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Hierarchy of Rural Localities in the Niakhar Area (Fatick, Senegal)

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Abstract

Although the study of the hierarchy of localities presents an important social and economic stake, studies focused on the hierarchy of rural localities are relatively weak, especially in Africa. It is important to highlight the hierarchy of rural areas in order to reveal poles that can support sustainable growth. Our main objective is to study the hierarchy of rural localities in the Niakhar area, using a geographic approach. The data come from the Niakhar demographic, epidemiological and environmental observatory database and the Niakhar Atlas project of the French Research Institute for Development (IRD). The net flow method, the primacy index, the median population threshold method and the measurement of the correlation between level of centrality and population size are used to analyze the data. Our study allowed us to determine the main types of centrality and to establish the hierarchy of rural localities in the Niakhar zone. It also highlighted the strong correlation between the rank of localities and the size of the population of the latter. The main contribution of our work is to have highlighted, in order, the structuring localities of the rural space of the Niakhar area, by combining several indicators of centrality.

Keywords

Hierarchy, Rural Localities, Centrality, Population Size, Service Functions, Attractiveness

1. Introduction

With the development of transport networks, a strong growth in mobility and

exchanges is currently observed at a global level [1]. Correlatively, spatial disparities in the distribution of resources (infrastructure, equipment and basic services) have increased the mobility needs of populations [2]. In addition, rural equipment projects stimulate socio-economic development, particularly of rural people. Socio-economic growth and mobility lead to an increase in the hierarchy of localities.

The hierarchy of localities is the product of their centrality. The centrality of an area is equal to the surplus of its importance, which is equivalent to the relative importance of this place compared to the region (zone) to which it belongs [3]. It is the result of the quality and quantity of central functions provided by a place. The hierarchy of places is closely linked to the central functions. The study of the hierarchy of localities presents an important social and economic challenge. Indeed, the development of the locality hierarchy is the best way to assess and determine the localities that can bear sustainable economic growth and reduce mobility needs [4].

The Senegalese rural environment, in particular the Niakhar area, is not free of mobility growth [5] and rural exodus [6]. Mobility can strengthen or weaken the attractiveness localities. In addition, the populations of under-equipped areas tend to move towards those which are better provided with equipment and services. Mobility is therefore both a factor and an indicator of spatial inequalities in terms of infrastructures and services. As for the rural exodus, it empties certain localities of their population and leads in the long run to the disappearance of some basic equipment and services, thus reinforcing the isolation and under-equipment of the latter.

To curb the rural exodus, it is important to strengthen existing centers or create new ones, by increasing the number of facilities and services and by stimulating creativity and innovation. In addition, rural development policies can rely on these centers to reduce spatial economic imbalances and spatial disparities in the allocation of basic amenities and collective services. For that, it is necessary to know the hierarchy of the localities, in particular the central places of the zone of Niakhar that can support sustainable development. The study of the hierarchy of rural areas, therefore, presents an important local development challenge for the Niakhar area.

Certainly, there are many studies on the hierarchy of rural localities. The works of ([4] [7] [8] [9]) can be cited. However, studies focusing on the hierarchy of rural Senegalese localities were not very well known. In the specific case of rural areas in the Fatick region to which the Niakhar area belongs, this study was not aware of any studies on this subject.

This work is thus interested in the hierarchy of rural localities, based on the fundamental concept of centrality in rural areas. Centrality can be defined in several ways. If some authors like [10] define it as a central position, that is to say, the capacity of polarization of space, others like [11] consider it as the capacity of organization and structuration of space and human activities. As for

[12], they specify that centrality is a combination of economic, political, administrative and social activities. For authors like [13], centrality refers to the notion of density, because the latter maximizes social interactions, and promotes functional diversity, fundamental to social space. It can also be considered as a gathering place ([14] [15]), a symbolic place [16].

However, in this study, centrality is considered as the combination of population size, attractiveness and service functions. That choice was made for the following reasons. The first is that these factors (population size, attractiveness and service functions) are those that are often mentioned in the literature reviewed. The second is that these dimensions make it possible to properly measure the capacity of localities to structure and organize the space of our study area. Moreover, these dimensions are easily measurable and mappable. Finally, the third reason is the availability of the necessary data at the scale of the study area.

Thus the hierarchy of rural areas is considered here as the arrangement of rural localities in a given area in a certain order of importance based on population size, range and number of services provided by the locality (village) and area influence of that locality. In other words, the hierarchy of localities is treated here as the configuration of places following an order determined by the combination of factors relating to population size, attractiveness and service functions.

To reveal the places that structure and organize the rural space, the study proposes to highlight the hierarchy of the localities on the scale of the Niakhar zone. So several questions arise. Is the space of the Niakhar zone polarized by one or more center(s)? How strong is the relationship between rank and locality population size? Is it the same throughout the space of the Niakhar area?

To answer these questions, the following assumptions were made. There are several central places in the Niakhar area, and also that there is a strong link between the rank and the size of the locality and that its intensity varies in the space of the Niakhar zone.

To verify these hypotheses, the study set itself the main objective of studying the hierarchy of localities in the Niakhar area. These include revealing the central places, the less important places, on the one hand, and determining the intensity of the relationship between the rank and the population size of the locality, as well as the variation of the latter in space, on the other hand. In order to achieve this objective, a structured approach in three major steps was adopted. The first consisted in determining the different indicators of centrality. The second stage made it possible to determine the hierarchy of localities. The third consisted in measuring the correlation between the level of centrality and the population size of localities.

The data come from the Niakhar demographic, epidemiological and environmental observatory database and from a survey carried out in 2018, as part of the Niakhar Atlas project of the French Institute of Research for Development.

For data analysis, four methods were used. The first one is the method for calculating net flows to determine the attractiveness of localities. Then, the use

of the median population threshold (MPT) defined by the method of Reed Muench [17] made it possible to measure the service functions of the localities. The calculation of the proportion of the population was decisive in evaluating the demographic weight in the measurement of centrality. Finally, the Pearson correlation coefficient was used to verify the relationship between the level of centrality and the size of localities.

2. Material and Method

2.1. Study Zone

The Niakhar area is located in the northern part of the department of Fatick (Fatick region), between 14˚28'59"N latitude and 16˚23'59"W longitude. It is bounded to the north by the department of Bambey (region of Diourbel), to the west by the department of Mbour (region of Thies), to the south by that of Fatick and to the east by the municipality of Patar. This area includes 30 villages divided between the municipalities of Ngayokhéme and Diarrére (**Figure 1**). In 2013, the population was 44,994 inhabitants, with a density of 221.6 inhabitants/km^2 [1]. This population is very young, since young people under the age of 20 accounted for 53% of the total population.

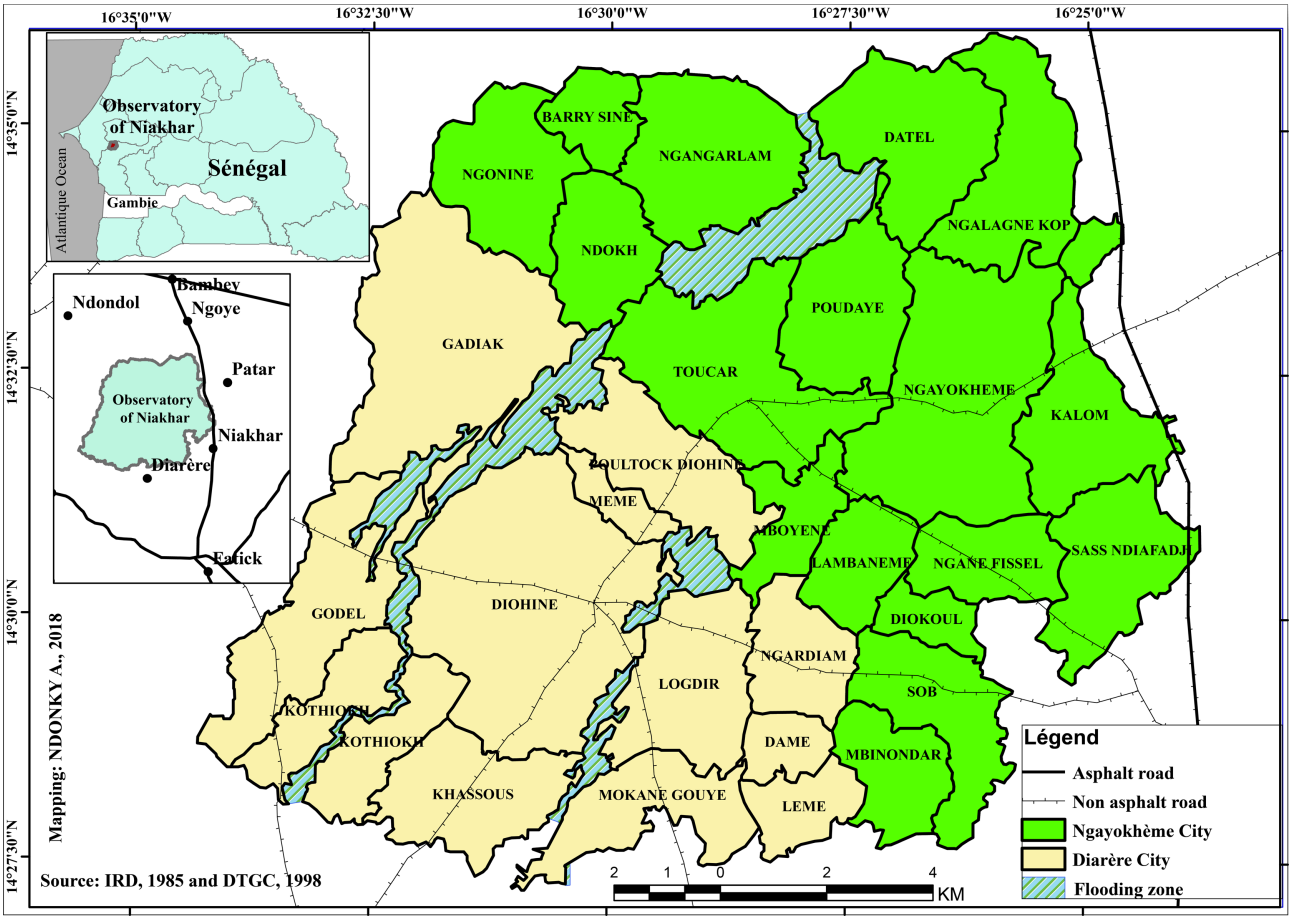

Figure 1. Presentation of the study area.

2.2. Data

The study used geolocation data for basic equipment and services, and from the rural mobility survey carried out by the IRD and from the database of the demographic, epidemiological and environmental observatory of Niakhar. With regard to data from the Niakhar demographic, epidemiological and environmental observatory database, the IRD conducted a census of the population, housing and agriculture. This allowed him to set up a database. This database is updated every 6 months by a team of IRD investigators who visit all households to provide information on all changes that have occurred during the last 6 months preceding the last update survey. The tool used for the update is the questionnaire.

Geolocation data for basic equipment and services was collected in 2018 during a survey where the geographical coordinates and characteristics of all equipment and services were entered. Thus, a collection sheet has been developed in order to collect all this information for each equipment or service.

Regarding the survey on mobility, the paper carried out a sampling plan taking into account the differences in social and cultural characteristics of the population of the study areas and the spatial dimension specific to these areas. Indeed, there is a social and spatial heterogeneity of the Niakhar area and an interlocking of meshes (commune, village and hamlet). The use of the finest mesh offered by the administrative network of the Niakhar area (hamlet allowing an exhaustive statistical treatment of the Niakhar area) was necessary to better understand this heterogeneity. Located below the village mesh, the hamlet is the smallest administrative unit in the Niakhar area. Therefore, it is often homogeneous from a socio-demographic and spatial point of view.

The number of people to be surveyed is essentially based on the proportion of people aged 6 or over who move outside their village of residence. Since this proportion is unknown, the following formula was used to determine the sample size:

$$n = D * 0.25 * t^2 / e^2 \quad (1)$$

adapted from [18]; where:

n = sample size of people aged 6 and over;

D = sampling effect set at 2.5;

e=margin of error set at 5%;

t^2: 95% confidence level corresponding to 1.96.

The result gives a minimum total sample size of 884 individuals. In order to increase the power of the test, the total sample size was raised to 900.

After determining the sample, a questionnaire survey of households in the study area was conducted.

Given the absence of an updated sampling frame, it was not possible to identify the target population by random selection before the survey. To solve this problem, a multi-stage cluster sampling was carried out. Each hamlet is defined as a cluster. In addition, a random draw at the following levels (hamlet, household and individuals), was used following rigid procedures and preserving the

random nature of the draw. In the first degree, the study randomly selected the hamlets, 90 in total. In each hamlet, 10 households were selected and in each household only one individual was randomly selected for the survey. The spatial distribution of the selected hamlets is shown in Figure 2.

The data collected during the survey relate to the socio-demographic characteristics of the household and the individual surveyed, the places, means and trip purposes (during the last 30 days preceding the survey). This survey was conducted in 2018.

2.3. Data Processing and Analysis Strategies

While the statistical processing of the data collected was done using CS Pro and Stata software, geo-processing, cartography and spatial analysis were carried out through ArcGIS, Philcarto and Quantum GIS software. Four methods have been used for data analysis: measurement of net flows, determination of the median population threshold and measurement of the correlation between the centrality level and the demographic weight.

The calculation method of net flows allowed the measurement of the attractiveness of localities. Thus, an attractiveness index was calculated for each village by relating, for each of them, the balance of flows to the total volume of flows.

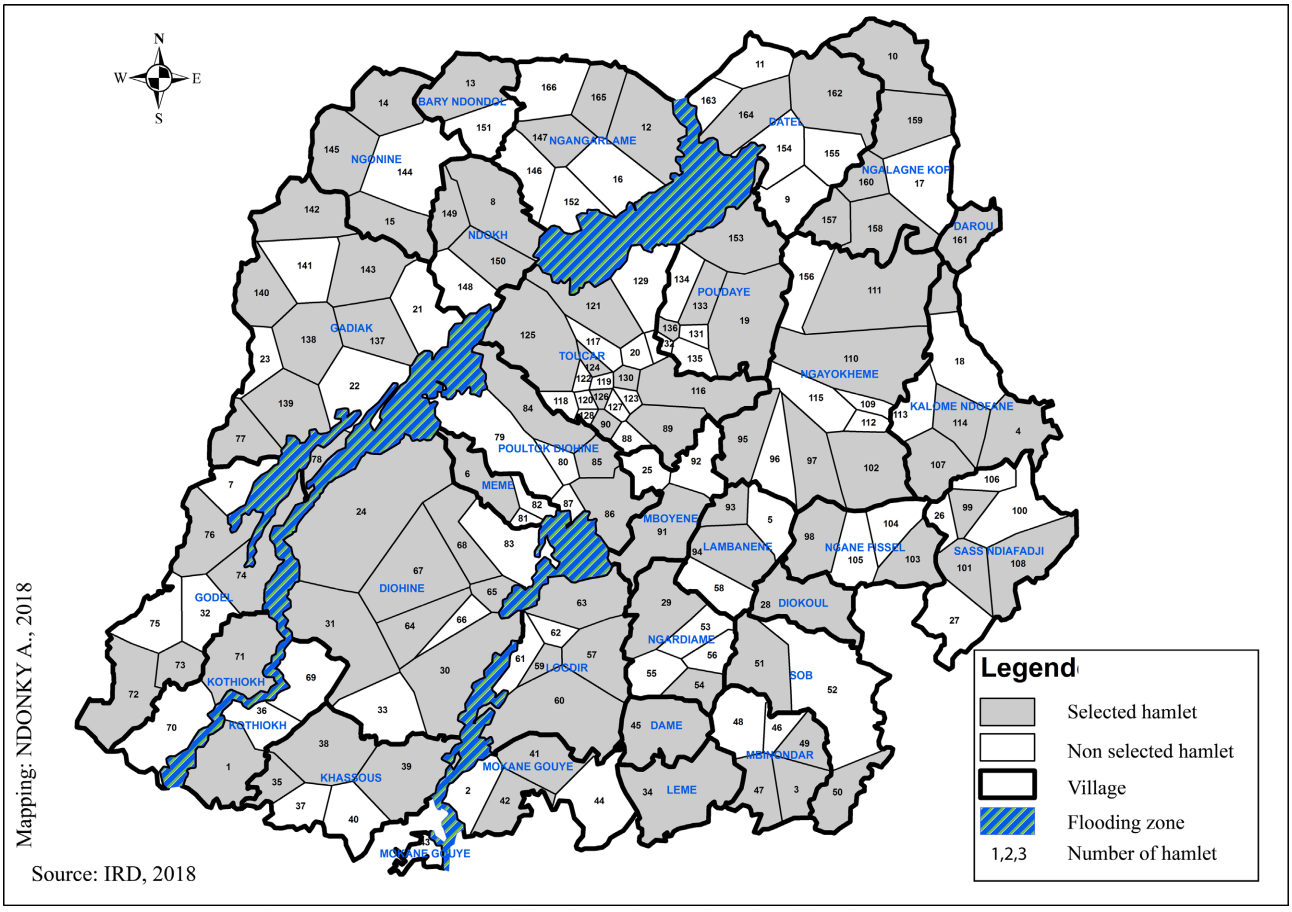

Figure 2. Hamlets selected for the investigation.

The median population threshold (MPT) method is defined by Reed Muench [17]. The threshold population is considered as the minimum number of users/consumers necessary to support a given service. This concept refers to the idea that there is a series of population data for each function below the lower limit of which the localities lack the equipment for this function. Beyond this limit, all localities have at least one piece of equipment for this function. The midpoint of this series was taken as the median population threshold. The weighing value was determined by assigning an arbitrary value of 1 to the infrastructure/service with the lowest threshold. For the other functions, we divided the MPT by the lowest threshold.

The demographic weight method consisted in calculating the proportion of the population of each place (ratio between the population of each locality and the total population of the area).

The global centrality index was used to determine the rank of localities. To verify the relationship between the centrality (or rank) and the size of a locality as formulated by [19], the Pearson correlation coefficient ([9] [20]); is used. According to this law, the size of a locality is inversely proportional to its rank (centrality). Pearson's correlation coefficient was preferred to the correlation graph of [19], because it offers, in addition to the power of visualization of the correlation, the possibility of producing the residual map, which is very important for representing in space the localities that deviate from the model, and reveal local specificities. Thus a graph was constructed to visualize this relationship, a correlation coefficient calculated to test the statistical significance of the latter and finally a map of the residuals of the relationship was produced.

3. Results

3.1. Median Population Threshold and Functional Weight of Infrastructure/Services in the Niakhar Area

This study would like to point out that the concept of median population threshold (MPT) refers to the idea that there is a series of population data for each function below the lower limit of which the localities lack the equipment for this function. **Table 1** shows that the value of the MPT varies from 1252 (minimum) to 4830 people (maximum) for all service functions in the area. The highest functions are associated with the highest values of MPT and the lowest functions with the lowest values.

In this study, the MPT of the hydraulic infrastructure/service (well) was retained as the basic measurement unit for the weighing with a weight equal to 1. The weights of the other infrastructures/services were calculated based on this basic unit. Thus, wells, shops/stores, health districts, places of worship, elementary schools have the lowest weights, while ordinary markets, weekly markets, health centres and pharmacies have the highest weights.

3.2. Concordance between Centrality Indicators

Table 2 globally highlights a strong correlation between the centrality indexes.

Table 1. Median population threshold and functional weight according to type of infrastructure or service.

Name of infrastructure/ services	Number of infrastructures/ services	Number of villages with this infrastructure/ services	Median population threshold	Functional weight
Hydraulic (well)	379	30	1252	1.00
Shop/store	105	29	1306	1.04
Health cabin	5	5	1317	1.05
Place of worship	96	29	1317	1.05
Primary school	30	24	1329	1.06
Maternal school	3	3	3018	2.41
Teleservice	8	3	3018	2.41
Administration	1	1	3018	2.41
Stadium	1	1	3018	2.41
Mutual savings	2	2	3569	2.85
Middle school	2	2	3924	3.13
Ordinary market	4	3	4120	3.29
Health post	4	3	4120	3.29
Weekly market	2	2	4475	3.57
Pharmacy	1	1	4830	3.86

Source: IRD, 2018.

Table 2. Correlation between centrality indices (significant at 5%).

Centrality indices	Population size	Attractiveness	Service functions
Population size (demographic)		0,85	0,83
Attractiveness	0,85		0,59
Service functions	0,83	0,59	

Source: IRD, 2013, 2018.

The correlation is stronger between population size and attractiveness (0.85) or service functions (0.83) and less strong between attractiveness and service functions (0.59). This strong correlation indicates the concordance between the indicators of centrality used.

3.3. Multiple Centralities

Figure 3 shows the spatial distribution of centrality indexes. The three indices have been represented on the same map to better visualize their spatial distribution simultaneously and to make reading more efficient. Generally speaking, the

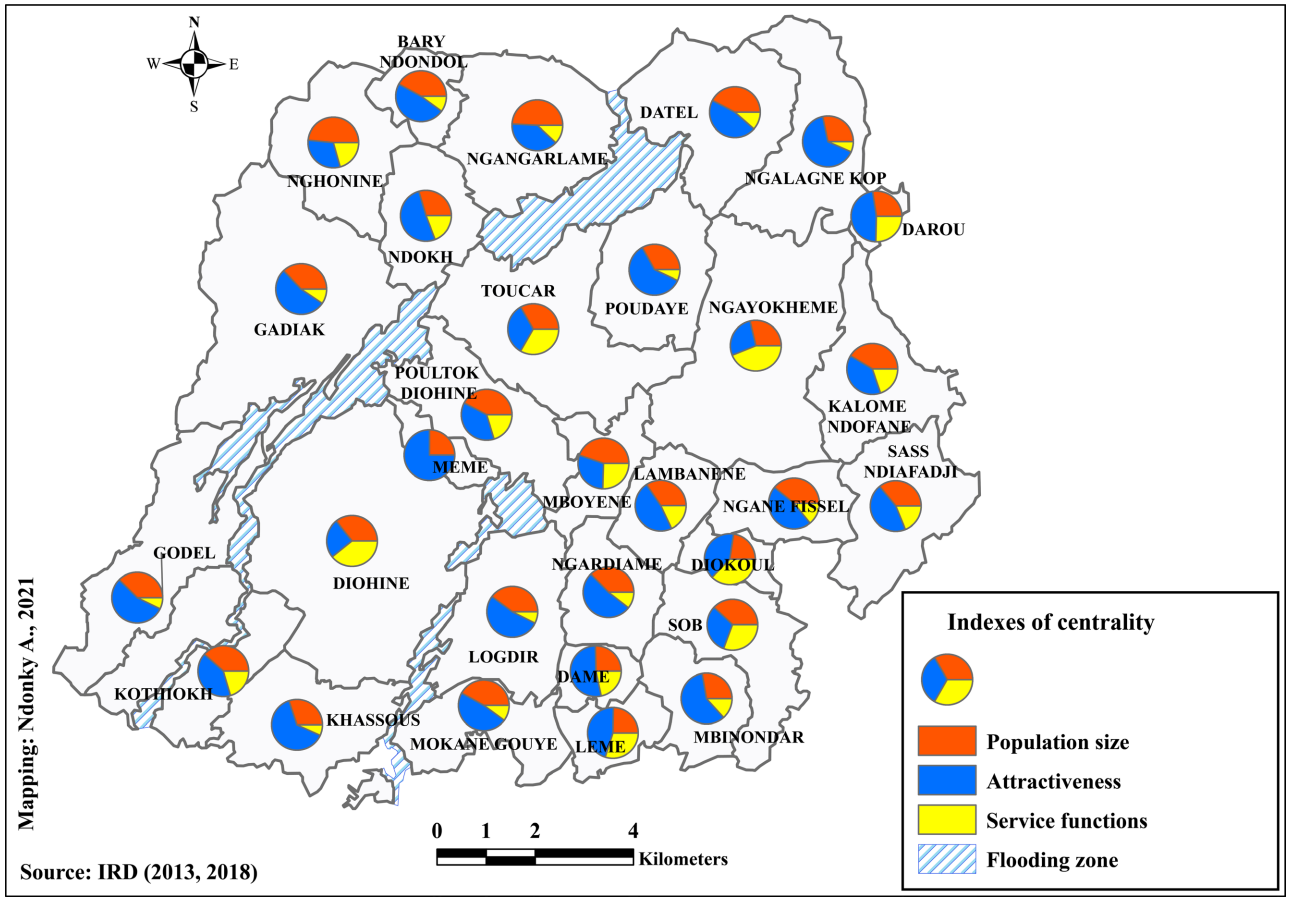

Figure 3. Indexes of centrqlity.

results show that attractiveness is the most important centrality index everywhere, followed by the population size centrality index. Finally, follows the centrality of service functions. These global observations hide local specificities.

- *Localities where the centrality of attractiveness dominates*. These localities are found almost everywhere in the Niakhar area (**Figure 3**). The villages of Meme, Godel, Khassous, Ngalagne Kop, Ndokh can be cited. These are often small, or even very small, villages.
- *Localities where populqtion size centrality dominates*. These localities are not numerous and are distributed in a concentrated manner in the area, particularly in the north of the study area. These are the villages of Nghonine and Ngangarlame.
- *Localities where there are several centralities*. These localities are quite few and are dispersed in space. These include the villages of Ngayokhème, Toucar, Diohine, Sob. These localities, except Sob, are characterized above all by a larger population size, the presence of infrastructure/services and the polarization of travel flows ([21] [22]).

3.4. The Relationship Structure between Rural Areas

In order to highlight the relationship between the three centrality indexes si-

multaneously, the triangular diagram (Figure 4) is designed. The triangular diagram allows you to establish a typology of your spatial units in relation to 3 variables whose total is equal to 100. Its purpose is to compare three complementary data, the sum of which for each spatial unit is equal to 100. It allows you to graphically represent the spatial entities in relation to these 3 variables, as well as to make a classification according to their profile.

An equilateral triangle is used for the graphical representation. This triangle has each side graduated and associated with one of the three variables considered. The spatial units of the basemap are positioned on the graph according to the values of the three variables. The diagram is read counter-clockwise, looking at the variable graduation lines.

The valuesof the indexes have been transformed and measured on the same scale ranging from 0 to 100 to represent them on this diagram. From Figure 4, the study has developed the typology of the relationship (Figure 5). Thus Figure 4 and Figure 5 reveal five types (classes) of relationship.

- *The mixed class, with the predominance of the centrality of attractiveness, the centrality of services functions and the demographic centrality.* These are the localities which are presented in Figure 4 and Figure 5 in light green color. These villages, such as Nghonine, Kalome Ndofane, Sass Ndiafadji, Datel, are found almost everywhere in the area, but more markedly in the north and east (Figure 5).
- *The mixed class, with the predominance of centrality of attractiveness and population size centrality*: The villages of this class are represented in Figure 4 and Figure 5 in green and are found further north and south of the study

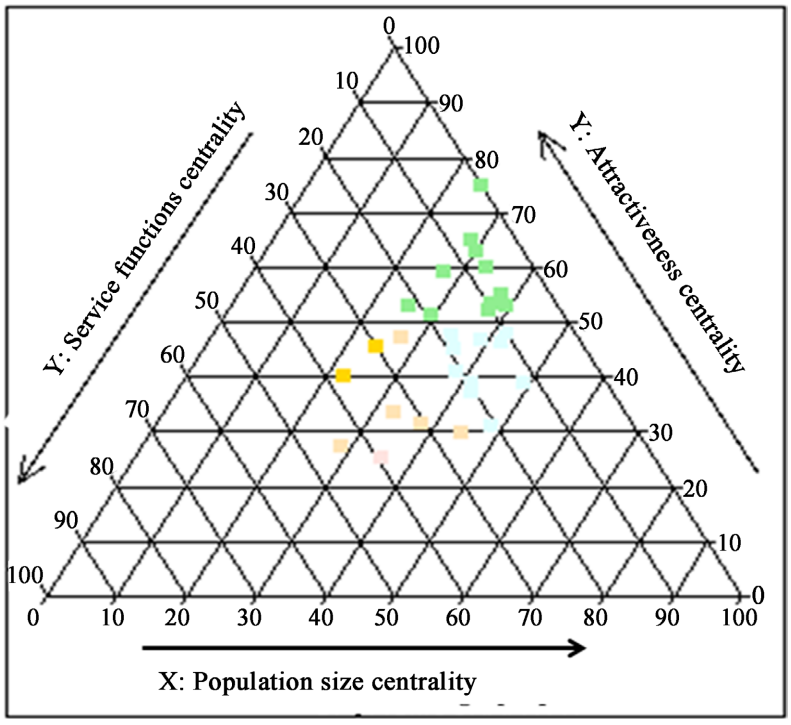

Figure 4. Relationship between centrality indices (Source: IRD, 2013, 2018).

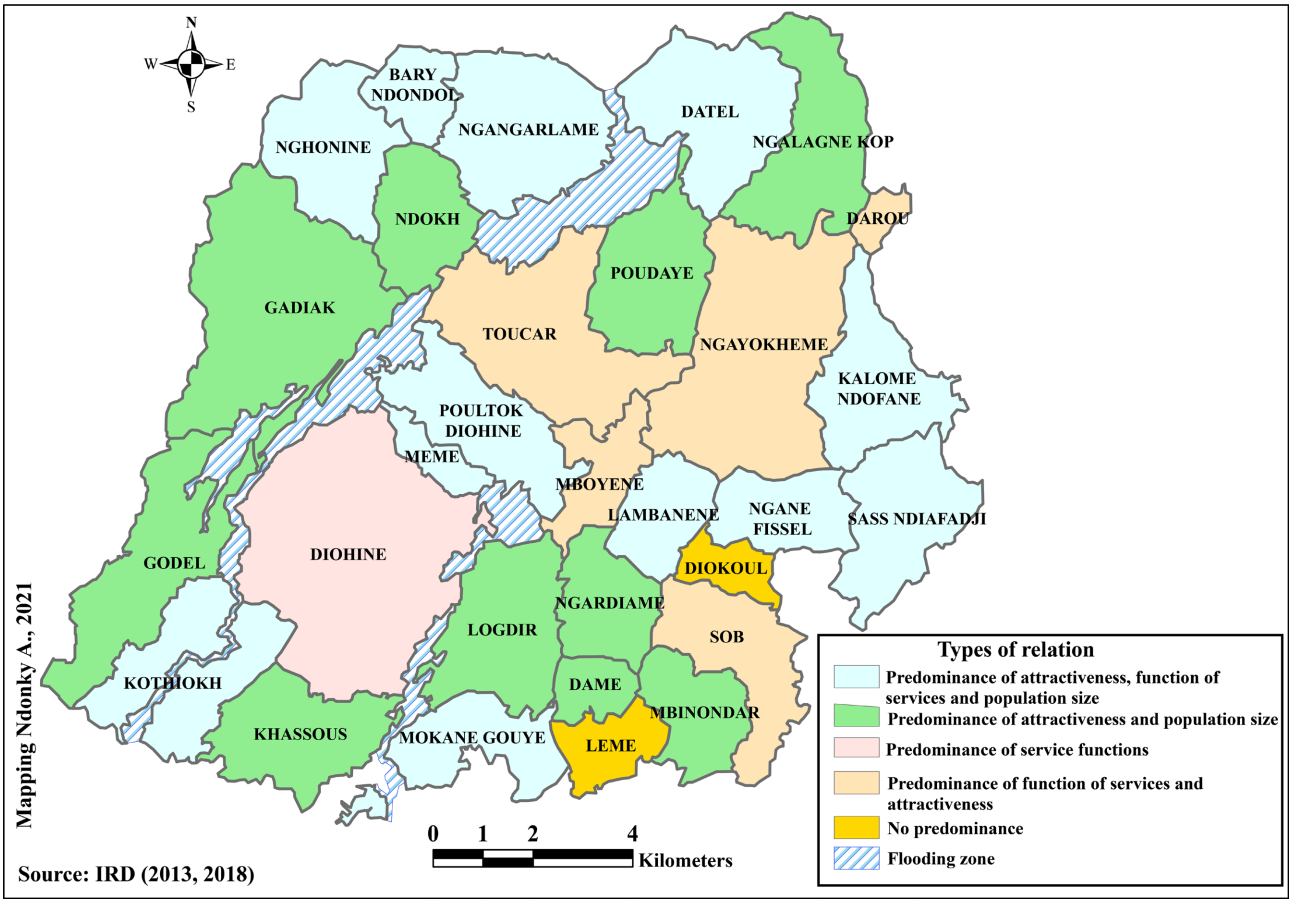

Figure 5. Types of relationship between centrality indexes.

area. These are the localities of Khassous, Mbinondar, Dame, Ngalagne Kop.

- *The mixed class, with a predominance of the centrality of attractiveness and the centrality of service functions*, are the localities which are represented in dark pink (**Figure 4** and **Figure 5**). The villages of this class are present in the east, center and southeast of the study area.
- *The homogeneous class, with the predominance of the centrality of service functions*. For this class, there is only one locality, Diohine, located in the south-west of the study area (**Figure 5**).
- *The mixed class, with no predominance of a centrality*, is represented on the map in dark yellow (**Figure 5**). It includes two villages: Diokoul and Lême, both located to the south-east of the study area.

This typology of the relationship is certainly interesting, because it allowed us to know how the centralities are associated, particularly in the area. But it does not allow to prioritize the villages. This is what the study will do in the next section.

3.5. Hiérarchy of Rural Areas

From the centrality indices measured and presented in the previous section, we have made up a global centrality indicator which made it possible to classify the villages of the area in hierarchical order. The calculation of this indicator con-

sists of summing up the centrality indices set out above. The result of the hierarchical classification is shown in Table 3 and Figure 6.

- *First hierarchical order.* Table 3 reveals that this class has a centrality score that varies between 53.22 and 59.71, a number of localities equal to 3 (10%) and an average distance between villages of 6.36 km. The average distance observed is much greater than the theoretical average distance which is only 2.18 km; this indicates a rather significant dispersion of the localities composing this class. The localities in this class are Ngayokhème, Toucar and Diohine, the largest villages in the area in terms of population, as well as polarization of

Table 3. Hierarchy of localities in the Niakhar area.

Hierarchical order	Centrality score interval class	Number of localities	Percentage of localities	Average spacing (km)
First order	53.22 - 59.71	3	10	6.36
Second order	53.21 - 12.64	5	17	8.32
Third order	12.63 - 7.6	9	30	8.71
Fourth order	7.59 - 1.64	13	43	7.12

Source: IRD, 2018.

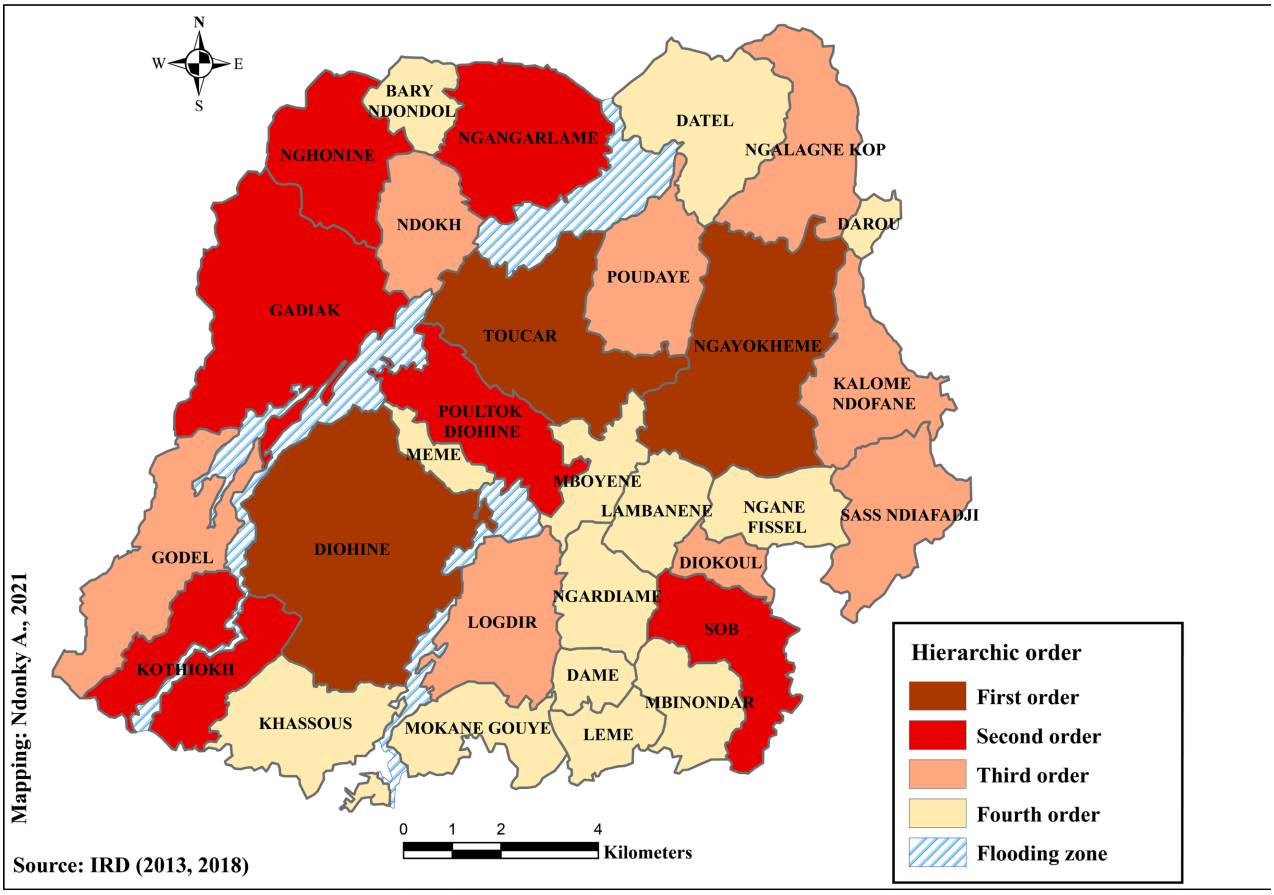

Figure 6. Hierarchy levels of villages in Niakhar area.

infrastructure/services and movement of people.

- *Second hierarchical order*. This order records a centrality score which varies from 12.64 to 53.22 and consists of 5 localities (17%). The average spacing between localities (8.32 km) is greater than that recorded in the previous class and indicates a greater spatial dispersion of localities. Figure 6 confirms this strong spatial dispersion of the villages of this class. However, there is a more evident presence of these villages in the northwest. Among the localities of this class, Nghonine, Gadiak, Sob, Kothiokh can be mentionned.
- *Third hierarchical order*. Composed of 9 localities (30%), this class is the largest in terms of numbers and has the greatest spacing between the villages that make it up (8.71 km). Its centrality score varies between 7.6 and 12.63. As in the previous class, the localities composing it are distributed in a very dispersed way in the study area. However, there is a more evident presence of these localities in the east of the study area (Figure 6). Among the localities of this class, Ndokh, Poudaye, Ngalagne Kop, Logdir, Godel, Diokoul, Sass Ndiafadji can be noted.
- *Fourth hierarchical order*. Table 3 reveals that this class has the lowest score, varying between 1.64 and 7.59 and much lower than the scores of the previous classes. On the other hand, the number of localities composing it is the highest of all the classes. The average distance between villages is 7.12 km, the third largest one. We can note a fairly significant spatial dispersion of localities. However, there is a more marked presence of these localities in the center and south of the study area (Figure 6). The localities making up this class are essentially small. They are Barry Ndondol, Datel, Mboyenne, Dame, Lême, Same, Lambanène, Ngane Fissel.

The results also reveal the absence of a link between hierarchical order (rank) and distance (Table 3). In other words, there is independence between rank and spacing of localities.

Certainly, it is interesting to identify the hierarchical order of the localities and to know if there is a link between this order and the spacing of the localities. However, it is also important to know the relationship between the hierarchical order of localities and their population size. This is what this work will do in the next section.

3.6. Strong Relationship between Centrality and Village Population Size

To test the relationship between population size and the centrality score (hierarchy), the Pearson correlation coefficient is used. Taking as independent variable the population size and the dependent variable, the score of centrality, the causality is calculated for 30 localities. The result of the analysis is presented in Figure 7, which highlights the strong correlation between population size and centrality, with a correlation coefficient of 0.77, significant at 1%. One can therefore say that there is a strong positive correlation between the population size and the centrality score.

Admittedly, there is a strong relationship between population size and centrality score. Nevertheless, it is important to analyze the residuals, *i.e.* the deviations from the adjustment curve (representing the values predicted by the model).

The results of the analysis are presented in Figure 8, which indicates three

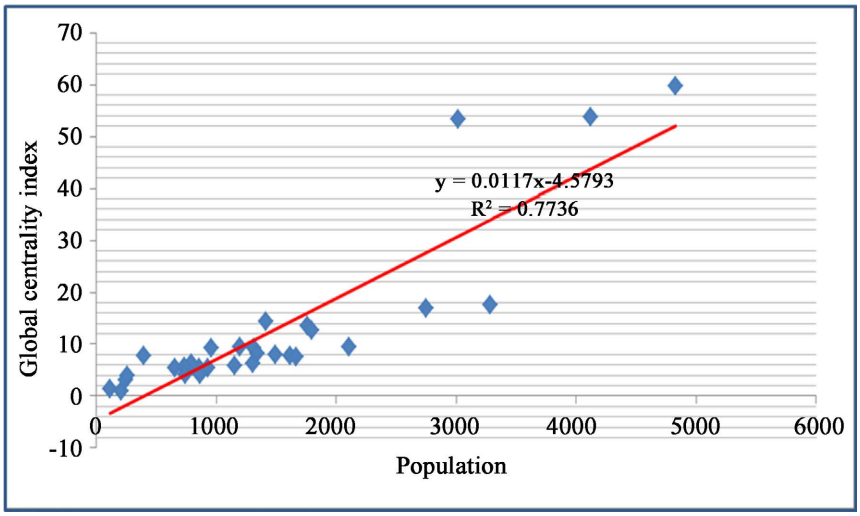

Figure 7. Correlation between population size and global centrality index (Source: IRD, 2018).

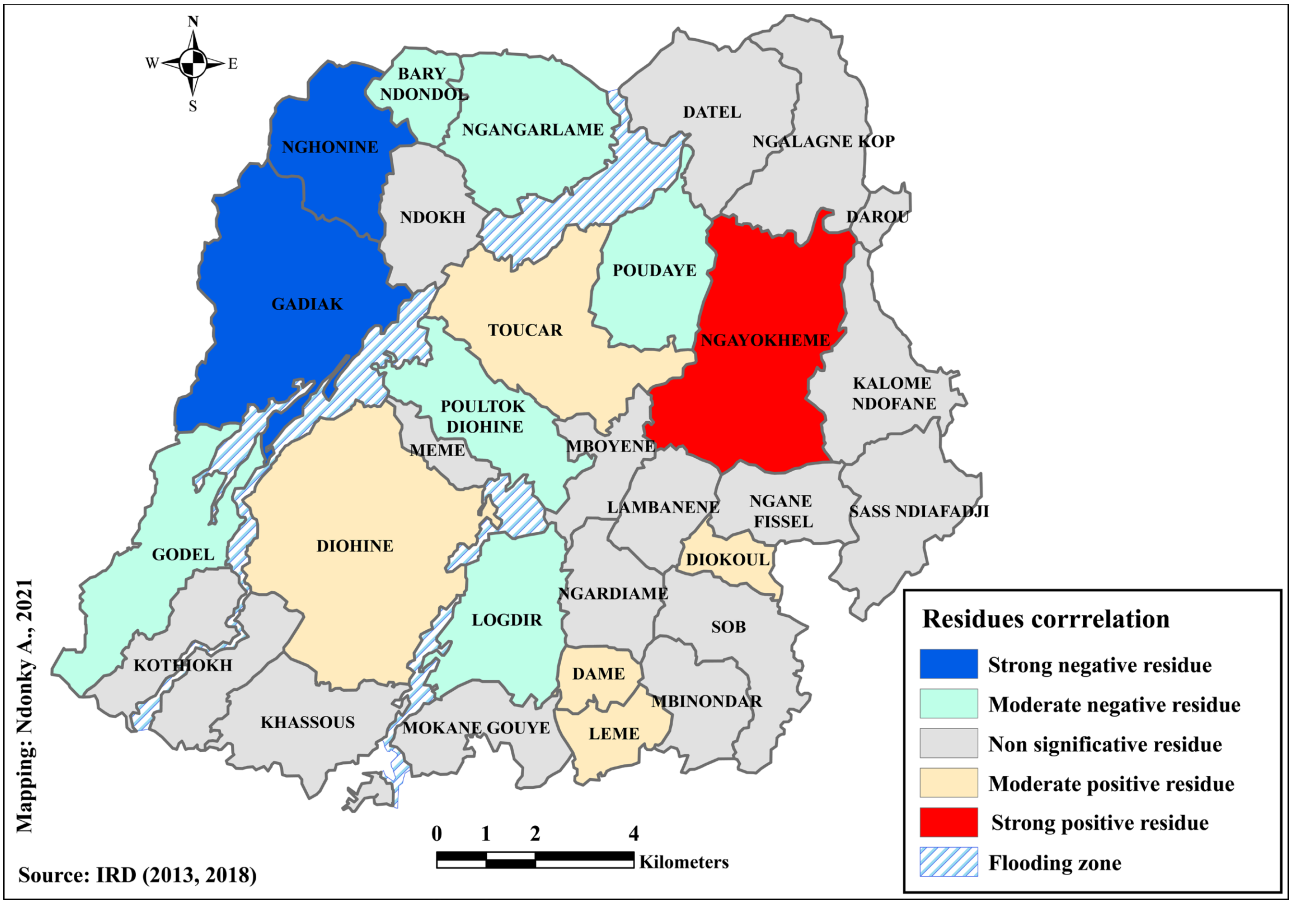

Figure 8. Residues of the correlation between population size and global centrality index.

main types of residues: positive residues and negative residues, all significant, and zero non-significant residuals. Among the positive residues, the strong positive residue and the moderate positive residue are noted (**Figure 8**). This type of residue indicates an overestimation of the variance (deviation from the model). The overestimation of the variance is stronger in the village of Ngayokhème and moderate in the localities of Toucar, Diohine, Diokoul, Dame, Lême.

On the other hand, the negative residues (strong and moderate) show the underestimation of the variance. The villages where there is a strong underestimation of the variance are Nghonine and Gadiak, all located to the northwest of the study area. In the localities of Barry Ndondol, Ngangarlame, Poudaye, Logdir, Poultok Diohine and Godel, the deviation from the model is moderate. These localities are dispersed in study area. Furthermore, **Figure 8** shows that positive residues and negative residues do not distribute in an autocorrelated manner in the area. It cannot therefore be said that these deviations are a random component linked to the imprecision of the model. The presence of significant residues rather means that there are variables other than population size that explain the centrality.

The localities represented in gray are those whose residues are not significant. They behave according to the model; that is, their rank corresponds to their population size. The spatial distribution of these places is in line with the Zipf's rank-size law [19].

4. Discussion

Our study has made it possible to determine the main types of centrality and to establish the hierarchy of rural localities in the Niakhar area. It also highlighted the strong relationship between the rank of localities and their population size, as well as its variation in the study area. This type of study is the first on the scale of this area, hence the difficulties of comparing its results with those of similar studies in the same area. Nevertheless, its results can be compared with studies done elsewhere.

Like other works carried out in various contexts, such as those of [4], in the Indian rural environment, of [23] in the Swiss alpine rural area, of [7] in the Canterbury district (English rural environment), our study revealed the hierarchy of rural localities. The results of our study, like those of the study of [4] in rural India, showed a strong correlation between the rank of localities and their population size. This convergence confirms the validity of our results and tends to reinforce the relevance of our methodological choices. But unlike the study [4], which took into account only the size of the population and the functions, ours has in addition to these indicators, taken into account the attractiveness; which is an important step forward. The approach adopted by [9] is based on the social and economic structure of the villages having generated an architectural landscape reproducing the social rank. The NCERT studies [24] on the structure of rural localities which have an approach based on the type of activity, the

morphology (spatial arrangement of dwellings), the nature of the site (plain, plateau, etc.) can also be noted.

In the specific case of the African continent, one can note the work of [8] which revealed the hierarchy of rural localities in the State of Kogi in Nigeria. These authors used some development indicators (water, agriculture, trade, education, health, infrastructure, institutions, socio-cultural services) to determine the hierarchy of localities in this state. The difference of our study from that of these authors is that, in addition to the functions and infrastructures (qualified by the latter as indicators of development), ours took into account the population and the attractiveness to determine the hierarchy of rural localities. From this point of view, our study has provided additional information in the definition and measurement of the hierarchy of African rural localities.

The main rural centers are Toucar, Diohine and Ngayokhème, already identified by [25], as main places of attraction that structure the space of the Niakhar area. These are the largest villages that concentrate more population, infrastructure, equipment and services, as well as certain administrative functions such as in Ngayokhème village, the capital of the commune [22]. Unlike the studies mentioned above, where each used a single dimension (attractiveness for the first and service functions for the second) to determine the importance of places, this study has made it possible to highlight the main centers, to establish the hierarchy of places, by combining several dimensions (attractiveness, population size and service functions). It also made it possible to highlight the structure of the relationship between the centralities. Thus our study has allowed a significant advance in the knowledge of the Niakhar area.

Even if they constitute, with Toucar and Ngayokhème the main structuring poles of the rural space of Niakhar, Diohine deserves special attention. Indeed, it alone constitutes a class, with the predominance of the centrality of functions. It has a level of equipment in infrastructure and services much greater than those of its two competitors, Ngayokhème and Toucar, which are respectively the administrative capital and the largest in terms of population.

The strong correlation between centrality indicators reveals a common and complex reality. The aggregation of these indicators made it possible to produce a more precise composite indicator (taking into account a complex reality), in this case the global centrality index. The results show that this index is valid, simple, easily interpretable and reproducible. It is therefore representative, operational and useful for decision-making.

The strong relationship between population size and locality rank observed confirms Zipf's law ([19] [26] [27] [28]). This shows that this law is also true in rural areas. Experimenting with this law in rural Africa and Senegal in particular is an important step forward.

On the other hand, it is necessary to highlight the absence of link between the hierarchical order (rank) and the distance between the localities. In other words, localities are distributed randomly in space, regardless of their size or their level of infrastructure and service equipment. The distance separating the largest vil-

lages is not greater than that separating the smallest villages, contrary to what Christaller's theory of central places recommends [3]. This independence between the rank of the localities and the distance between them can be explained, on the one hand, by the nature of the places studied which are villages which often shelter minor services/infrastructures whose location does not often require a market area (distance) important to be economically profitable. On the other hand, this lack of relationship can be associated with the low spatial resolution of our study area, which means that, in general, the distances between localities are small.

The advantage of our approach, compared those used by these authors, is to have combined population size with functions (services/infrastructure) and attractiveness (polarization of trip flows) to determine the hierarchy of rural localities. From this point of view, our contribution is obvious.

Our study presents a certain originality compared to those carried out so far in the study area, since it allowed to determine the hierarchy of the localities, to show the structure of the relationship between the different centralities. In addition, it allowed us to highlight the hierarchy of localities in the study area, based on a synthetic centrality indicator. The spatial organization thus revealed constitutes an important advance in the knowledge of the Niakhar area. Highlighting the hierarchy of places makes it possible to reveal structuring poles of territorial development and to reduce economic imbalances in space and spatial disparities in terms of the allocation of basic collective services. From this point of view, our study produced results of some utility.

5. Conclusions

The cross study of centralities, the hierarchy of localities, the relationship between rank of localities and their population size, on the one hand, and distance, on the other hand, combining several methods, confirm the relevance of our methodological choices. This constitutes a significant advance, compared to the studies carried out so far, at the scale of the study area.

Our results raise the debate on the relationships between spatial planning policies, population distribution and spatial disparities in rural areas. With the strong demographic growth in rural Africa, particularly in Senegal, and the lack of regulation of the spatial allocation of basic equipment and infrastructures, spatial imbalances are increasing. We are therefore in a situation that is all the more worrying because the rural poles, territories structuring socio-economic activities in rural Africa and Senegal, in particular, are often poorly defined. Thus, our results correct this weakness.

The production of these results is a promising first step in the analysis of the hierarchy of rural localities. Nevertheless, it is important to make improvements to refine the results. Thus for future studies, it would be necessary to highlight the factors which explain the hierarchy identified, to carry out a study on a larger area.

Finally, knowing that our approach has been validated in the case of Niakhar, it could, from a perspective of comparison, be applied to other Senegalese or African rural areas.

Conflicts of Interest

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

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