

Spatial Analysis of Socio-Collective Infrastructure and Territorial Inequalities in a Rural Context: Evidence from Fokoué Subdivision (West Cameroon)

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Spatial Analysis of Socio-Collective Infrastructure and Territorial Inequalities in a Rural Context: Evidence from Fokoué Subdivision (West Cameroon)

Abstract

This study assesses the spatial adequacy of socio-collective infrastructure provision in the Fokoué Subdivision (West Cameroon) by analyzing distribution patterns, accessibility levels, and compliance with planning standards. Despite decentralization reforms and national development policies, rural areas continue to experience persistent territorial inequalities in access to essential services. The study adopts a mixed-methods GIS-based approach combining normative standards, spatial datasets, and field surveys. Spatial analyses were conducted using QGIS and ArcGIS Pro, including proximity analysis, buffer zoning, slope assessment, spatial joins, and multicriteria evaluation. The results reveal a highly uneven spatial distribution of infrastructure, with strong concentration in central localities and significant deficits in peripheral areas, particularly in the southeastern and northwestern zones. Approximately 49% of infrastructures do not comply with established standards. Accessibility analysis shows that most settlements are located beyond acceptable thresholds for potable water access, while educational and health infrastructures are characterized by overcrowding and uneven service provision. In addition, a significant proportion of facilities are exposed to environmental risks such as flooding and slope instability, reflecting insufficient integration of biophysical constraints in planning processes. These spatial disparities generate cumulative vulnerabilities affecting health, education, and living conditions, particularly in remote rural communities. The study highlights the value of GIS-based spatial analysis as a decision-support tool for identifying priority intervention areas and promoting more equitable and resilient territorial planning. The findings support the need for integrated spatial planning approaches aligned with sustainable development objectives in decentralized rural contexts.

Keywords: Spatial analysis, Infrastructure accessibility, Territorial inequalities, GIS, Rural planning, Cameroon

1. INTRODUCTION

Equitable access to socio-collective services represents a major global challenge for local authorities, directly influencing quality of life, social cohesion, and local development. These services, including education, healthcare, water supply, transport, and community infrastructure, constitute essential forms of social capital (Bourdieu 1984). However, their spatial distribution remains uneven, with pronounced disparities between urban and rural areas, particularly in developing countries such as Cameroon. Rural territories are often confronted with structural deficits linked to limited resources, insufficient planning capacity, and a lack of reliable spatial data (Camara 2025; IFAD 2020).

The municipality of Fokoué, located in the western highlands, covers an area of approximately 162 km² and comprises five chiefdoms and about twenty villages. Its population increased from 30,379 inhabitants in 2013 to nearly 45,000 in 2023, corresponding to an annual growth rate of approximately 2% (BUCREP, 2020; PNDP, 2013). This demographic dynamic, driven by a predominantly agricultural economy (maize, banana, coffee, cassava), has led to a significant increase in demand for socio-collective infrastructure, particularly schools, healthcare facilities, and potable water points. Despite ongoing development efforts, territorial inequalities persist, especially in peripheral villages where poor road conditions limit access to basic services, in contrast to the better-served administrative center (Commune de Fokoué, 2022).

Moreover, many infrastructures do not comply with existing national and international standards. Several village water points fail to meet hydraulic standards defined by the Ministry of Water and Energy (MINEE, 2011), while some schools and healthcare facilities do not satisfy Quality, Hygiene, Safety, and Environmental (QHSE) standards recommended by the World Health Organization and national education authorities (WHO 2017; MINEDUB 2018). These shortcomings contribute to increased social vulnerabilities, particularly in terms of public health, access to education, and environmental risks.

Since 2018, the municipality has engaged in sustainable development initiatives, notably through the implementation of gravity-fed water supply systems. However, the absence of coordinated spatial planning significantly limits the effectiveness and sustainability of these interventions. The lack of updated and integrated territorial data constitutes a

major constraint on evidence-based decision-making and coherent planning (IFAD, 2020). In this context, ensuring equitable access to services and compliance of infrastructure with QHSE standards emerges as a strategic priority.

Spatial analysis provides a relevant methodological framework to address these challenges. Through the use of Geographic Information Systems (GIS), it enables the mapping, analysis, and evaluation of infrastructure distribution, accessibility, and compliance with planning standards (Camara, 2025; OpenEdition, 2022). These approaches align with international frameworks, particularly the United Nations Sustainable Development Goals (SDGs), notably SDG 3 (health), SDG 4 (education), SDG 6 (water and sanitation), and SDG 11 (sustainable cities and communities).

At the national level, Cameroon has strengthened decentralization through Law No. 2019/024 of 24 December 2019, granting municipalities increased responsibilities in the management of local public services (Republic of Cameroon 2019). This reform is embedded in the National Development Strategy 2020–2030 (SND30), which aims to promote territorial equity and sustainable development (MINEPAT, 2020). Planning instruments such as the National Spatial Planning and Sustainable Development Scheme (SNADDT) and regional schemes (SRADDT) have been developed to guide territorial development; however, their implementation remains constrained by technical and financial limitations (MINEPAT, 2022).

Although programs such as the National Participatory Development Program (PNDP) support municipal development plans, the limited integration of geomatics tools reduces their effectiveness. Similarly, funding from FEICOM and international partners, notably World Bank, struggles to generate sustainable impacts in the absence of a comprehensive spatial vision (World Bank 2023; FEICOM 2024). In this context, spatial analysis emerges as an essential decision-support tool, enabling the identification of access deficits, optimization of infrastructure location, and promotion of equitable socio-collective service provision in rural municipalities such as Fokoué.

2. STUDY AREA

The Fokoué Subdivision is located in the West Region of Cameroon, within the Menoua Division, approximately 18 km southeast of Dschang (Fig. 1). Covering an area of 162 km² at an average elevation of 1,256 m, it comprises five traditional chiefdoms: Fokoué, Fotomena, Fomopea, Fontsa-Touala, and Bamegwou. Bordered by Dschang, Penka-Michel, Nkong-Zem, and Santchou, this territory is characterized by a hilly landscape conducive to agriculture and ecotourism. However, the steep slopes constitute a major constraint for infrastructure siting and accessibility.

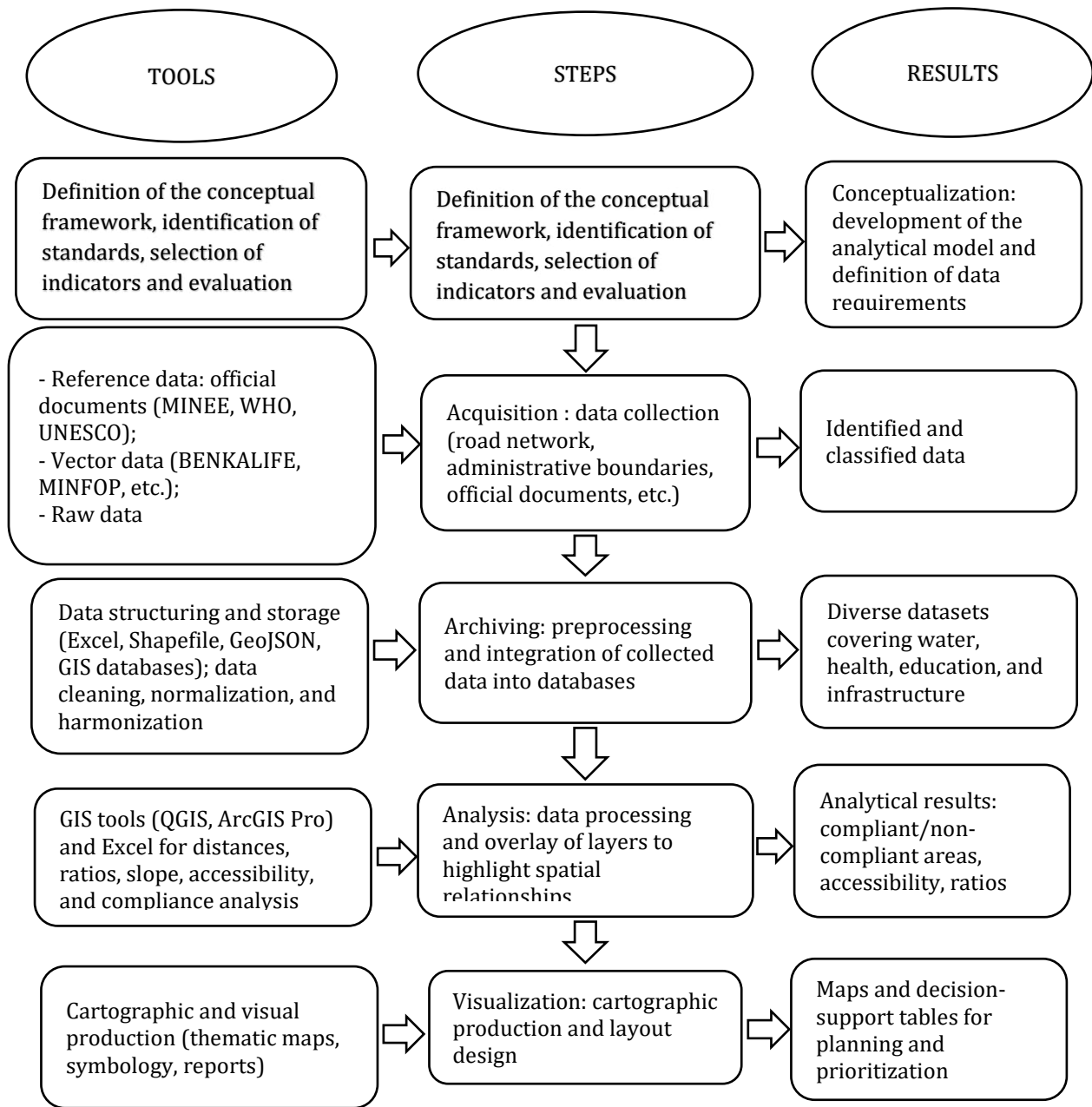


Fig. 2. Workflow of the GIS-based methodological framework for assessing socio-collective infrastructure in the Fokoué Subdivision

3.2 Data Sources and Normative Framework

Three types of data were mobilized:

(i) Normative data: derived from national reference frameworks (MINEE, MINEDUB, MINSANTE) and international standards (WHO, Sphere Handbook), defining compliance thresholds such as service distance, student-to-classroom ratios, and topographic constraints (Table 1).

- (ii) Spatial data: including vector data (administrative boundaries, infrastructure, road networks, hydrography) sourced from MINFOF (2021), Geofabrik (2025), and field surveys (BENKA LIFE, 2024), as well as raster data (SRTM Digital Elevation Model, USGS, 2014).
- (iii) Attribute data: collected from the municipality (CELCOM) through questionnaires and administrative documents (school enrollment figures, health facility equipment).

Sector	Indicator	Threshold
Water	Distance to standpipe	≤ 1000 m
Water	Population per tap	≤ 250
Health	Terrain slope	3–10%
Education	Students per classroom	≤ 42

Table 1. Main normative indicators used for compliance analysis

3.3 Data Preprocessing

The data were cleaned, harmonized, and integrated into a GIS database. The operations included duplicate removal, attribute standardization, reprojection into a unified coordinate system (WGS 84 / UTM Zone 32N), and structuring into Shapefile and GeoJSON formats.

Preprocessing was carried out using QGIS 3.34 for topological verification and format conversion, while Microsoft Excel 2013 was used for statistical validation and table structuring. These steps ensured data consistency and quality, which are essential conditions for the reliability of spatial analyses (Camara, 2025).

3.4 Spatial Analyses

Spatial analyses were conducted using ArcGIS Pro 3.1. The main methods included:

- Proximity analysis: distance calculations (Near tool) to assess accessibility to infrastructure;
- Buffer analysis: delineation of service coverage areas (300 m for watercourses, 1,000 m for water points);
- Raster analysis: slope computation from the Digital Elevation Model (Slope tool) and reclassification into constraint classes;
- Spatial joins: assignment of environmental variables to infrastructure datasets;
- Multicriteria analysis: integration of variables (distance, slope, ratios) to evaluate compliance.

These processes enabled the identification of compliant and non-compliant areas, as well as spatial disparities in access to services (IFAD, 2020).

3.5 Map Production

The results were presented in the form of thematic maps (distribution, accessibility, compliance, and ratios). Symbolization was based on both qualitative and quantitative classifications (graduated scales and bivariate maps), facilitating interpretation for territorial decision-making.

3.6 Accuracy Assessment and Validation

Validation relied on data triangulation: (i) comparison with field data (BENKA LIFE, 2024), (ii) cross-verification with administrative sources, and (iii) visual inspection of spatial inconsistencies.

Consistency tests were conducted on distances and ratios, while the spatial accuracy of the data was assessed through overlay with official reference datasets. This approach ensured the robustness and reproducibility of the results (El Garouani et al., 2021).

4. RESULTS AND DISCUSSION

4.1 Spatial Organization of Socio-Collective Infrastructure and Territorial Inequalities

Spatial analysis reveals a highly uneven structure of socio-collective infrastructure provision in the Fokoué Subdivision. The distribution of water infrastructure (Fig. 3) shows a marked concentration of the 19 public standpipes in the Fontsa-Touala (7 units) and Fomopea (4 units) chiefdoms, whereas the urban center of Fokoué has only two supply points. This pattern shows spatial inequality, with better services in central areas and poorer access in peripheral zones, especially in the southeastern and northwestern parts of the subdivision.

This territorial organization is consistent with classical patterns of infrastructure allocation in sub-Saharan Africa, where public investments are primarily concentrated along accessible corridors and in administrative centers (Pullan et al. 2014; World Bank 2023). In Fokoué, this dynamic is further reinforced by morphological constraints of the relief, as steep slopes increase installation costs and limit network expansion toward remote areas (Weiss et al., 2018).

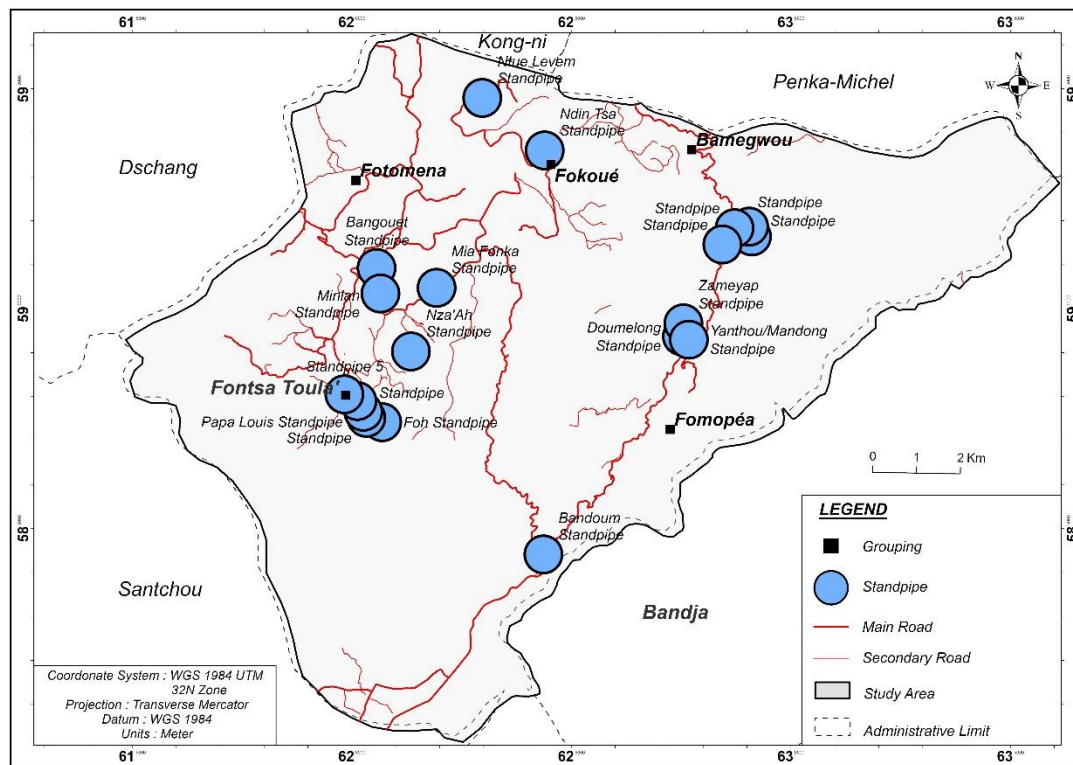


Fig. 3. Spatial distribution of water infrastructure in Fokoué Subdivision

In the health sector, the distribution of healthcare facilities (Fig. 4) confirms this pattern of spatial concentration, with a preferential location in the urban center and in Fomopea, to the detriment of peripheral areas. This uneven distribution results in differentiated access to healthcare services, with rural populations facing longer travel times, a well-documented factor contributing to the avoidance or delay of care (Ouma et al., 2018).

With regard to education, the distribution of schools by level (Fig. 5) highlights the predominance of primary schools across the territory, whereas secondary and technical institutions are highly concentrated in urban centers. This

configuration restricts access to post-primary education for rural populations and fosters school dropout phenomena, widely reported in the literature (UNESCO, 2015; Filmer, 2007).

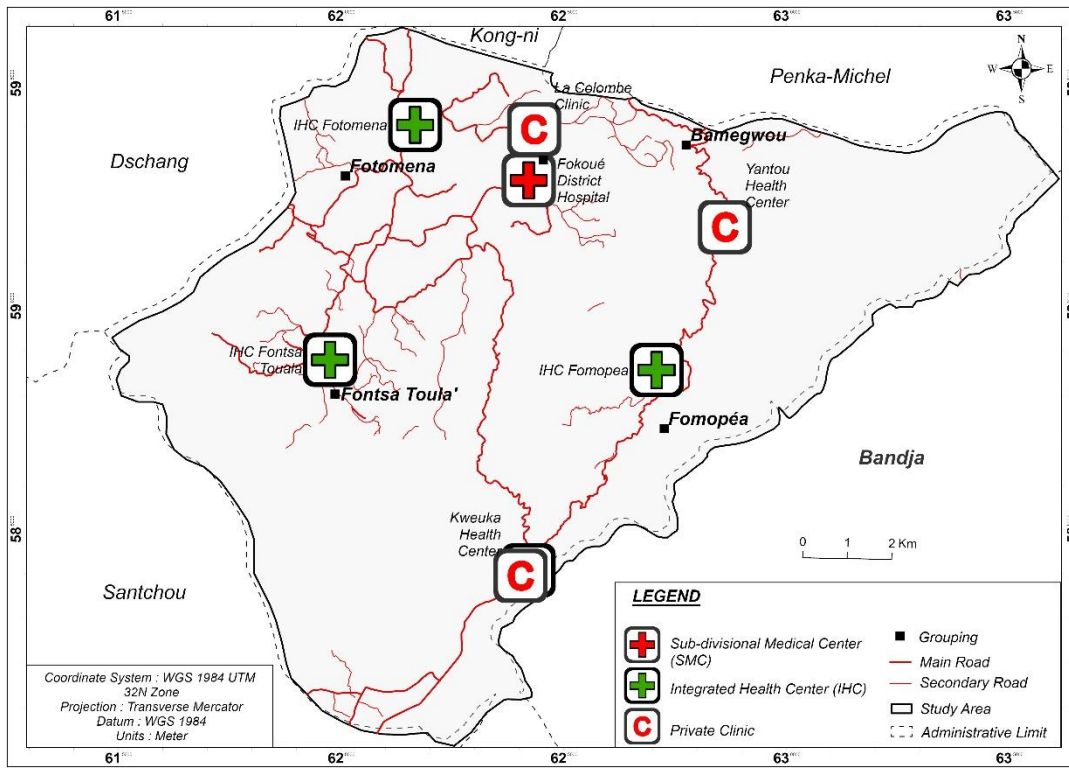


Fig. 3. Spatial distribution of health facilities in Fokoué

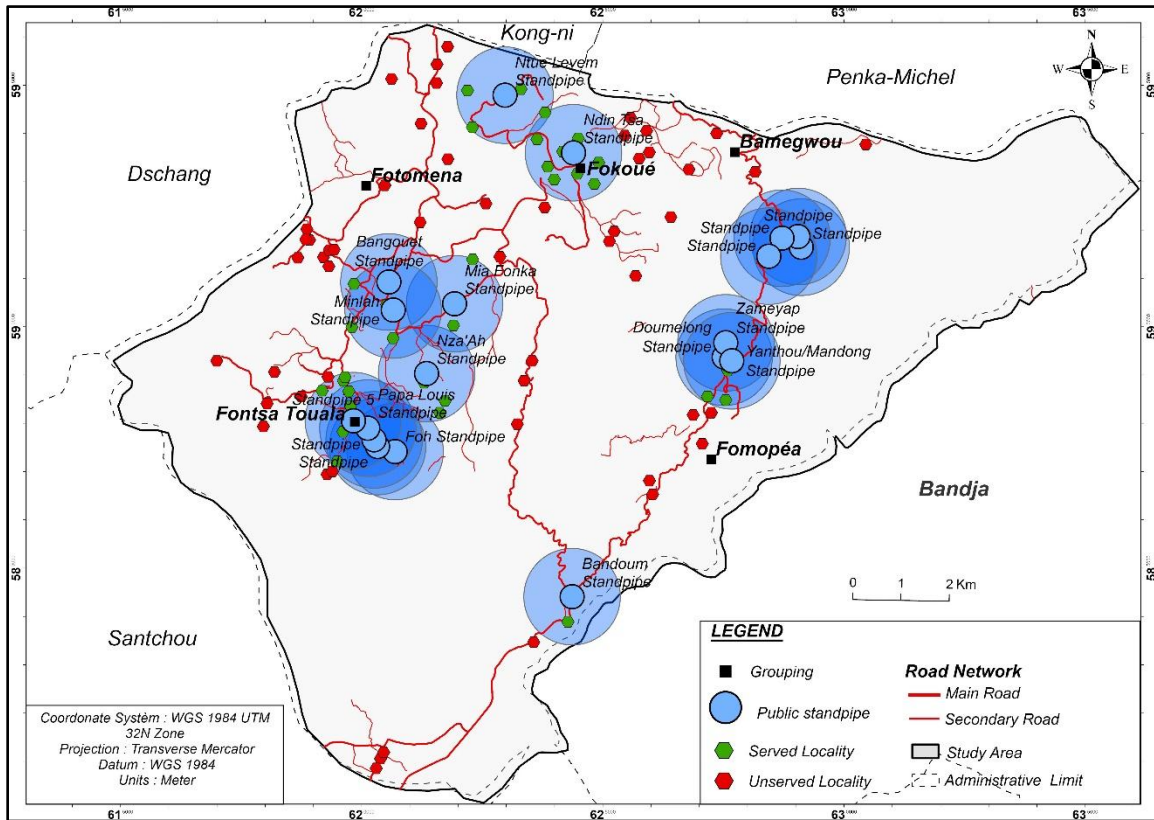


Fig. 5. Accessibility to water infrastructure

In the education sector, the compliance map of the student-to-classroom ratio (Fig. 7) indicates that 60.60% of schools comply with the MINEDUB standard (≤ 42 students per classroom), while 24.24% exceed it. However, the situation is considerably more critical for the student-to-teacher ratio (Fig. 8), where only 21.22% of schools meet the standard, compared to 63.63% operating under overcrowded conditions, with extreme cases reaching up to 145 students per teacher.

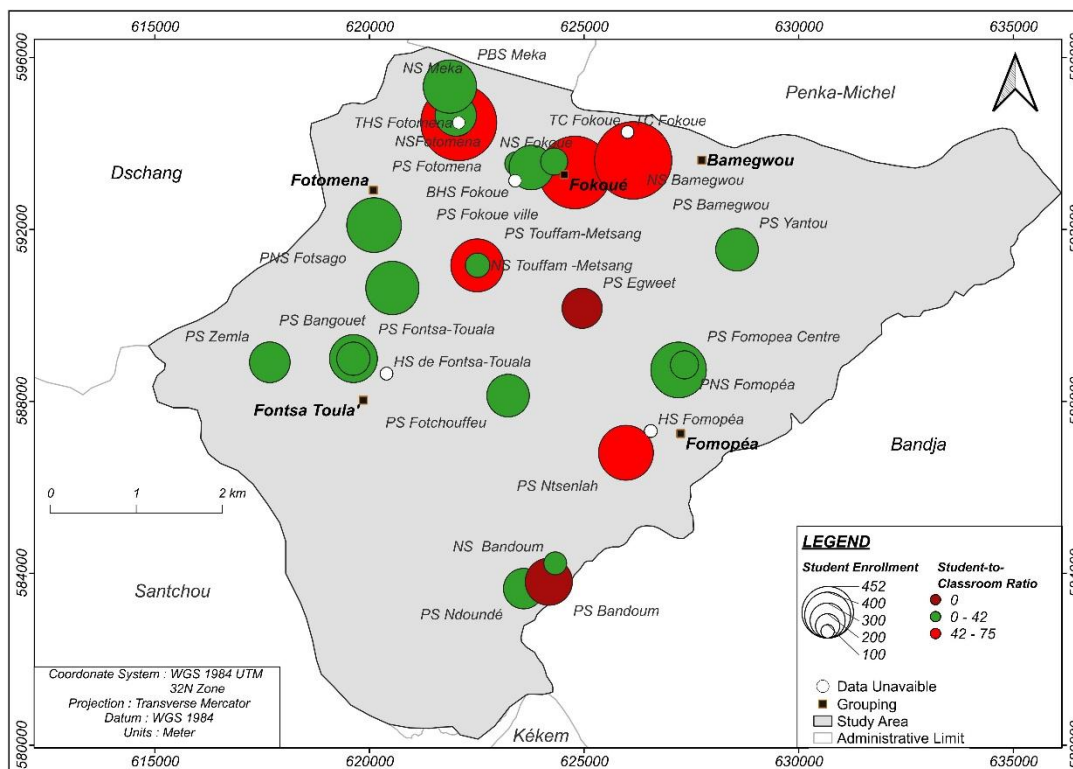


Fig. 7. Map of school compliance with the student-to-classroom ratio relative to the MINEDUB standard

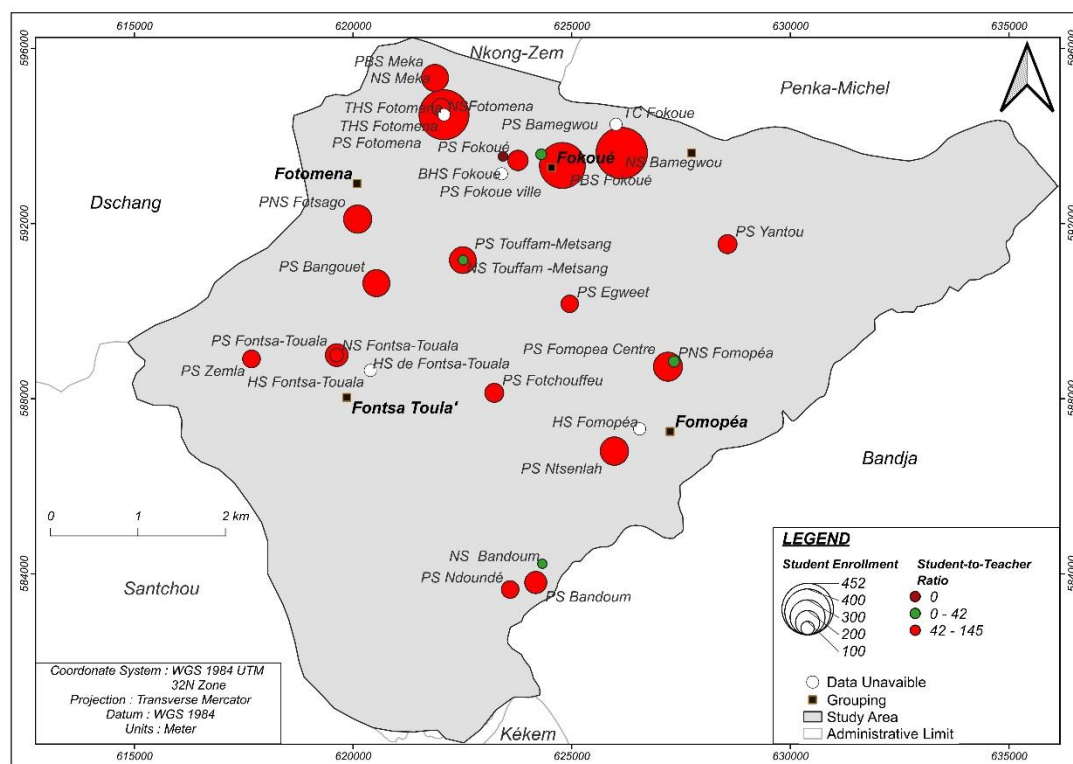


Fig. 8. Map of school compliance with the student-to-teacher ratio according to the standard of the Ministry of Basic Education (MINEDUB)

The classroom-to-teacher ratio map (Fig. 9) reveals an even more pronounced level of non-compliance, with 84.85% of schools failing to meet the standard of one classroom per teacher. This situation reflects a structural deficit in investment in educational infrastructure in the context of demographic growth.

These findings are consistent with the work of Lewin (2009) and UNESCO (2015), which demonstrate that overcrowded classrooms and excessive teacher workloads significantly undermine the quality of education, leading to higher failure rates and increased school dropout.

Thus, the observed non-compliance in Fokoué appears to be systemic and multidimensional, simultaneously affecting accessibility, service quality, and learning conditions.

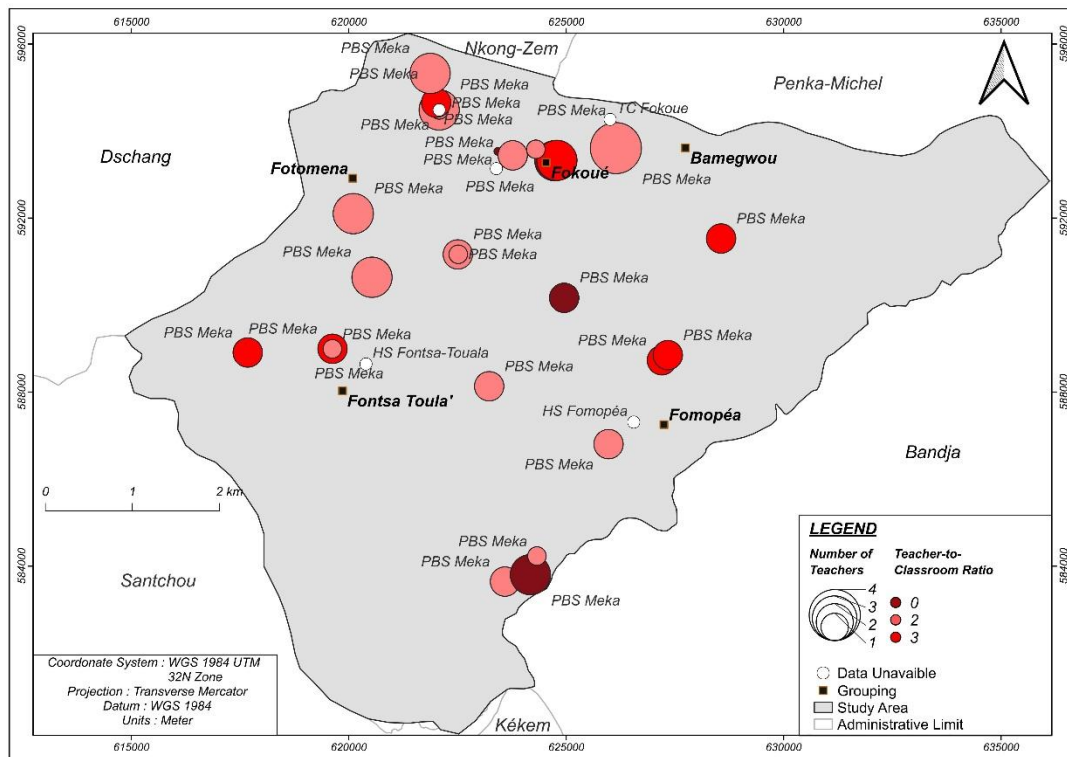


Fig. 9. Compliance of schools with the classroom-to-teacher ratio (MINEDUB standard: 1 classroom per teacher)

4.3 Exposure to Environmental Risks and Unsuitability of Site Location

The assessment of infrastructure compliance with environmental constraints reveals significant vulnerabilities. The compliance map of healthcare facilities with combined risk factors (Fig. 10) shows that 12.5% of health centers are located in high-risk zones, while 50% are exposed to moderate risk. Similarly, the compliance map of schools (Fig. 11) indicates that approximately 24% of educational facilities are exposed to significant risks related to slope instability and flooding.

These siting patterns largely result from historical planning processes that insufficiently integrated geotechnical and hydrological constraints. This observation is consistent with the findings of UNDP (2021), which highlight that many infrastructures in Africa were developed without prior environmental risk assessments.

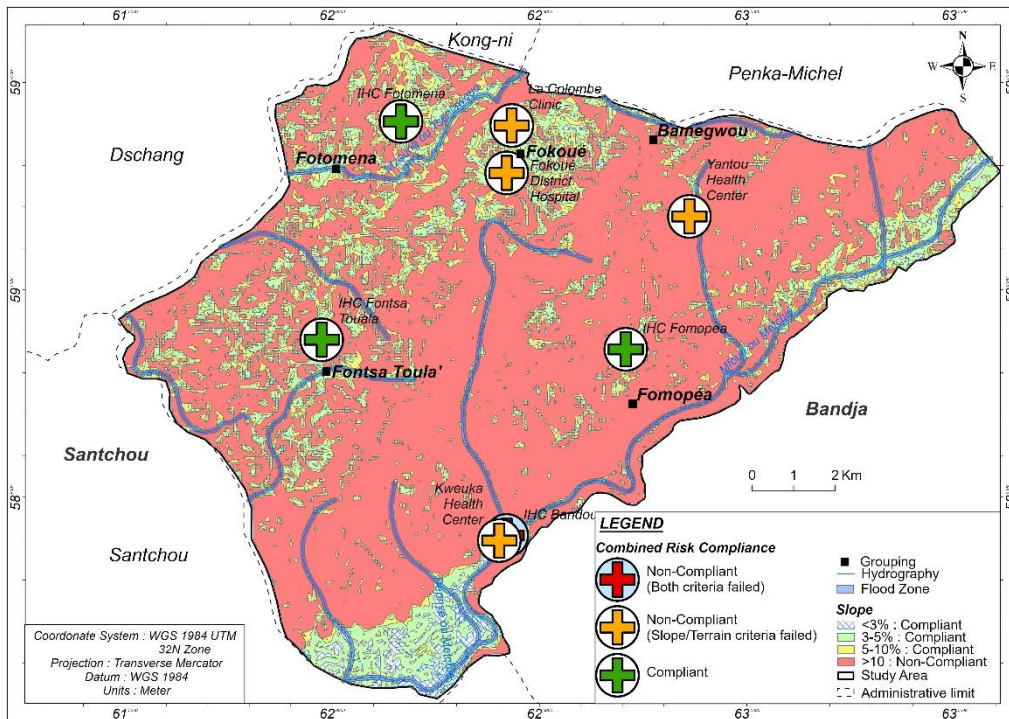


Fig. 10. Compliance of healthcare facilities with combined environmental risks

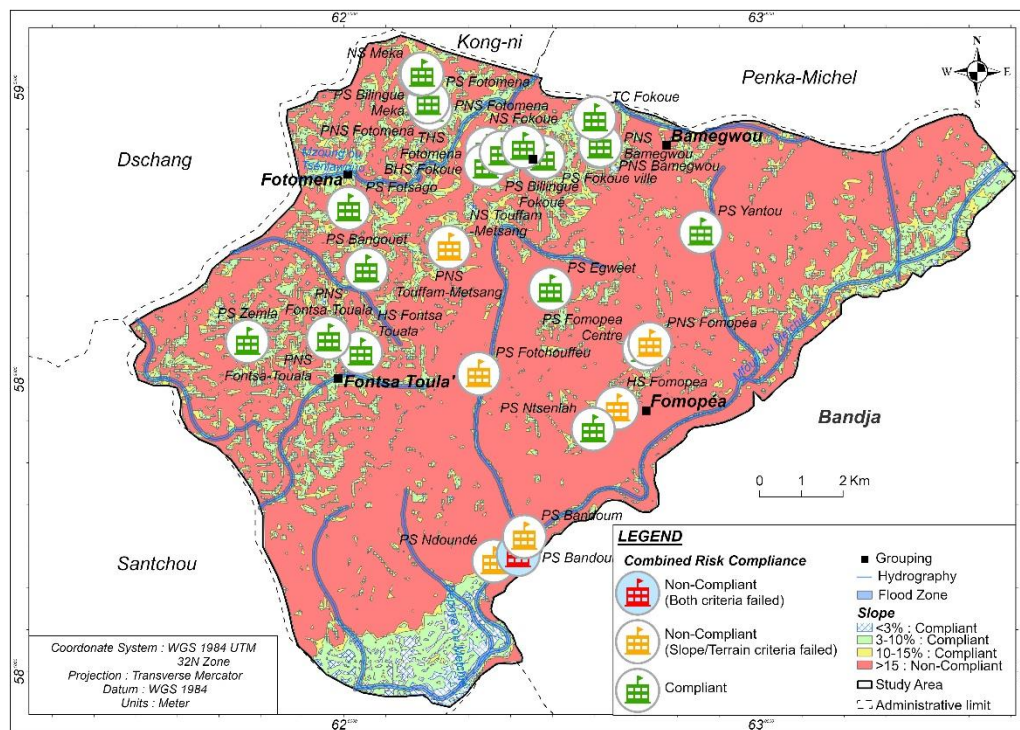


Fig. 11. Compliance of schools with combined environmental risks

In the context of climate change, characterized by an intensification of extreme events (IPCC, 2022), this exposure represents a critical vulnerability factor. Infrastructure located in high-risk areas, such as the Bandoum health center, is likely to experience service disruptions, thereby compromising access to healthcare for already marginalized populations.

These findings underscore the need to systematically integrate environmental criteria into territorial planning processes, particularly through spatial suitability analyses and resilience-oriented planning approaches.

4.4 Cumulative Territorial Vulnerabilities and Multisectoral Inequalities

The synthetic analysis of indicators (Table 2 and 3) reveals an overall non-compliance level of 49.27% across the subdivision, confirming the existence of structural deficits across all studied sectors.

Beyond sector-specific indicators, the integrated approach highlights a spatial overlap of deficits. Peripheral areas often accumulate multiple forms of vulnerability, including poor access to potable water, insufficient educational infrastructure, and limited access to healthcare services.

This phenomenon corresponds to the concept of “spatial poverty traps,” in which geographical and infrastructural disadvantages reinforce one another (Bird et al., 2010; Barbier, 2010). In Fokoué, these dynamics are exacerbated by territorial isolation and topographic constraints.

Sector	Category	Indicator	Value (%)	Status
Drinking water	Accessibility	Localities located > 1 km from a water point	59	Non-compliant
Education	Ratios	Schools: student/classroom ratio > 42	28.57	Non-compliant
		Schools: student/teacher ratio > 42	75	Non-compliant
		Schools: classroom/teacher ratio < 1	84.85	Non-compliant
	Compliance	Schools located on non-compliant slopes	27.73	Non-compliant
		Schools in flood-prone areas	7	Non-compliant
Health	Compliance	Health centers located on non-compliant slopes	73.66	Non-compliant
		Health centers in flood-prone areas	14.73	Non-compliant

Table 2. Comparative table of standards versus the current situation

The analysis of the final synthesis table (Table 3) confirms this trend, with high levels of sectoral non-compliance in potable water (59%), education (44.6%), and health (44.2%). Thus, the observed inequalities are not sector-specific but systemic and interrelated, requiring integrated responses.

Sector	Curent Situation	Status
Drinking Water	59	The Fokoué Subdivision is non-compliant at 49.27%
Education	44,6	
Health	44,2	

Table 3. Overall compliance status of the Fokoué Subdivision

4.5 Implications for Territorial Planning and Decision-Making

The findings underscore the persistent shortcomings of current planning approaches in a decentralization context. Although local governments have been granted expanded responsibilities, planning instruments remain weakly supported by rigorous spatial analysis. The delineation of priority intervention zones (Table 4) provides an essential operational tool for evidence-based public decision-making. It allows for the precise identification of localities requiring urgent investment, with particular emphasis on the southeastern and northwestern parts of the study area.

No.	Geographic Area	Water	Health	Education	Overall Level	Priority
1	South-East (Alatet, Lefet, Balé)	Critical	Critical	Critical	Triple deficit	Maximum
2	North-West (Meudjieu)	Critical	High	Moderate	Double deficit	Very high

No.	Geographic Area	Water	Health	Education	Overall Level	Priority
3	Bamegwou western group	High	High	Moderate	Double deficit	Very high
4	Fokoué Centre (headquarters)	High	Moderate	High	Double deficit	High
5	Fotomena central group	Moderate	Moderate	Critical	Sectoral deficit	High
6	Fomopea central-east group	Low	High	High	Sectoral deficit	High
7	Fontsa-Touala north-central group	Low	Low	Moderate	Relatively covered	Normal

Table 4: Overall synthesis of priority intervention zones

Three strategic priorities emerge:

- Spatial rebalancing of infrastructure toward underserved areas
- Compliance with national and international standards
- Integration of environmental risks into planning processes

These orientations are aligned with the Sustainable Development Goals, particularly SDG 3, SDG 4, SDG 6, and SDG 11 (World Bank 2023).

Furthermore, the study demonstrates the added value of GIS as a decision-support tool, enabling the transformation of heterogeneous datasets into strategic information (IFAD, 2020). Their integration into Municipal Development Plans appears essential for improving the effectiveness of local public policies.

5. CONCLUSION

This study aimed to assess the spatial adequacy of socio-collective infrastructure provision in the Fokoué Subdivision by analyzing its distribution, accessibility, and compliance with planning standards, within a territorial decision-support framework. The results reveal an uneven spatial organization characterized by a concentration of infrastructure in central areas and a marked deficit in the southeastern and northwestern peripheral zones. The compliance analysis highlights significant deficiencies across the three sectors examined, including limited access to potable water, overcrowding of educational infrastructure, and exposure of certain healthcare facilities to environmental risks. Overall, these deficits reflect systemic and cumulative territorial inequalities, primarily affecting isolated rural populations. These findings underscore the need for a spatial rebalancing of public investments and a stronger integration of planning standards into local policies, in line with the Sustainable Development Goals and decentralization processes. From a methodological perspective, the study demonstrates the relevance of an integrated GIS-based approach, enabling the combination of multisectoral indicators and the identification of priority intervention areas, thereby strengthening evidence-based spatial decision-making. However, certain limitations must be acknowledged, particularly the lack of detailed and up-to-date demographic data, as well as gaps in sector-specific datasets, which may affect the precision of the analyses. In future research, the integration of updated datasets, the development of territorial information systems, and the extension of this approach to other municipalities appear essential to enhance territorial planning and promote more equitable and resilient rural development.

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8. Conflict of interest

The authors declare that they have no conflict of interest.

9. Ethics statement

This article does not contain any studies involving human participants or animals performed by any of the authors.

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