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Geographical Accessibility to Basic Infrastructures and Services in Rural Senegal: The Case of the Niakhar Area

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Abstract

Access to basic infrastructure and services is a factor in economic development and an important aspect in combatting social and spatial disparities. But this access is often subject to several constraints, including geographical accessibility. In this article, we aim to analyze the geographical accessibility to basic infrastructure and services in the Niakhar area, using the improved two step floating catchment area method and local spatial association indicators. The results reveal that the areas with high accessibility to health and education infrastructures and services are mainly located along the south-east and north-west gradient, while those with low accessibility are found in the south-west and north-east center. They also show high accessibility to trade services in the center of the study area.

Keywords

Two-Stage Floating Areas, Spatial Disparities, Local Spatial Association Indicators

1. Introduction

In this study, our main objective is to analyze geographical accessibility to basic infrastructures and services in the Niakhar area using a large-scale approach, the improved two step floating catchment area method and local spatial association indicators. The data used comes from the Niakhar demographic, soil and environmental observatory, geo-referencing of basic infrastructures and services, and the 2018 mobility survey.

Access to basic infrastructure and services is a factor in economic and social development, and an important dimension in combatting social and spatial disparities. However, this access is often subject to several constraints, including geographical accessibility. The requirements of agglomeration economies result in a high concentration of infrastructure and services in areas of high strategic value, to the great regret of the population living in areas of low strategic value. Compared with urban areas, rural municipalities generally have a low level of equipment of basic infrastructure and services. To address this situation, efforts have been made by the Senegalese government through projects for the construction of basic infrastructures and services in rural areas. However, it is not known whether this increase in the number of basic infrastructures and services resulted in a reduction in disparities in geographical accessibility.

Inequalities in geographical accessibility to basic infrastructures and services are often a source of political grievances, especially among the populations of poor communities. A more equitable spatial allocation policy for basic infrastructures and services has become a pressing necessity. To implement it, however, one must have knowledge of the social and spatial disparities in geographical accessibility to basic infrastructures and services at a precise spatial resolution. The question of geographical accessibility to basic infrastructure and services, for certain, has long been a concern for researchers. While some authors emphasize the density of infrastructure or services within an administrative unit [1], others focus on the closer access distance [2]-[5].

Distance is a barrier to access [6] that often causes inequalities in geographical accessibility. However, the distance unit is imperfect because it is a one-dimensional measure that does not consider the number and diversity of existing infrastructures and services [7]. The measurement of the density of infrastructures and services within administrative areas provides simple and practical indicators for public authorities. However, it does not take account of the potential interaction between infrastructure and services and the population across administrative boundaries, nor does it reveal spatial variations within administrative areas, which are often heterogeneous [8]. The gravity model, on the other hand, measures the effects of mass on interactions between zones. Given that this model depends on zoning, it does not provide a clear picture of social and spatial disparities as far as accessibility is concerned. Furthermore, subjective space is of great interest for the analysis of geographical accessibility, as it is laden with values and meanings that codify spatial practices [9] [10]. Fuzzy set logic is the most relevant approach for analyzing this type of space, as it allows for the formalization of uncertainty, subjectivity and imprecision [10]. We have excluded it from this study because it requires information that we do not have. Therefore, we chose to use the improved two step floating catchment area method as it allows for the consideration of potential supply-population interaction across administrative boundaries and highlights spatial variations in accessibility within administrative areas [11].

2. Material and Method

2.1. Study Area

Located in the department of Fatick, the Niakhar area comprises 30 villages in the communes of Ngayokhéme and Diarrére (**Figure 1**). Of a Sahelo-Sudanese type, its climate is characterized by two alternating seasons. In 2013, it had a population of 44,994, with a density of 222 inhabitants/km^2. It grew to 52,700 in 2021 with a density of 259 inhabitants/km^2.

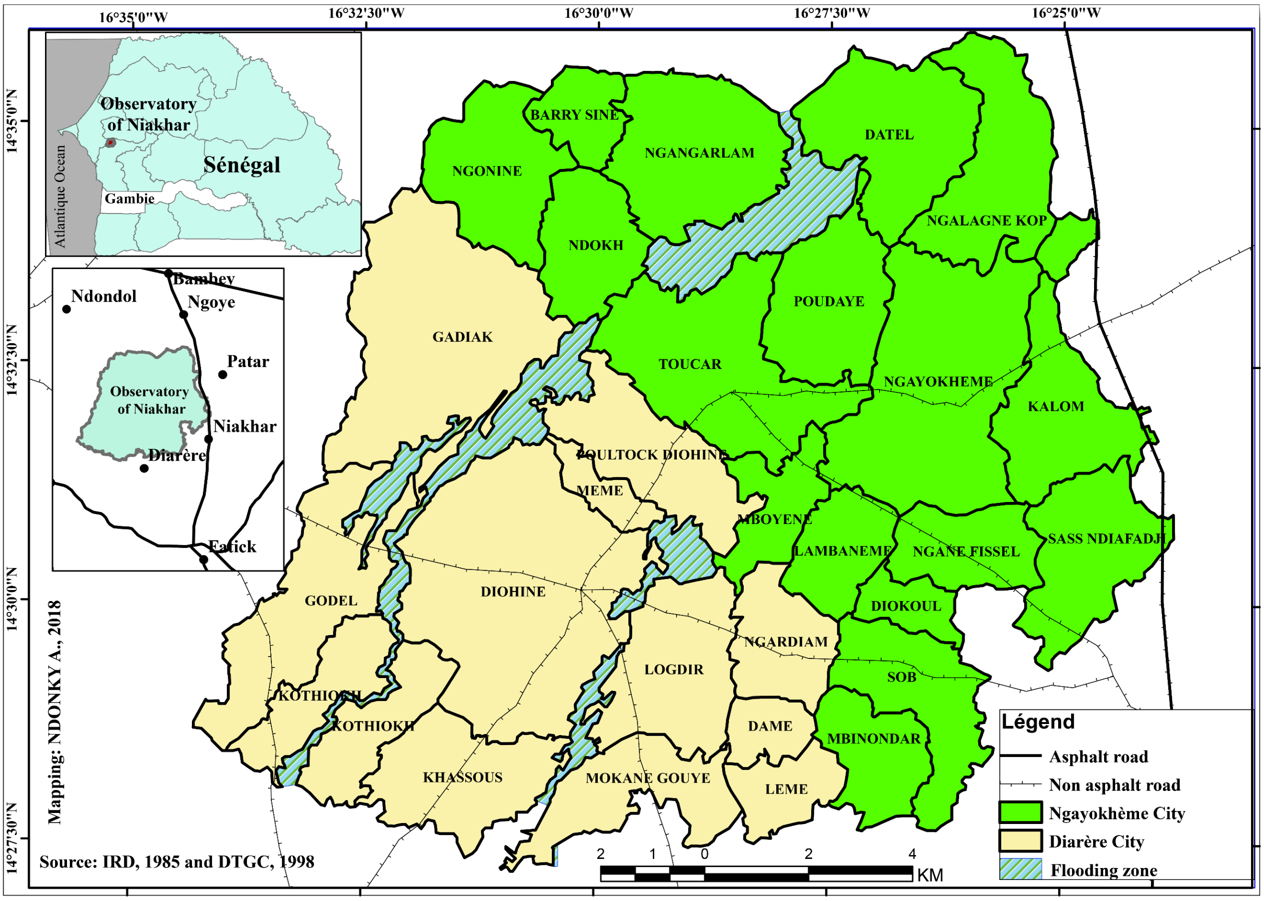


Figure 1. Presentation of the study area.

2.2. Definition of Concepts

2.2.1. Geographical Accessibility

Accessibility refers to the notion of an obstacle to accessing a service or infrastructure. Physical distance is generally used to qualify it as it allows for a more intuitive interpretation of the notion of obstacle itself. Accessibility is, therefore, considered to be an eminently geographical concept. However, the geographical dimension is insufficient in defining it, as accessibility also has socio-demographic, economic, cultural dimensions [12]. Accessibility can therefore be seen as a combination of several factors: attributes of populations, attributes of resource locations, attributes of resources to which access is available, distance between people's place of residence and the location of resources [13], quality of the transport network and functional partitioning of space [14] [15]. Even when used metaphorically, the concept of accessibility still has an important meaning, since it describes the difficulties or ease of access to places, resources or services [16]. It is therefore important to specify the perspective from which this concept is used. We are interested in geographical accessibility, especially because it measures spatial disparities in the coverage of basic infrastructure and services.

Geographical accessibility is often considered as a measure of distance or density of infrastructures or services within an administrative territory. It is therefore defined as a measure of proximity, the relationship between the location of infrastructures and services and the population's place of residence; this relationship must consider the mobility of the population, the time-distance and the travel cost [17]. A measure of friction that should reduce the level of service attendance as the distance separating them increases is defined as the ability of a place to be reached from other places in the geographical location [18].

In short, geographic accessibility is defined here as a measure that takes account of both distance and potential interactions between the provision of infrastructures and services and the populations expected to use them, as well as use value and scarcity.

2.2.2. Basic Infrastructure and Services

Basic infrastructures and services correspond to the basic facilities that underpin contemporary societies and are part and parcel of spatial planning and public service policies. They are foundational for the functioning of a society, as they are used daily by the population. These infrastructures and services include the following types: commercial (shops, markets, etc.), water (wells, public taps, boreholes, watering places for livestock), religious (mosques, churches), educational (Arab schools, nursery schools, primary schools, secondary schools), health (health boxes, health posts or dispensaries, pharmacies, etc.) and services (teleservices, mutual or savings credits, administrations, etc.).

2.3. Data and Data Collection

2.3.1. Types of Data Collected

Three types of data were collected: demographic data, geolocation of basic infrastructures and services data, and data on mobility and the use of basic infrastructures and services. The first type of data was collected during the six-monthly census carried out by the French Institute for Development Research (IRD). The IRD updates the Niakhar observatory database every six months. The second type was collected during the geolocation survey of basic infrastructures and services in the Niakhar area in 2018, again by the IRD. During this operation, the following information was collected: GPS coordinates, type, date of installation, status (functional/non-functional), name of the hamlet or village where it was installed, and use of infrastructures/services. The village chief was the respondent for this survey. The village chief was chosen because he is an authority and, as such, has a good knowledge of the village, particularly the infrastructure and services in his village. The third type was collected during a household sample survey. During this operation, we collected data on the location and frequency of the population's journeys, the use of basic infrastructure and services, the reasons for and duration of journeys, and the means of transport used. The target population consisted of households in the Niakhar area.

2.3.2. Sampling

Calculation of sample size

We conducted a cluster survey. As we did not know p, the minimum sample size was calculated using the following formula:

$$N = \left(t^2 * 0.25 * \text{deff}\left(1\right)\right) \big/ m^2 \quad \text{(adapted from [19])}$$

N: Minimum sample size for obtaining significant results for a given event and risk level;

t: Confidence level (the standard value for the 95% confidence level will be 1.96)

m: Margin of error (set at 5%);

deff: Clustering effect set at 2.34 and used to increase the sample size and compensate for the effects of cluster sampling on sample reliability.

The sample size is therefore 900 households.

Drawing up the sample design

The sample design describes the sampling methodology used. Its implementation is guided by respect for the differences in the social and cultural characteristics of the population in the study areas and the integration of the specific geographical (spatial) dimension of these areas. In fact, the Niakhar area is socially and spatially heterogeneous, and the meshes are interlocking. Overall, two criteria (constraints) guided the methodological choices. The first was to respect the socio-demographic diversity of the Niakhar zone. The Niakhar area reflects socio-demographic heterogeneity. Taking this heterogeneity into account ensures that the sample is socio-demographically representative. The second is to consider the heterogeneity of the rural area. The study area is socially and spatially very heterogeneous. To take this heterogeneity into account and map it at a fine resolution, it is important to take space into account in the sampling. The location of individuals can influence their practices, so it is important to consider it in the sampling. Another advantage of this method is that it saves on resources.

Definition and choice of sites

Only the smallest possible administrative grid in the Niakhar area (a hamlet allowing exhaustive statistical processing of the Niakhar area) can accurately measure the mobility and geographical accessibility to basic infrastructure and services. The hamlet is the smallest administrative unit in the Niakhar area, below the village level. It is often homogeneous from a socio-demographic and spatial point of view, due to its small size. Compliance with the constraints defined above led us to select 90 of the 166 hamlets (**Figure 2**). This ensures that the sample is more spatially representative.

Methods for drawing and selecting concessions, households and individuals

In the absence of an up-to-date sampling frame, the target population could not be identified by random sampling prior to the survey. However, the number of hamlets per village was chosen instead of the population size per village for two reasons. The first is that the number of hamlets per village is 99.68% correlated with the population size per village, and the second is because the study of geographical accessibility is carried out at the hamlet level to achieve a high level of accuracy. A random draw was therefore used at the following levels: Concession, household and individual, following rigorous procedures and guaranteeing the random nature of the draw.

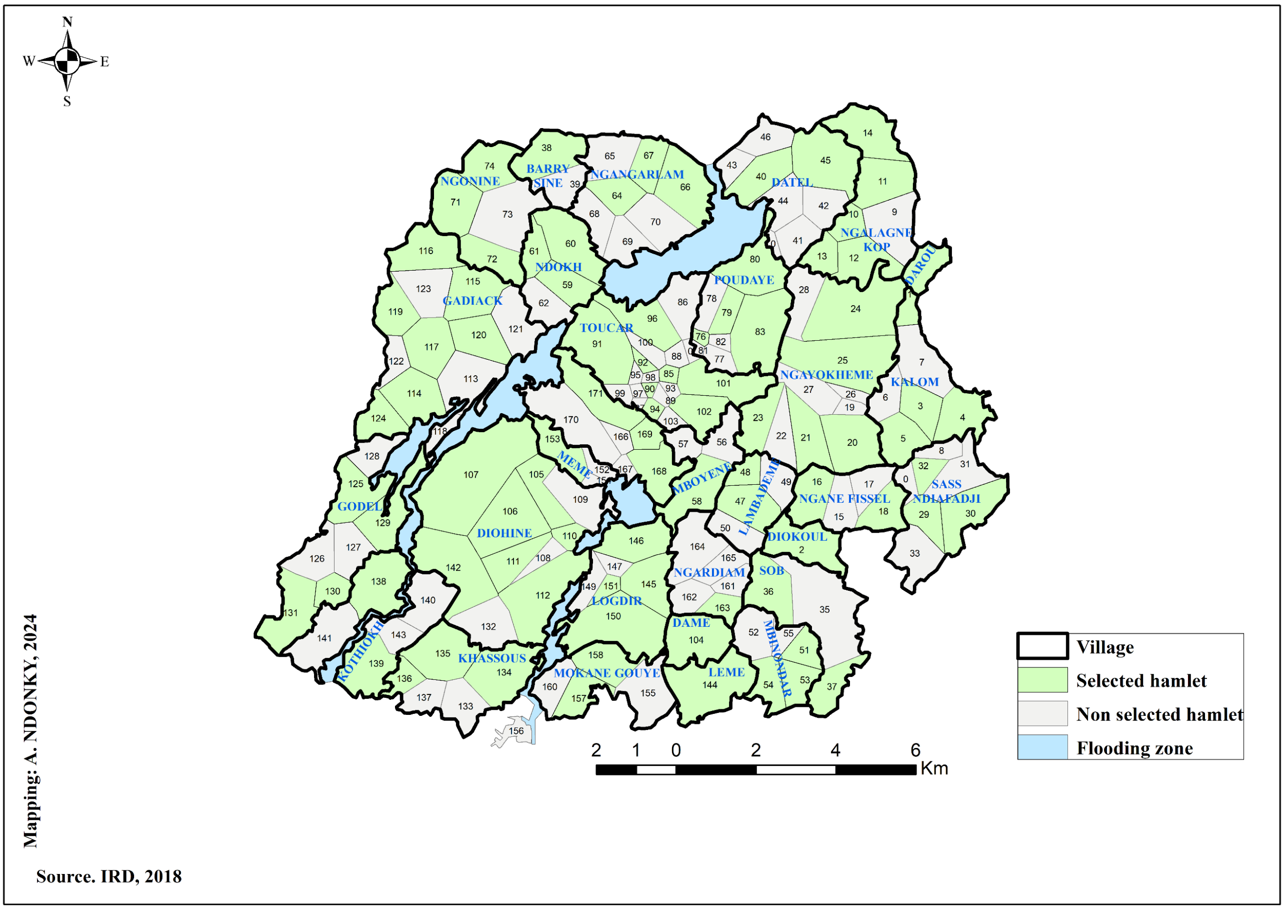


Figure 2. Hamlets selected for the investigation.

2.4. Data Processing and Analysis Strategies

2.4.1. Data Processing

Processing of the collected data began with data entry using CS Pro software, followed by purging the data to obtain a clean database. Spreadsheet software (Excel and SPSS) was then used to carry out a descriptive analysis of the data. The combination of the data obtained after the survey with the IRD database made it possible to set up a spatial database using geographic information system (GIS) software such as Quantum GIS and ArcGIS.

2.4.2. Method for Measuring Geographical Accessibility

Scale of accessibility measurement

Because of its often-large surface area and the generally heterogeneous spatial distribution of infrastructures and services, the village often conceals internal disparities. To measure accessibility more accurately, the hamlet level was chosen. This also allows us to capture the differences in access that exist within the village itself.

Selection of infrastructure and service sub-types based on weight calculations

To select the sub-types of infrastructures and services to be used to measure the geographical accessibility indicator, we calculated their weights. This calculation is based on the following criteria: spatial differentiation and frequency of use of facilities. Spatial differentiation makes it possible to focus on infrastructures and services that are only present in the study area and that differentiate the space as opposed to "ordinary" infrastructures and services (wells found everywhere in the area) that are easier to access. Frequency of use provides an indication of the sub-types of infrastructure and services to which the population has frequent recourse. This criterion is defined based on the number of times each sub-type of infrastructure and service in the zone is used. This reflects, in a way, the use value conferred on the infrastructure or service.

The results of the weight calculations show that the sub-types with a high use value and a high power of spatial discrimination are health posts, health boxes, primary schools, secondary schools and markets (**Table 1**). These have therefore been used to calculate geographical accessibility.

Table 1. Sub-types of infrastructure/services sectioned for the calculation of accessibility.

Types of infrastructures and services	Sub-types of infrastructures and services
Health facilities	Health posts
	Health boxes
School facilities	Primary schools
	Colleges
	High schools
Trade services	Marketplaces

Improved two step floating catchment area method for calculating geographical accessibility indicators

This approach was developed by [11] and adopted by [16]. It assumes that individuals located within the same area of attraction have the same level of accessibility relative to the reference point. Indeed, "the improved two-stage floating area method is a way of erasing these artificial breaks in geographical accessibility, which is a continuous phenomenon in space. This method makes it possible to consider the variability of the spatial distribution of population size within administrative boundaries, based on population data for small spatial units [16]. It also offers the possibility to take account of the potential interaction between population and infrastructures and services across administrative boundaries, by varying the radius of the theoretical circle of attraction of these infrastructures and services, and the differential accessibility within the area of attraction.

In the Niakhar area, the average surface area of hamlets is 1.15 km^2. To better reveal accessibility and provide a detailed and sound analysis of intra-zonal disparities in the coverage of basic infrastructure and services, it is important to use grids smaller than the hamlets. Although there is no consensus on the optimum size, the grids used in urban areas often vary between 100 m and 500 m square [20]. Given that the spatial distribution of the population is looser in rural areas, we opted for a 200 m grid. The data were broken down into these grids, multiplying the area of each grid by the population density of the hamlet containing it.

As infrastructures and services fall into different categories, these must be considered when calculating accessibility indicators, by assigning each category a specific weight and radius of attraction. This weighting involves choosing a basic category. The health box was chosen as the basic category. A weight of 1 was assigned to this category according to the criteria defined above. Still using the same criteria, a weight of 1.5 was assigned to the primary school, a weight of 2 to the college, a weight of 2.3 to the dispensary/health post and a weight of 2.5 to the high school and market.

As we had no information on the staffing of all the basic infrastructures and services, or the age-based structure of the resident population, we used the basic infrastructures and services/population ratio. This ratio is calculated in two stages. First, based on the geographical position of each basic infrastructure and service, all mesh centroids within the defined radius of attraction are found and the ratio of basic infrastructures and services to population within this radius is calculated. The initial ratios are then added together in the overlap zone (multi-attraction zone), where resident populations potentially have access to several basic infrastructures and services. This method is illustrated in **Figure 3**, which shows meshes, basic infrastructures and services, and two areas of attraction centered on basic infrastructures/services A and C. For example, let's assume that each mesh has a population of 1 and the basic infrastructures and services have equal weights, the range of trips to access basic infrastructure and service is 1000 m for all residents of the catchment area, and the friction of the distance is the same everywhere. In the first step, the basic infrastructures and services/population ratio is calculated for the meshes in the zone of attraction centered on basic infrastructure or service A, noted R1 = 2/9, and for the meshes in the zone of attraction centered on basic infrastructure or service C, noted R2 = 3/10. The ratio of basic infrastructures or services to the population of the meshes in the multi-attraction zone (R3) is calculated in the second stage, by summing the initial ratios: R3 = R1 + R2.

A minimum radius of attraction of 2000 m has also been assigned to this basic category. The choice of this radius is based, on the one hand, on the measurement of the average distance traveled to access infrastructure and services, which was 1,800 m in 2018, and, on the other hand, on the low capacity of users (young children) to travel long distances and the low weight of this category of infrastructure and service. Considering the differences in the weight of infrastructure and services, we have assigned a radius of 3200 m, 5000 m and 7000 m to the primary school, college and health post/high school/market respectively.

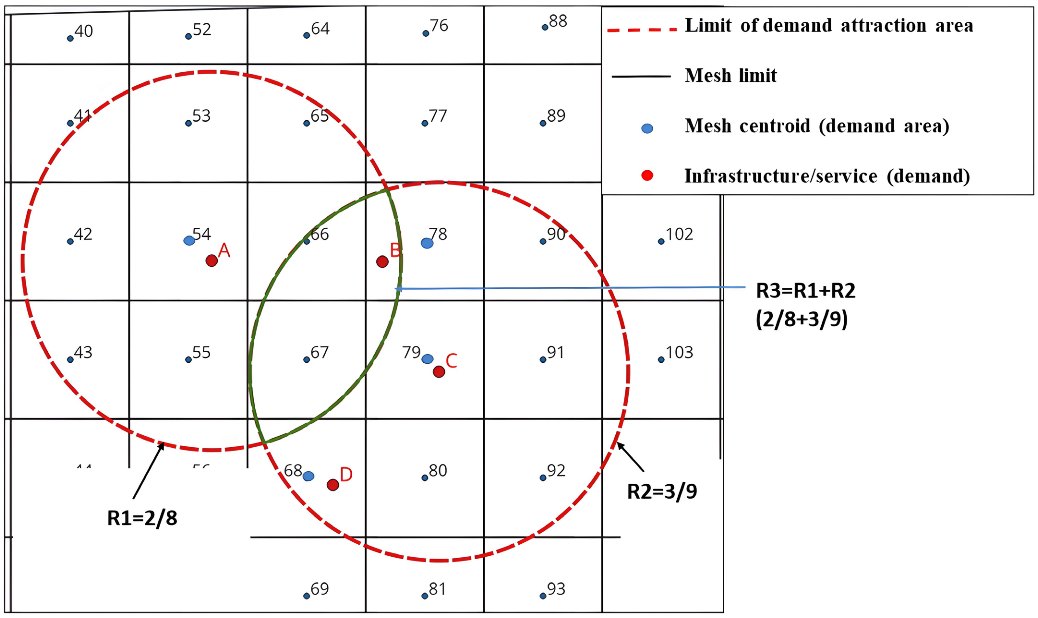


Figure 3. Two-stage floating area method (adapted from Luo and Wang, 2002b)

To obtain differential accessibility within each catchment area, we created 3 sub-areas for each category of basic infrastructure or service: (0 - 1200 m, 1201-1600 m and 1601 - 2000 m) for health boxes, (0 - 1600 m, 1601 - 2400 m and 2401 - 3200 m) for primary schools, (0 - 3000 m, 3001 - 4000 m and 4001 - 5000 m) for colleges, (0 - 5000 m, 5001 - 6000 m and 6001 - 7000 m) for markets, dispensaries and high schools. This discretized conception of distance decay is a reasonable approximation to the gravity model (which considers spatial interaction as a continuous phenomenon in space), because people are not concerned about these small differences in distance in their decision to use basic infrastructure and services [11]. Euclidean distance is highly correlated with the distance (length) of the shortest network or distance-time in urban areas [21] [22]. In addition, only one type of road, which is the unpaved track, is predominant in the Niakhar area. We therefore used the Euclidean distance.

The accessibility index is calculated using the following equation (**Box 1**).

Mapping the geographic accessibility

We are going to see in space the indicators of the geographical accessibility, on the one hand, and the other, measure the local spatial association between the different types of geographical accessibility indicators. The act of mapping is set for visualizing the indicators of geographical accessibility to basic infrastructures and services. The importance of this technique is to highlight spatial disparities in access to basic infrastructures and services at the level of the study area. To measure the local spatial association between the indicators of geographical accessibility to different types of infrastructure and services, we used the method of local spatial association indicators (LISA - [23]) in their bi-variate dimension, also called BiLISA. BiLISA measure the degree of spatial association between values of a variable in one location and values of another variable in its vicinity ([24] [25]).

$$R_j = \frac{S_{qj}}{\sum_{k\in(d_{kj\in} D_r)} P_k W_r^f} = \frac{S_{qj}}{\sum_{k\in(d_{kj\in} D_1)} P_k W_1^f + \sum_{k\in(d_{kj\in} D_2)} P_k W_2^f + \sum_{k\in(d_{kj\in} D_3)} P_k W_3^f}$$

(adapted from de [11]) (1),, Hence :

- P is the population of the mesh of the grid k located within the area of attraction (dkj Dr),
- Sqj, the number of infrastructures/services weighted by the weight of each infrastructure/service category (q) instead of j,
- dkj, the distance between k and j
- Dr, the nth sub-area within the attraction area (r=1-3)
- Wrf, the weight of the distance for the nth zone measured by the distance to infrastructure or service j weighted by the the distance problem f. Here this problem is equal to 1, because the Euclidean distance is used.
- Rj, infrastructure or service/population ratio weighted by the distance problem.
- Overlapping areas get the sum of all contributions (ratios) from overlapping areas.

In the second step, we searched for all infrastructures/services (j) located within the defined radius around this location i (catchment area i) for each location of population i, then added up the ratios infrastructure and services/population calculated in the first step, Rj, in these locations, as follows:

$$A_i^F = \sum_{k\in(d_{kj\in} D_r)} R_j W_r^f = \sum_{k\in(d_{kj\in} D_1)} R_j W_1^f + \sum_{k\in(d_{kj\in} D_2)} R_j W_2^f + \sum_{k\in(d_{kj\in} D_3)} R_j W_3^f$$

(adapted from [11]) (2), Henceforth:

-A_i^F, the accessibility of infrastructures/services for the population of the location i

-Rj, the infrastructure or service ratio of the location of the infrastructure/service within the attraction subzone centered around the population.

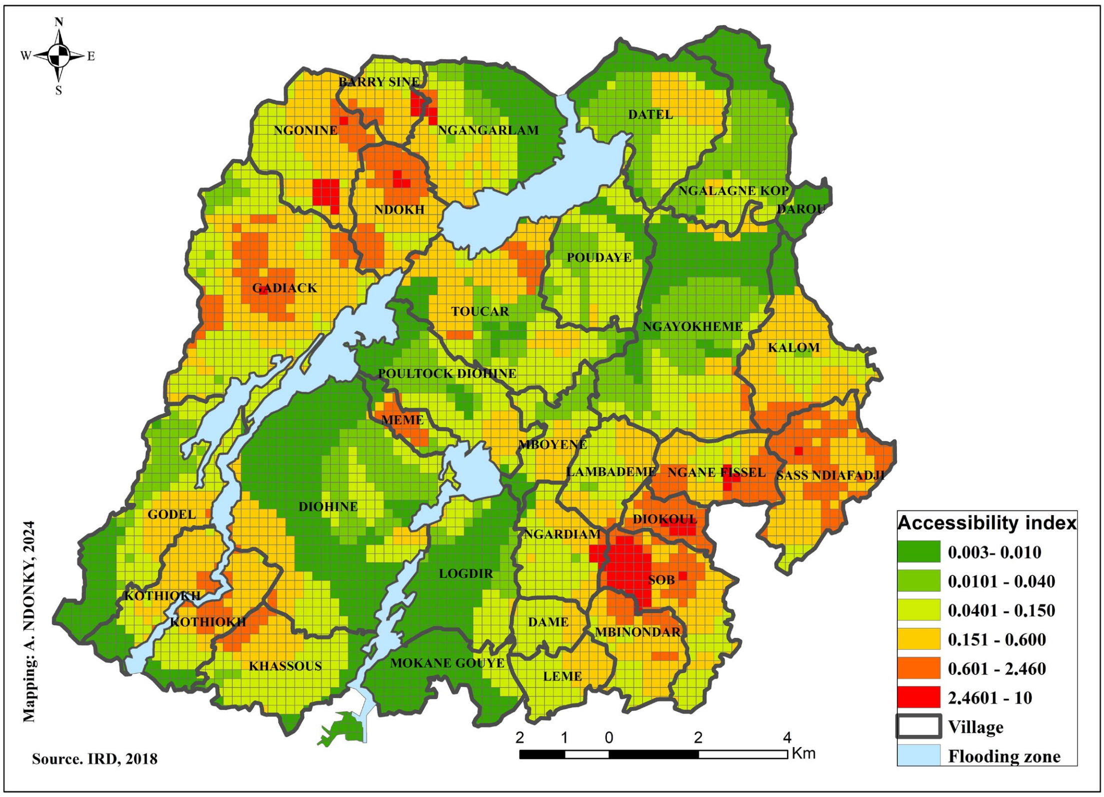
Box 1. Method for calculating the geographical accessibility index.

3. Presenting of the Results

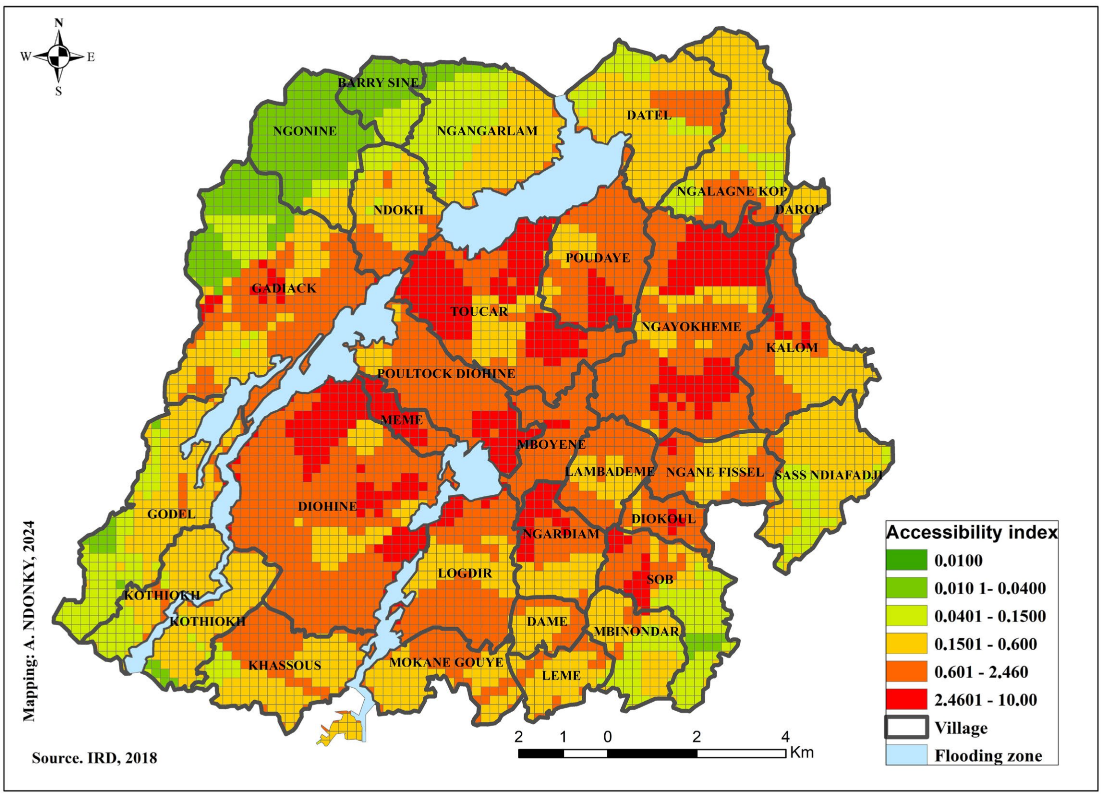
The results demonstrate disparities in geographical accessibility in space and according to the type of infrastructures and services. An analysis of the results by type of infrastructure showcases the following.

3.1. Widely Varying Levels of Access to Health Infrastructures and Services in Different Parts of the Country

The results show that accessibility indicators for health posts are generally higher than those for health boxes (**Figure 4**). They also show marked spatial disparities in geographical accessibility to health infrastructures and services (**Figure 4**). Areas of high accessibility to health boxes are located almost everywhere in the study area, but most markedly in the east and north-west (**Figure 4(A)**). These areas include the villages of Sob, Ngardiam, Ngonine, Diokoul, Ndokh, etc. On the other hand, the diagonal from the north-east through the center to the center-south has low levels of accessibility. The villages in this diagonal are Datel, Ngalagne Kop, Diohine, Mokane Ngouye, Logdir, etc. Health services are better covered overall, as the areas with the highest levels of accessibility are more numerous and larger (**Figure 4(A)**, **Figure 4(B)**). These areas are more prevalent in the center, particularly in Diohine, Mboyenne, Meme, Toukar, etc. On the other hand, the lowest accessibility indicators are in peripheral areas, particularly in the north-west (**Figure 4(B)**).



(A)



(B)

Figure 4. Accessibility of health infrastructure and services.

3.2. High Levels of Access to Trade Infrastructures and Services Concentrated in the Center of the Zone

In terms of accessibility to trade infrastructures and services, the areas with the highest levels of accessibility are found in the center, particularly in the villages of Poultok Diohine, Mboyene, Meme, Logdir, etc. (Figure 5). However, localities on the outskirts have low levels of accessibility. These include the villages of Ngalagne Kop, Ngonine, Godel, Sob, etc.

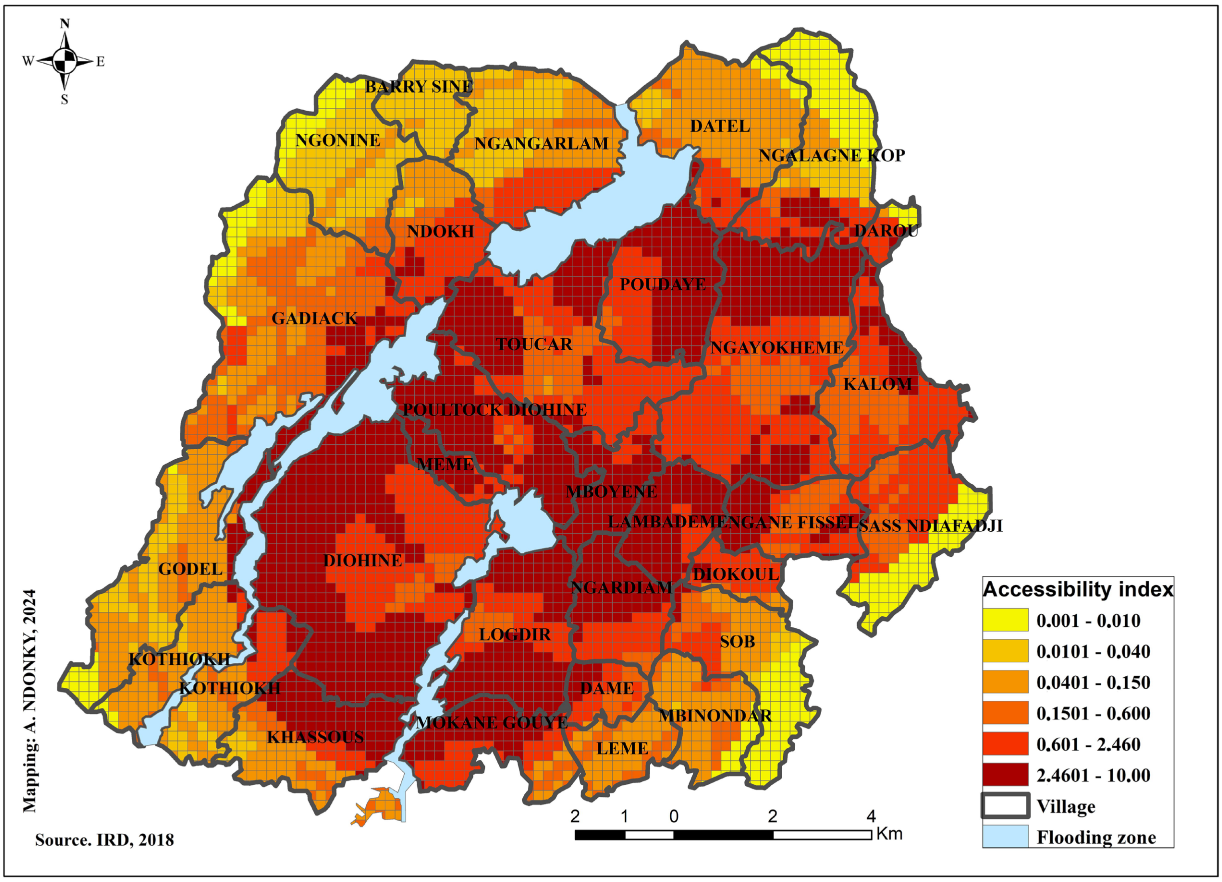
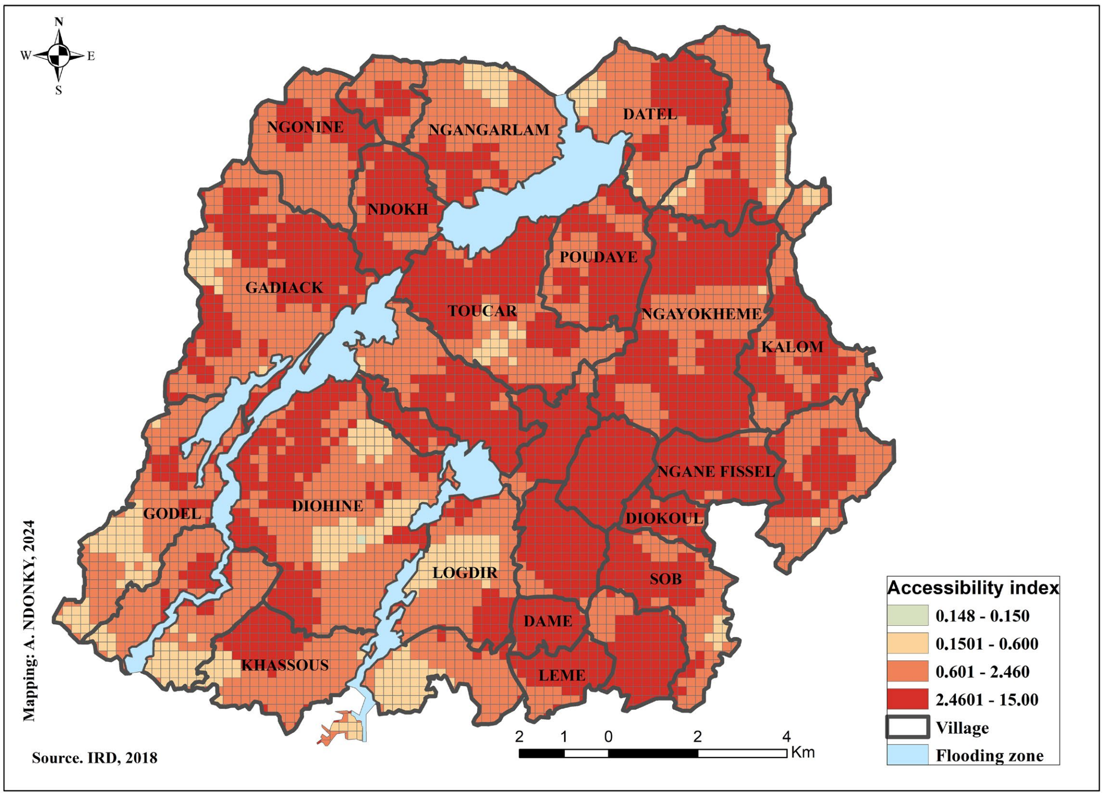


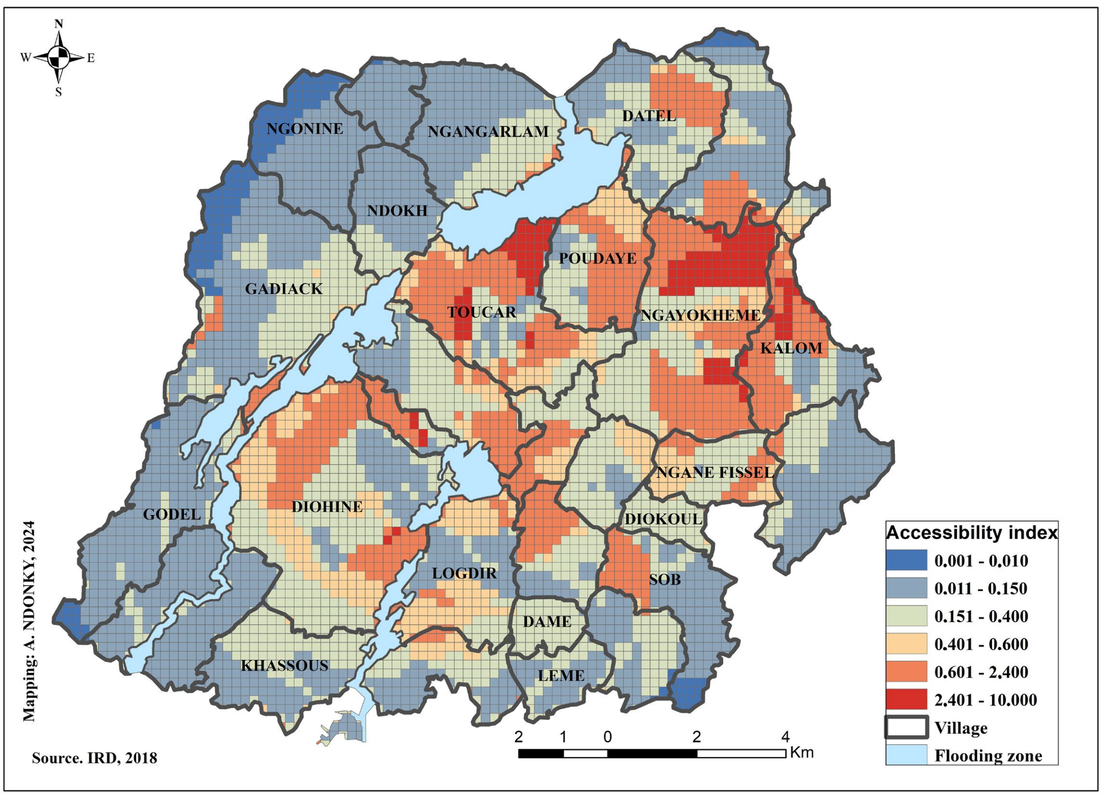
Figure 5. Geographical accessibility to commercial infrastructure and services.

3.3. A Very Uneven Access to School Infrastructure and Services

The results show strong spatial disparities in terms of geographical accessibility to school infrastructures and services. They also show that accessibility levels are generally higher for primary schools compared to colleges/high schools (Figure 6). Areas with high levels of access to primary schools are found almost everywhere, but more markedly in the center and center-east, particularly in the localities of Diokoul, Ngane Fissel. Areas of poor accessibility are found in the South-west. In terms of high schools/colleges, accessibility is highest in the center and center-east, particularly in Toucar, Ngayokeme and Diohine, Dame. On the other hand, the localities with the lowest levels of accessibility are to be found further to the north-west.



(A)



(B)

Figure 6. Geographical accessibility to school infrastructure and services.

3.4. Local Spatial Association between Levels of Accessibility to Different Types of Basic Infrastructures and Services

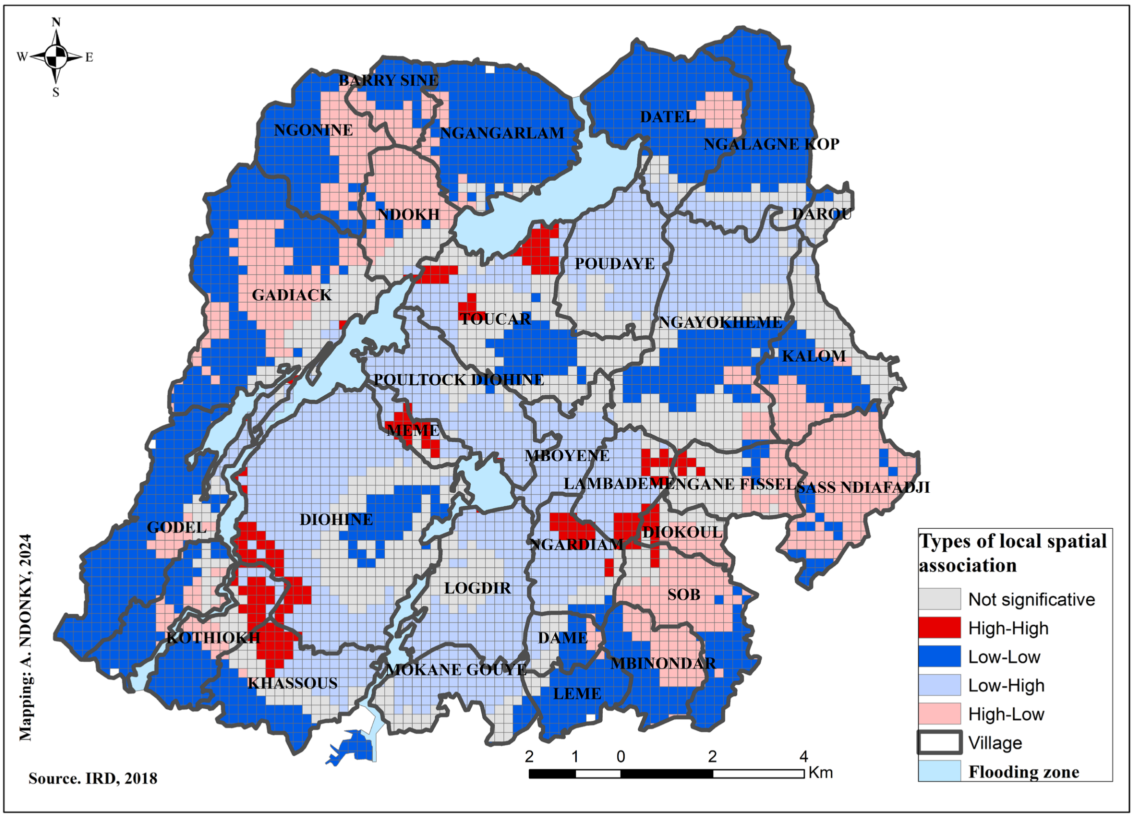
To highlight areas of high or low accessibility, we measured the local spatial association between levels of accessibility to different types of basic infrastructure and services. Only the first two types of local spatial association (high-high and Low-low) are of interest to us in this study. The results of this measurement allow us to make the following observations.

Figure 7 reveals the clusters of local spatial association between levels of accessibility to health infrastructures and services and levels of accessibility to school infrastructures and services. There is a greater presence of clusters of local spatial association of low levels of accessibility (zones of cumulative low accessibility). Clusters of local spatial association with high levels of accessibility (high accessibility accumulation zones) exist, but their presence is low.

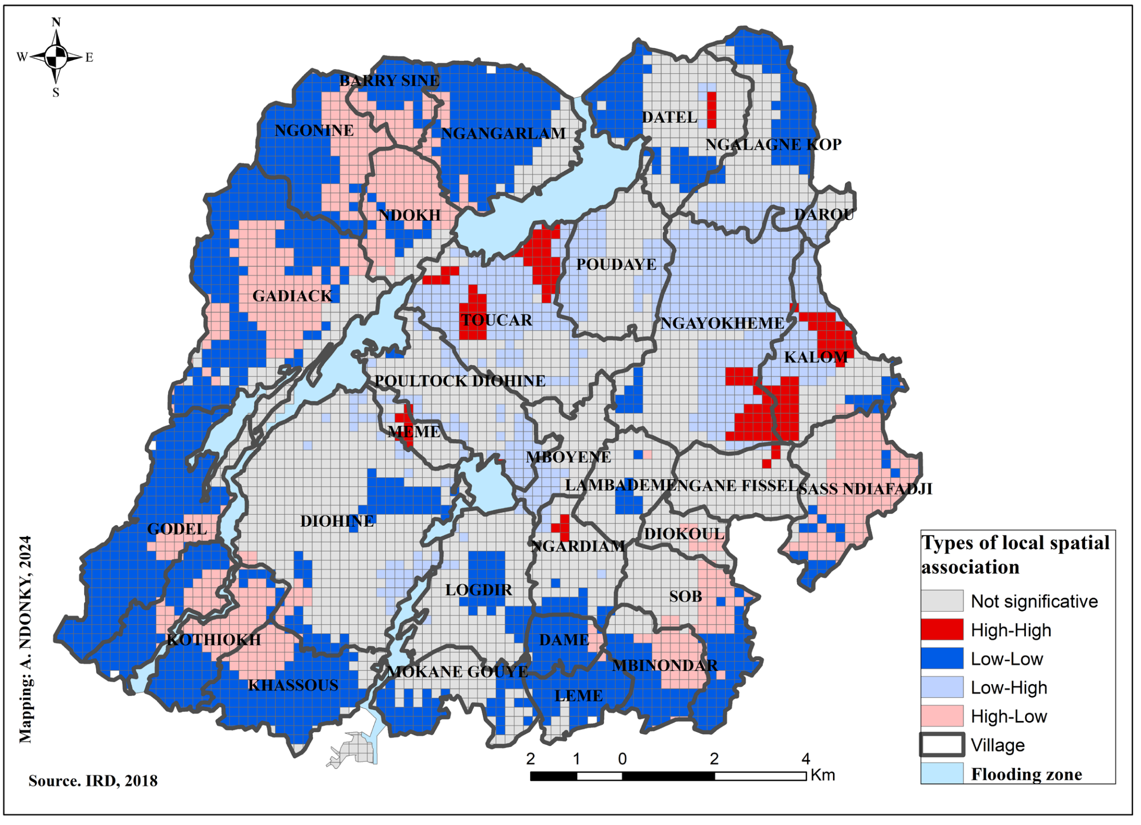
However, there are variations according to the type of infrastructure and services. Zones with high levels of cumulative accessibility to health boxes and primary schools are larger than those with high levels of cumulative accessibility to health boxes and secondary schools; they are found further east and south-east (Figure 7(A), Figure 7(B)). Zones with high levels of combined accessibility to health boxes and high schools/colleges are found more in the east and south-east. Zones with low levels of combined accessibility to health boxes and primary schools are found more in the north-east, center-south and north-west, while zones with high levels of combined accessibility to health boxes and high schools/colleges are found more in the north-west, south-west and south-east.

The results also show that the areas with high levels of combined accessibility to health posts and primary schools are more spatially dispersed than those with high levels of combined accessibility to health posts and high schools/colleges (Figure 7(C), Figure 7(D)). Almost the same thing can be observed regarding areas with high levels of low accessibility. Zones with high levels of accessibility to health boxes and secondary schools occupy vast areas in the north-west and south-west, and smaller areas in the south-east. On the other hand, areas with a combination of low accessibility to health centers and schools are almost non-existent in the south-east.

Figure 8 reveals a greater presence of clusters of local spatial association with low levels of accessibility, which are found more at the periphery of the study area. Zones of high accessibility are not very present compared to those of low accessibility. They are more markedly located in the center. However, there are differences between types of infrastructure and services. For example, the areas of high accessibility to health boxes and trade services are the least represented. The zones with high levels of combined accessibility to health boxes and trade services are the least represented, while zones with low levels of combined accessibility to health boxes and trade services and zones with high levels of combined accessibility to high schools/colleges and trade services are the most represented. Figure 8 highlights the clusters of local spatial association of health services and trade


BARRY SINE
NGONINE
NGANGARLAM
DATEL
NGALAGNE KOP
NDOKH
DAROU
GADIACK
POUDAYE
TOUCAR
NGAYOKHEME
KALOM
POULTOCK DIOHINE
MEME
MBOYENE
LAMBADEMENGANE FISSEL
SASS NDIAFADJI
GODEL
DIOHINE
NGARDIAM
DIOKOUL
LOGDIR
SOB
KOTHIOKH
DAME
MBINONDAR
KHASSOUS
MOKANE GOUYE
LEME
Mapping: A. NDONKY, 2024
Source. IRD, 2018
Types of local spatial association
Not significative
High-High
Low-Low
Low-High
High-Low
Village
Flooding zone
2 1 0 2 4 Km

(A)


BARRY SINE
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DATEL
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NDOKH
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POULTOCK DIOHINE
MEME
MBOYENE
LAMBADEMENGANE FISSEL
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GODEL
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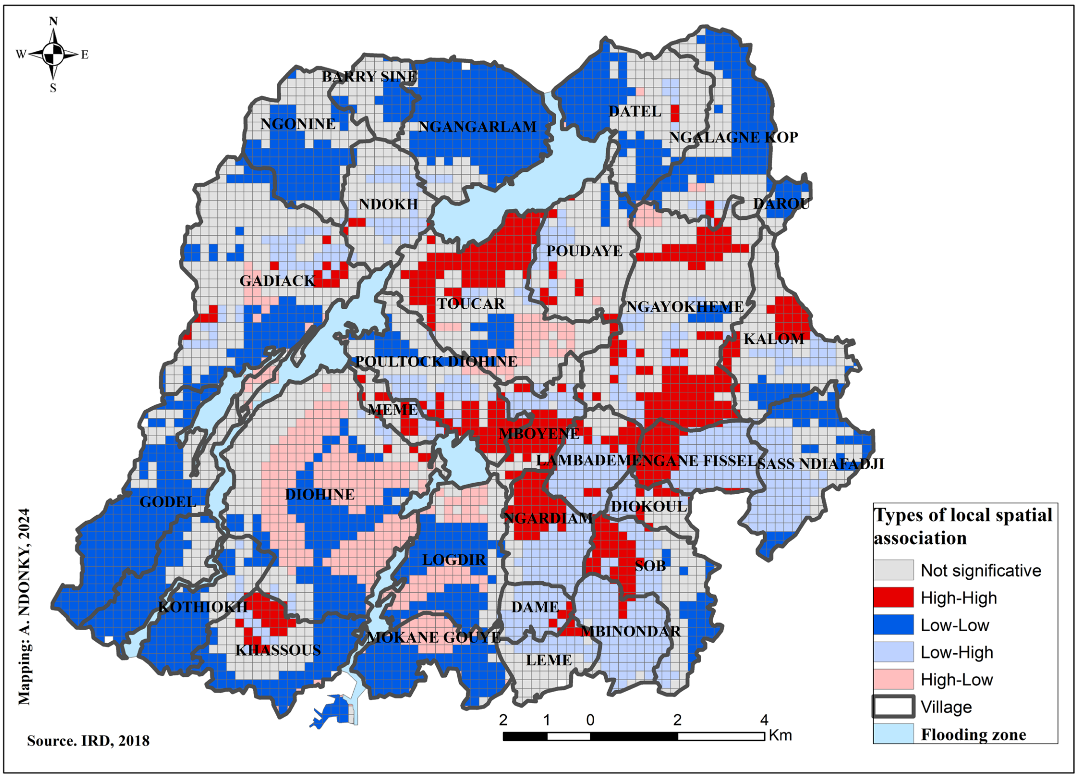
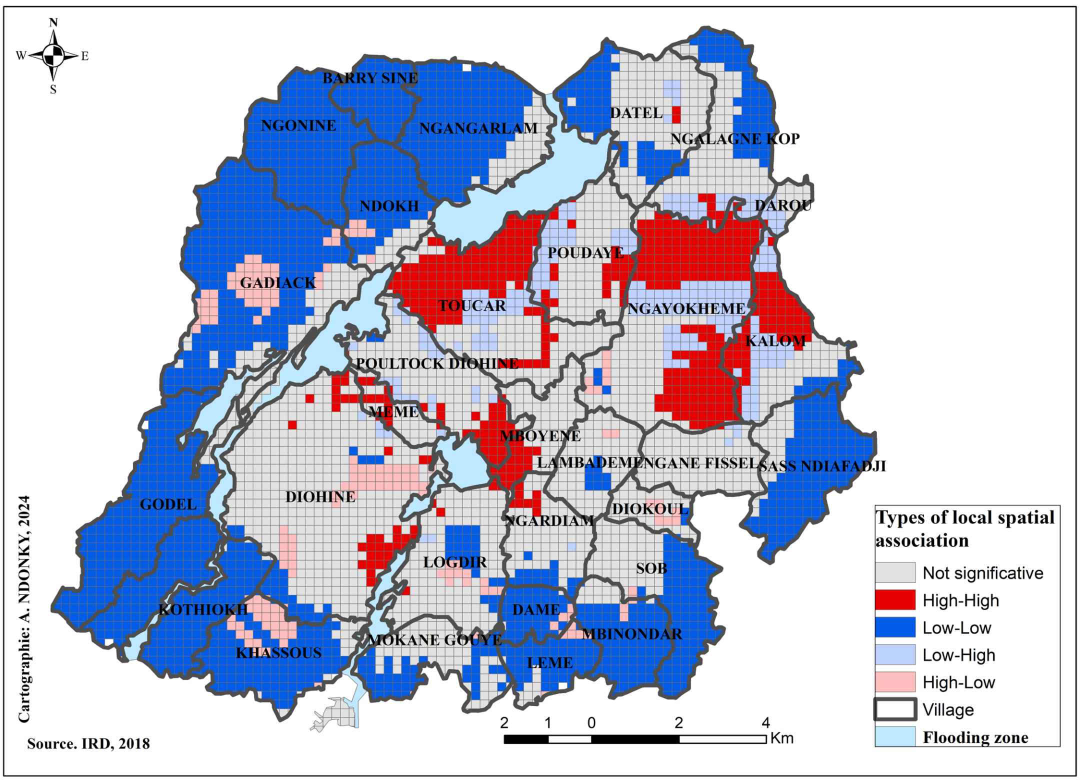
LOGDIR
SOB
KOTHIOKH
DAME
MBINONDAR
KHASSOUS
MOKANE GOUYE
LEME
Mapping: A. NDONKY, 2024
Source. IRD, 2018
Types of local spatial association
Not significative
High-High
Low-Low
Low-High
High-Low
Village
Flooding zone
2 1 0 2 4 Km

(B)

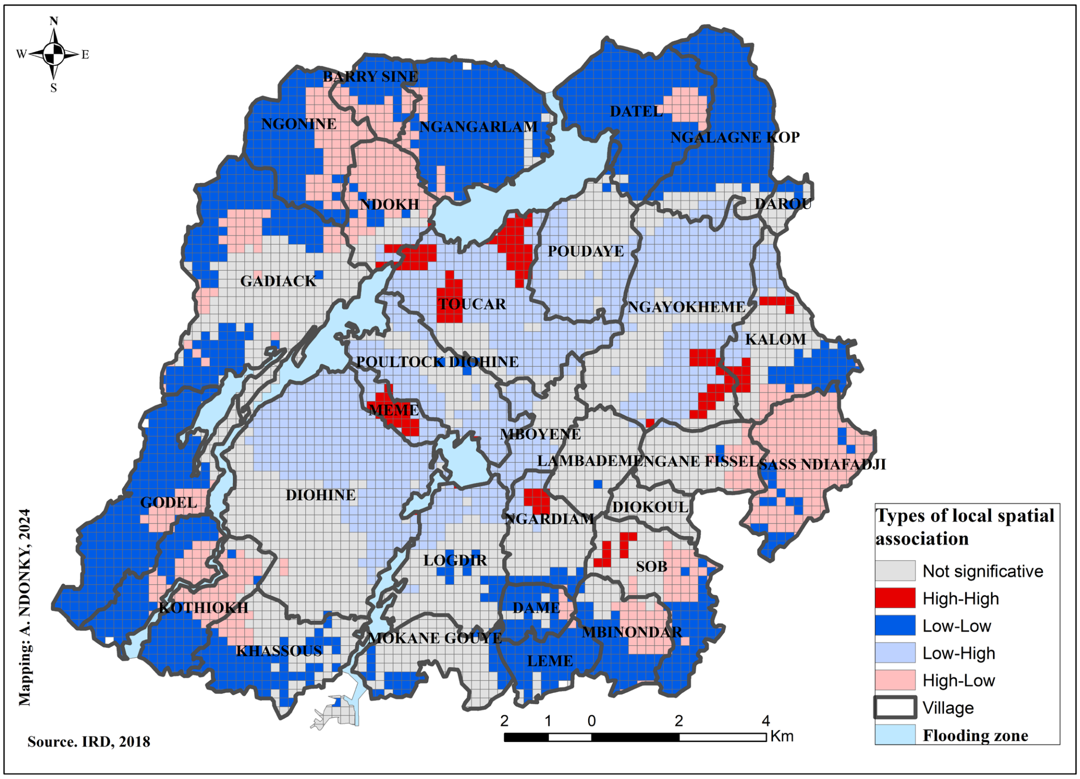


(C)

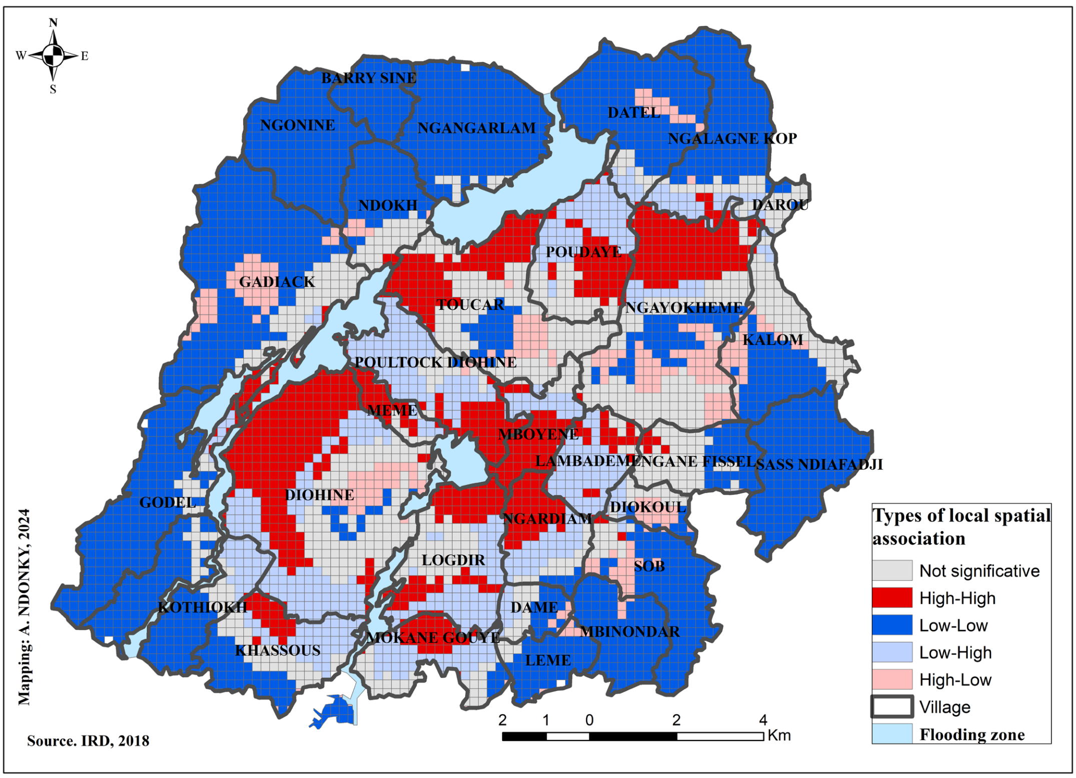


(D)

Figure 7. Clusters of local spatial association between level of accessibility to health and education infrastructure and services.

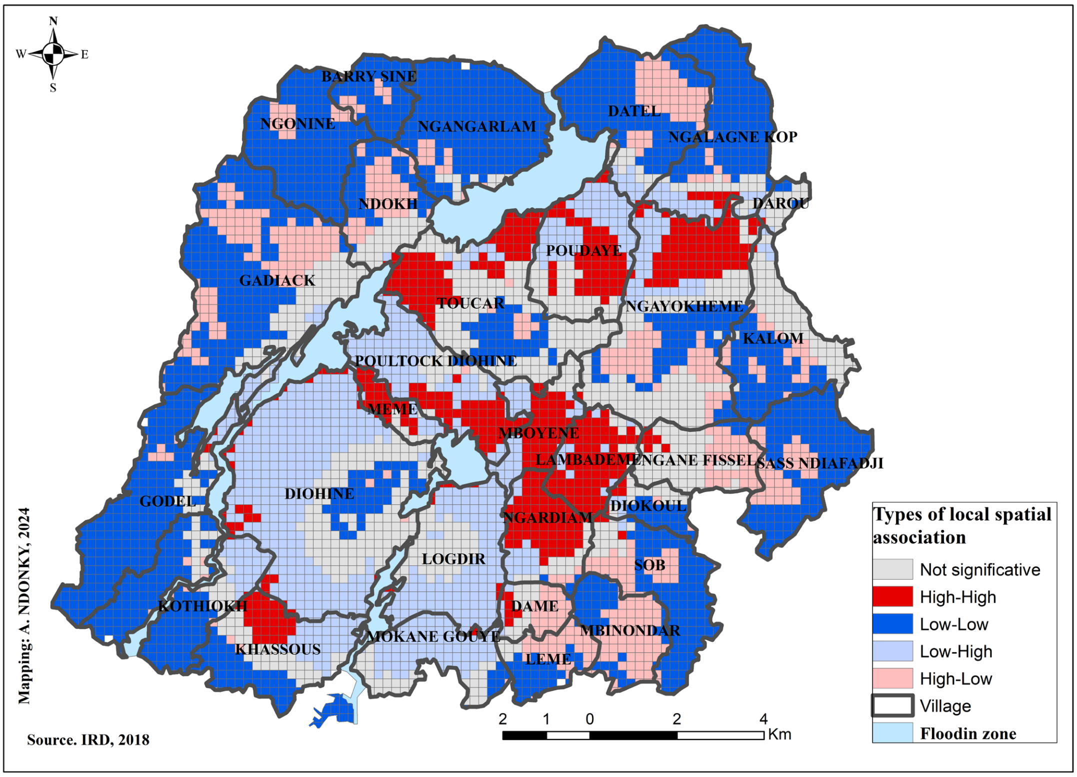


(A)

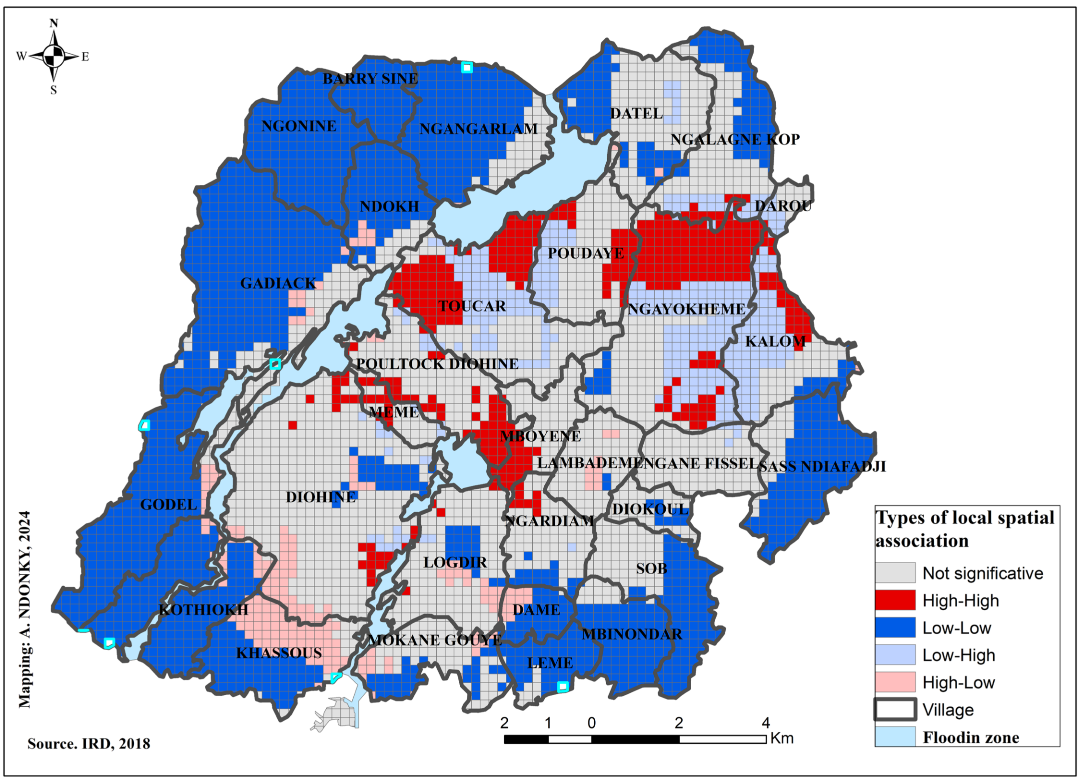


(B)

Figure 8. Clusters of local spatial association between levels of accessibility to health infrastructures and services and trade services.



(A)



(B)

Figure 9. Clusters of local spatial association between levels of accessibility to school infrastructures and trade services.

services. The clusters of high accessibility are more important between health posts and trade services and are found more in the center. Those of low accessibility are recorded further to the periphery.

Figure 9 shows the clusters of local spatial association of school services and trade services. Clusters of high accessibility between primary schools and trade services are found further in the center-east and center-north, while clusters of high accessibility between high schools/colleges and trade services are more recorded in the center-north.

We have drawn up the map below (Figure 10) to highlight the areas where there are high levels of accessibility to all types of basic infrastructure and services, and those where there are low levels of accessibility. On this map, we can see that the areas with low levels of access to all types of basic infrastructures and services are by far the largest, and are found mainly in the north and south-west. The areas with high levels of accessibility are located mainly in the center and are in the form of small, scattered clusters; these are very privileged areas, but they are few in number.

The other, more numerous areas are those where there is no combination of low or high accessibility to all types of infrastructure and services.

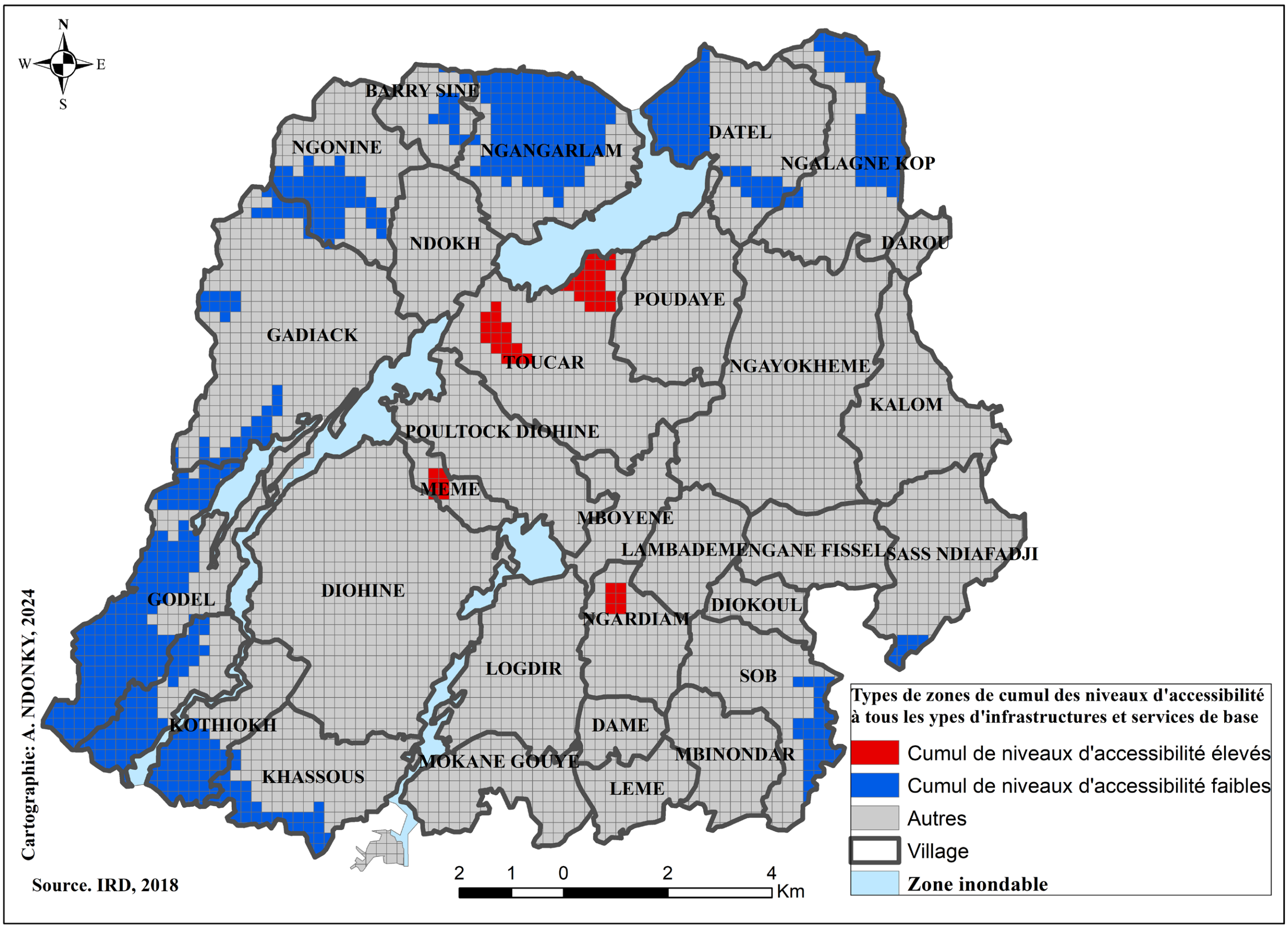


Figure 10. Types of cumulative accessibility levels to all types of basic infrastructure and services.

4. Discussion

Our results have highlighted major disparities in geographical accessibility to basic infrastructure and services, with areas of high cumulative accessibility found mainly in the center and areas of low cumulative accessibility located mainly in the north and south-west of the Niakhar area. Overall, they show little complementarity in the distribution of the various basic infrastructures and services. On the contrary, the different types of infrastructure and services tend to be stronger in areas of high accessibility and less present in areas of low accessibility.

In this study, we used the Euclidean distance. It can be thought that this may limit the accuracy of the measurement of the displacement impedance in a mainly rural environment with variable road conditions. However, the limitations related to the use of the Euclidean distance are negligible in this study. Indeed, the relief is very flat. Only one type of road, which is the unpaved track, is predominant in the Niakhar area. So the topographic and road conditions are not very variable in the study area.

Due to a lack of data, it has not been possible to consider the affordability, availability, quality of services, staff, and physical equipment needed for basic infrastructure and services. Yet, these dimensions often influence the level of attractiveness of infrastructures and services. However, the bias associated with this problem can be neglected, since the study focuses on potential accessibility, where the focus is on the location of demand and supply, and their interaction. Given that not everyone has the same capacity for mobility, nor the same mobility spaces, the use of a fixed radius of attraction for the entire population of the catchment area of an infrastructure or service can pose a problem. This bias, nonetheless, has been minimized by the fact that we have based our analysis on the average distance travelled by the population of the area. It should also be noted that, for a lack of data, the effects of centrality, edge and spatial organization of activities, and the effects of competition between infrastructures and services could not be explicitly considered.

Given the type of accessibility measured (potential accessibility) and the methodology used, these limitations can be considered negligible. Our results, therefore, have a certain validity that allows them to be compared with those of others.

To our knowledge, this type of study has never been carried out in the Niakhar area, which makes it difficult to compare its results with other studies on the same subject in this zone. Nevertheless, we will compare our work with studies carried out elsewhere. In this way, our results can be compared with those of [16] [26] [27], who also found that areas with poor access to health facilities are mainly found on the outskirts. Also, using the floating area method, [28] showed that accessibility to maternity facilities is higher in the center than in the periphery. Furthermore, the work of these authors, like ours, revealed that the different types of infrastructure do not complement each other spatially, but rather tend to reinforce each other in areas of high geographical accessibility.

The results of a study of [29] on the analysis of the level of access to social services in Senegal reveal strong disparities between regions. Accessibility was measured at a very low spatial resolution (regional level), thus limiting the precision of the measurement. In addition, the form of distribution of social services and the population supposed to use them, as well as the interaction between the two, were not taken into account. The results of the study of [30], like ours, highlighted spatial disparities in terms of accessibility to health infrastructures in Senegal. However, from a methodological point of view, there are differences between the two. Indeed, the author of this study used too low a spatial resolution (region and health district) and the Radius Token Action Theory to measure geographic accessibility. This method only uses the area of the zone and the number of health infrastructures in this zone. It does not take into account the way in which supply and demand are distributed in space, nor the interactions between the two.

This comparison highlights the similarity of the forms of spatial inequality in the coverage of basic infrastructures and services in areas that are nonetheless located in different historical and geographical contexts. It can be said that the location of basic infrastructures and services in rural areas is generally subject to the same socio-economic logic and the same spatial constraints, whatever the area. From a methodological point of view, our study, compared to these studies, provides more precision in the measurement of geographical accessibility, by taking into account the form of spatial distribution of demand and supply of service, as well as the interaction between the two.

There is a contrast between a center with more infrastructure and a periphery with less. This is because the largest villages, notably Ngayokheme, Toucar and Diohine, are in the center. Given their size, these villages concentrate on the economic, commercial, administrative and accessibility functions that distinguish them from the others, with which they have a dominant relationship.

Our results may be useful for policies on the spatial allocation of resources and the fight against spatial inequalities. Indeed, with the development of geographic information systems and spatial analysis, the methodology for measuring geographic accessibility has become a popular tool in spatial planning policies. It makes it possible to consider, in particular, the availability of infrastructures and services, spatial variations in the distribution of the population, the interaction between this offer and the population, the decreasing effect of distance, independence from the administrative grid, and to highlight spatial disparities at a very fine spatial resolution [16]. This is what the improved two-stage floating area method has made it possible to do in the Niakhar area and to produce information useful for correcting spatial inequalities in geographical accessibility to basic infrastructures and services. For example, the zones of cumulative accessibility levels to all types of basic infrastructure and services can be defined as priority intervention areas in terms of struggling spatial inequalities. Better identification and targeting of priority intervention areas is very important, especially in the context of scarcity of resources which characterizes rural Senegal.

However, in the process of spatial allocation of basic infrastructure and services, these results must be interpreted with care, since our study focuses on potential accessibility and not actual accessibility. Actual accessibility (use of supply) also depends on other factors, such as the functional organization of space, the effects of spatial competition and non-spatial aspects not considered in this study.

5. Conclusions

Our results show disparities in geographical accessibility to basic infrastructures and services, revealing differences in the strategies of socio-economic players in terms of the location of basic infrastructure and services in the study area, and levels of spatial value. In the specific case of the Niakhar area, our study has made a definite contribution to our knowledge of the geographical accessibility of basic infrastructures and services in the area. Our results may be useful for spatial planning and resources allocation policies.

This work represents a definite methodological advance, since it is based on an approach that combines spatial and demographic factors, producing rich results. This methodological approach can therefore be applied to other areas in Senegal and Africa to produce very fruitful comparisons.

This study is a stimulating first step in the analysis of geographical accessibility to basic infrastructure and services. However, there is still room for improvement if we are to gain a better understanding of this phenomenon. Our study opens up a number of avenues of research: 1) The inclusion in the analysis of basic infrastructure and services close to the boundary of the study area but outside it, 2) the inclusion of travel time and cost, 3) the condition of roads to refine the analysis of geographical accessibility to road transport, 4) the development of a typology of areas of geographical accessibility to basic infrastructure and services.

Conflicts of Interest

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

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