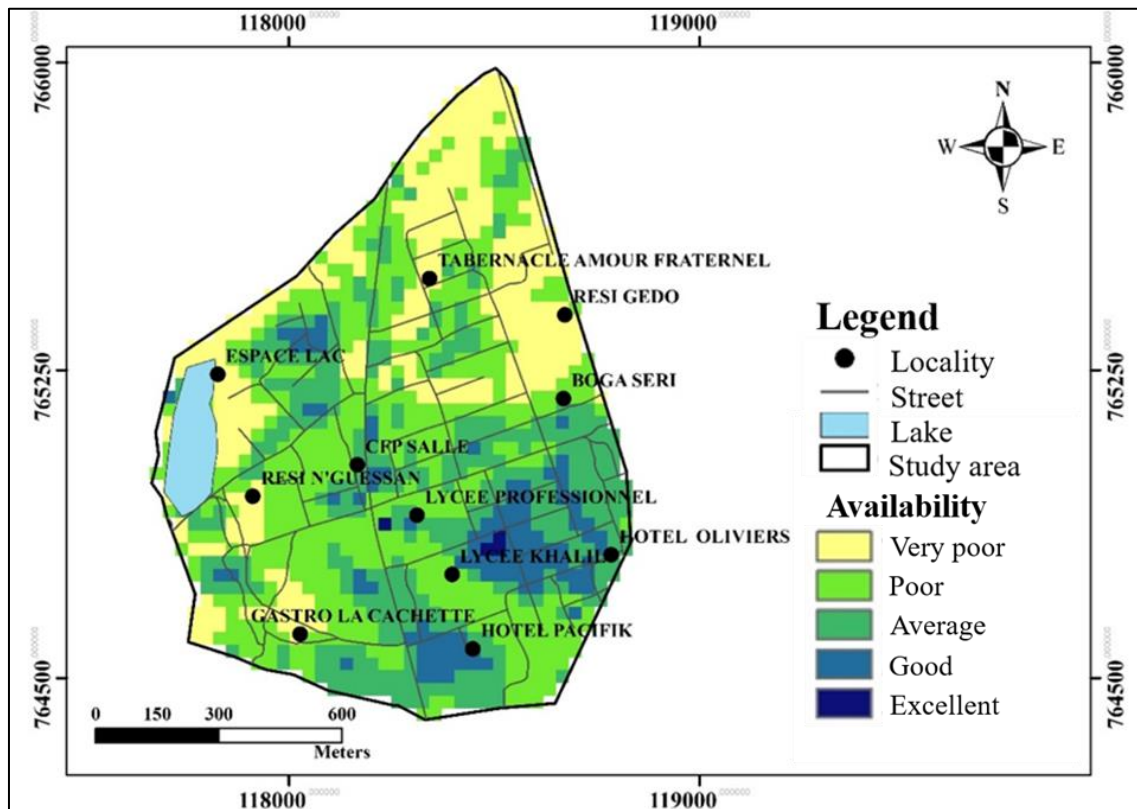


Figure 7: Groundwater availability map of the Gbokora neighborhood

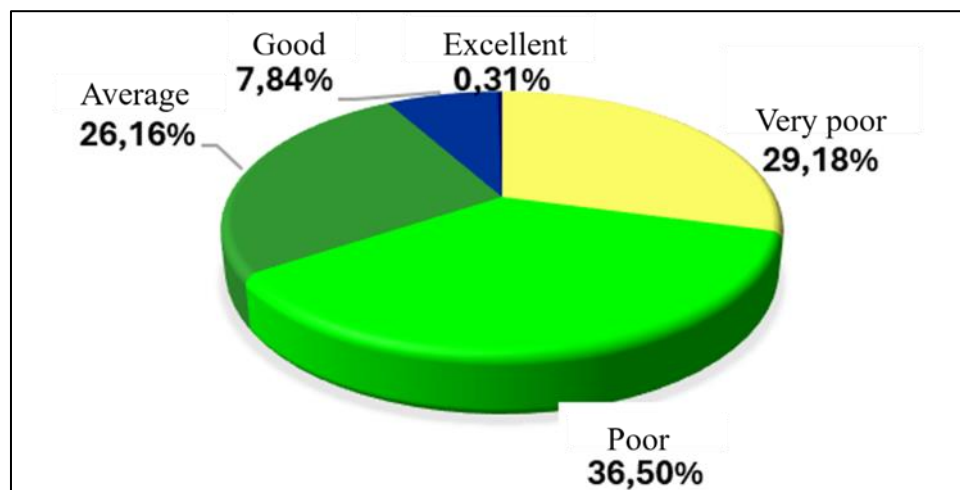


Figure 8: Proportion of availability classes

The above diagram presents the various proportions of the availability classes observed in the Gbokora neighborhood of Daloa. This diagram clearly shows that the groundwater availability indicator in this neighborhood is dominated by

the “poor” class, with a rate of 36.50%, followed by the “very poor” and “mediocre” classes, which account for 29.18% and 26.16%, respectively. The “good” availability class accounts for 7.84%, while the “excellent” class is virtually nonexistent, with a rate of 0.31%.

4 DISCUSSION

The study of the groundwater availability indicator for the alterite aquifers in the Gbokora neighborhood of the city of Daloa provided a better understanding of the spatial distribution of areas likely to contain water in this neighborhood. Five availability classes were mapped, namely: very poor, poor, fair, good, and excellent. Overall, the neighborhood is characterized by poor groundwater availability, as the “very poor” and “poor” classes account for a combined 65.68% of the area. Furthermore, these classes are located in low-lying areas and on slopes. This situation can be explained, on the one hand, by the fact that slopes (steep inclines) do not facilitate the infiltration of runoff into aquifers and, on the other hand, by the fact that permeability in these areas was low compared to that of the neighborhood’s plateau. Unlike the other classes, the “good availability” class is located on the plateau in the southeast and south of the neighborhood. The presence of this class in this area is due to the fact that the slopes here are relatively gentle, which facilitates the infiltration and accumulation of water resources in the aquifer. The average permeability recorded in this area implies moderate groundwater recharge without, however, promoting the formation of significant underground reservoirs (Mangoua et al. 2019).

In terms of proportions, the results of this study differ from those of Mangoua et al. (2019) and Yao et al. (2014). Indeed, in this study, the “poor” availability class dominates, accounting for 36.50% of the study area, whereas in the studies by Mangoua et al. (2019) and Yao et al. (2014), the dominant classes were, respectively, the “moderate” class (26%) and the “good” class (68%). This difference could be explained by the nature of the study areas. Those two authors worked on watersheds, whereas this study was conducted not only at the neighborhood level (the Gbokora neighborhood of the city of Daloa) but also in a neighborhood located on the ridgeline between the Lobo and Goré watersheds. It is important to note that mapping groundwater availability in an area is a subjective methodology, and the assessment of its parameters may differ from one author to another. The order of the interpolated hydrographic network used to determine drainage density can vary significantly from one author to another and is often the cause of the differences observed in the final maps.

5 CONCLUSION

The assessment of groundwater availability in the alterite aquifers of the Gbokora neighborhood in the city of Daloa (Central-West Côte d’Ivoire) is made possible through the mapping and aggregation of parameters related to the availability indicator. The results show that the groundwater availability indicator for alterite aquifers is heterogeneous, with five availability classes: very poor (36.50%), poor (29.18%), fair (26.16%), good (7.84%), and excellent (0.31%). The southeastern part of the district is more favorable for groundwater storage in alterite aquifers compared to the north and west. To ensure better water supply in general and drinking water in particular, it is necessary to tap into fractured aquifers, whose water tables are not necessarily recharged by infiltrating water.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgments

We would like to thank the team at the Environmental Science and Technology Laboratory at Jean Lorougnon Guédé University and all the authors for their contributions to the fieldwork and writing of this study.

Funding Source

The article was funded by the Environmental Science and Technology Laboratory at Jean Lorougnon Guédé University

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

- [1] Adjiri O.A., Kone B., Aka N., Djabakate, I. and Dibi B. (2019). Caractérisation physico-chimique et source de la minéralisation des eaux souterraines des départements de Daloa et Zoukougbeu, Côte d’Ivoire. *International Journal of Biological and Chemical Sciences*, 13(4), 2388-2401. DOI: 10.4314/ijbcs.v13i4.40

- [2] Ahoussi K.E. and Yapo A.P. (2021). Étude de la minéralisation des eaux de surface en éléments traces métalliques (ETM) des zones d'orpaillage de la sous-préfecture de Kokumbo, Centre-Ouest de la Côte d'Ivoire. *Afrique SCIENCE*, 19(4) : 36-50.
- [3] Joerin F. (1995). Méthodes multicritères d'aide à la décision et SIG pour la recherche d'un site, 15 p.
- [4] Jourda J.P.R. (2005). Méthodologie d'application des techniques de télédétection et des systèmes d'information géographique à l'étude des aquifères fissures d'Afrique de l'Ouest. Concept de l'hydrotechnique spatiale : cas des zones tests de la cote d'ivoire. Thèse de Doctorat en Hydrogéologie et Télédétection, Université Félix Houphouët Boigny (Abidjan, Côte d'Ivoire), 435 p.
- [5] Kablan K.A., Kouadio F.J. and N'Guessan, B. (2023). Qualité organoleptique et physico-chimique de l'eau de robinet distribuée par la SODECI dans la ville de Daloa (Côte d'Ivoire). *Journal of Water and Environmental Studies*, 15(2) : 101-118.
- [6] Kouadio F.J.L.H., Ouattara A.S. and Coulibaly Y. (2025). Accès à l'eau potable en Côte d'Ivoire : progrès réels, disparités persistantes et nouveaux défis. *European Scientific Journal*, 21 (4) :55-72.
- [7] Kouassi J.M. (2021). Contribution des sources dans l'approvisionnement en eau potable des populations en contexte de socle cristallin : approche couplée hydro-géophysique et par modélisation hydrodynamique (Daloa, Centre-Ouest de la Côte d'Ivoire). Thèse de Doctorat, Université Jean Lorougnon Guédé, Daloa, 210 p.
- [8] Mangoua J. (2013). Évaluation des potentialités et de la vulnérabilité des ressources en eau souterraine des aquifères fissurés du bassin versant de la Baya (Est de la Côte d'Ivoire). Thèse de Doctorat, Université Nangui Abrogoua, Abidjan, Côte d'Ivoire, 209 p.
- [9] Mangoua M.J., Yao A.B., Douagui G.A., Kouassi K.A, Goula B.T.A. and Biemi J (2019). Évaluation des potentiels en eau souterraine des aquifères fissurés dans le bassin versant du Bandama (Côte d'Ivoire). *Larhyss Journal*, ISSN 1112-3680, 8 : 53-74.
- [10] UNICEF (2025). Progress on household drinking water, sanitation and hygiene 2000-2024: Special focus on inequalities. WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene, 176 p.
- [11] UNESCO (2022). The United Nations World Water Development Report 2022 : Groundwater-Making the Invisible Visible. Paris : UNESCO World Water Assessment Programme, 246 p.
- [12] Recensement Général de la Population et de l'Habitat (RGPH 2014) : Résultats globaux. République de Côte d'Ivoire, Abidjan.
- [13] Saley M.B. (2003). Système d'informations hydrogéologiques à référence spatiale, discontinuités pseudo-images et cartographies thématiques des ressources en eau de la région semi-montagneuse de Man (Ouest de la Côte d'Ivoire). Thèse De Doctorat, Université Félix Houphouët Boigny, Abidjan, (Côte d'Ivoire), 211 p.
- [14] Sampah G.E., Yao A.B., Anoh K.A. and Konan K.S. (2022). Assessment of the physico-chemical quality of waters of the Lobo reservoir (West-central Côte d'Ivoire). *International Journal of Innovation and Scientific Research*, 59(1) : 1-11
- [15] Yao A.B, Goula Bi T.A, Kaneb A, Mangoua Oi M.J. and Kouassi K.A (2014). Cartographie du potentiel en eau souterraine du bassin versant de la Lobo (Centre-Ouest, Côte d'Ivoire). Approche par analyse multicritère. *Hydrological Sciences Journal* : 4-5.
- [16] Zébré A.C., Attien, Y.P., Sina H., Yao A.B., Koffi-Nevry R., Connil N., Konaté, I. and Baba-Moussa, L. (2025). Physicochemical and Microbiological Characteristics of Surface and Groundwater Frequently Used by Households in Some Districts of Daloa, Côte d'Ivoire. *Journal of Advances in Microbiology*, 25(3), 1-12. DOI : 10.9734/jamb/2025/v25i3903