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Evolution of the Spatial Distribution of Basic Infrastructures and Services in the Niakhar Area (Fatick), Senegal

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Abstract

Basic infrastructures and services present an important socio-economic and territorial equity issue, because the availability of these makes it possible to improve the living conditions of populations, makes territories attractive and stimulates their development. The objective of our study has been achieved, so our results provided information on the rate of propagation of basic infrastructures and services, as well as the evolution of the forms of spatial distribution of the latter. The data used comes from the census and geolocation of basic infrastructures and services in the Niakhar area, carried out by the IRD in 2018. Centrographic measurements were used to describe the overall spatial distribution and the use of chi-square statistics confirmed the existence of a preferential direction of distribution. To verify the existence of a spatial structure of infrastructure and service seeding, the Ripley statistic is used. Our results can be useful for land use planning and spatial resource allocation policies. Indeed, the identification of different types of spatial aggregates and the highlighting of the preferred directions of the distribution of basic infrastructures and services, make it possible to correct disparities in the spatial distribution of basic resources.

Keywords

Spatial Structure, Spatial Disparities, Ripley Statistic, Centrographic Measurements

1. Introduction

Since the 1970s, the Niakhar area, like the rural areas of the peanut basin of Senegal, has been subject to drought and the socio-economic crisis, pushing its farmers to rush to the cities. At the same time, the policy of structural adjustment and neoliberalism imposed by donors on underdeveloped countries including Senegal has drastically reduced public spending, particularly that intended for the construction of infrastructures and basic services ([1] [2] [3] [4]). That policy has had serious impacts particularly on rural areas.

However, since the 2000s, the State of Senegal has initiated several programs/projects for the construction of basic infrastructures and services. Particular attention was paid to the rural environment, mainly with the national rural infrastructure project (PNIR), the drinking water for all project and support for community activities, the national rural electrification program (PNER) of Senegal ([5] [6]). These programs/projects aim to improve access of rural areas to basic infrastructures and services. One can therefore note a revival of the State of Senegal for the development of infrastructures and basic services.

Basic infrastructures and services present an important socio-economic and territorial equity issue ([7] [8]). Indeed, the availability of such services allowed some improvement of the living conditions of populations, especially the access to health care, transport, education, water and energy. It also makes territories more attractive [9] and promotes the impetus of territorial development [10].

Infrastructures can be defined in several ways, all of which emphasize their fundamental role in economic and territorial development. According to the Dictionary of Urban Planning and Development [11], infrastructures are defined as "all the installations made on the ground or underground allowing the exercise of human activities through space". The geography dictionary also provides the same meaning. As for services, they are defined as activities or services that do not produce material goods. In this study, infrastructures and services are considered as defined above. Among the infrastructures and services, roads, sanitation networks, health and education infrastructures, teleservices, banks, etc., can be mentioned.

Indeed, the issue of the spatial distribution of infrastructures and basic services has long been a major concern for researchers and professionals. Some authors emphasize the density or the time taken to access these infrastructures and services. For example, the work of the National Agency for Statistics and Demography of Senegal ([12] [13]) on the distribution of health structures at the regional level in 2016 and at the departmental level in 2015 can be cited. [14] in his work on the distribution of health structures, insists on the analysis of densities and the time taken to access the nearest health structure.

Other authors emphasize the distance between structures. One can mention the work of [15] on the spatial distribution of services and rest areas on the European Union road network, where the authors used, as an analysis method, the measurement of the distance between the spatially closest services.

The literature review also showed that cartographic visualization and frequency table analysis have been used as a method of analyzing the spatial distribution of infrastructure and services. The work of [16] on the spatial distribution of health services in urban centers can illustrate that. The authors of the work also addressed the question of the use of these health services by urban and rural populations. The work of [17] focuses on inequalities in the distribution of health structures and the level of access to them in the city of Jeddah in Saudi Arabia. The method used consisted in creating buffers around health structures, then counting the population inside these buffers and finally, comparing the population size of the buffers. Authors like [18] insist on the analysis of the adequacy between the spatial distribution of health structures and that of the population.

Obviously, this work is important, because it helps to determine the density, distance or access time, and map locations. It also allows to measure inequalities of access and analyze the adequacy between the spatial distribution of basic infrastructures and services, and that of the population. However, they have limitations linked to the fact that they do not allow the analysis of the spatial structure of the distribution of basic infrastructures and services. However, knowledge of this spatial structure is of great interest for the fight against spatial disparities and territorial planning. Indeed, it makes it possible to reveal the forms of spatial distribution, the preferred directions and clusters of spatial association of basic infrastructures and services. In addition, the application of spatial structure analysis methods of the spatial distribution of basic infrastructures and services is weak in Africa, particularly in Senegal. In the Niakhar area, the application of these methods is not known.

Our work therefore has the main objective of analyzing the evolution of the spatial structure of the distribution of basic infrastructures and services in the Niakhar area through the strategies developed by the State of Senegal, NGOs and local actors, as well as verifying whether spatial disparities in the distribution of these basic infrastructures and services have decreased or increased.

2. Material and Method

In this section, the study area will be first presented, then the data and finally, the methods for describing the spatial structure of distribution of basic infrastructures and services.

2.1. Study Zone

The Niakhar zone is located in the northern part of the Fatick department (Fatick region). Bounded to the north by the department of Bambey (region of Diourbel), to the west by the department of Mbour (region of Thiès), to the south by that of Fatick and to the east by the commune of Patar, it brings together 30 villages distributed between the commune of Ngayokhéme and that of Diarrére (**Figure 1**). Sahelo-Sudanian type, its climate is characterized by the

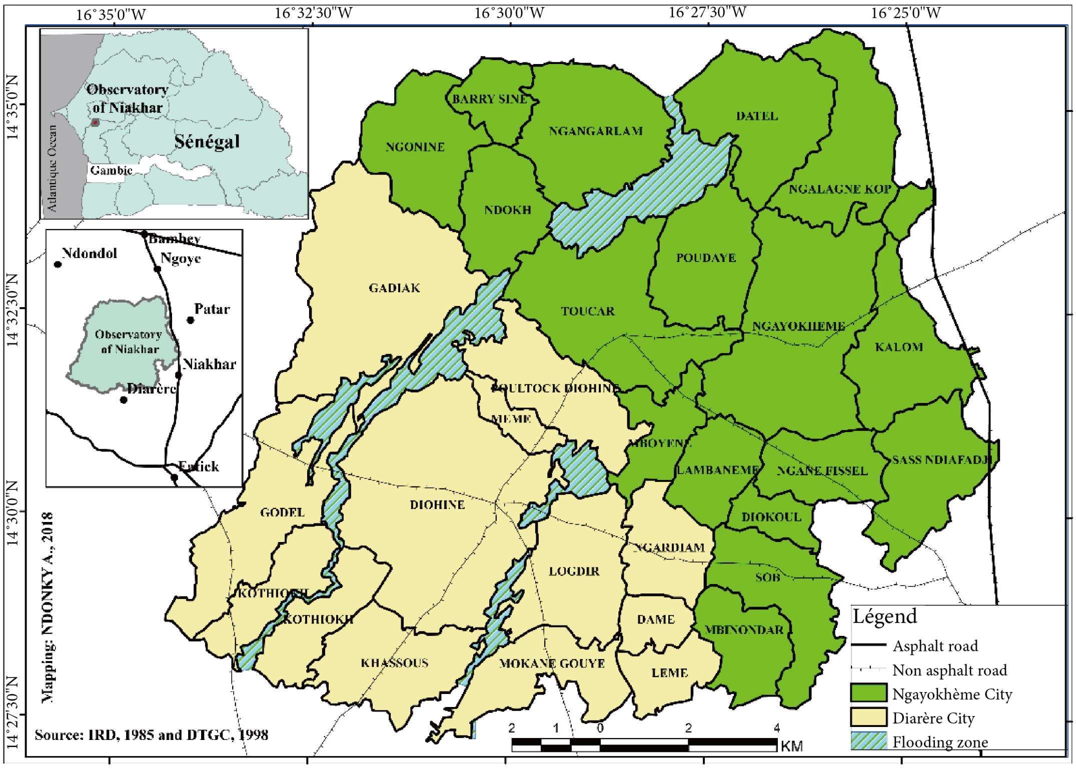


Figure 1. Presentation of the study area.

alternation of two seasons (rainy season and dry season). In 2021, the population amounted to 52,700 inhabitants (*i.e.* a density of 259 inhabitants/km^2) [19], compared to 44,994 inhabitants in 2013 (*i.e.* 222 inhabitants/km^2) [20].

2.2. Data

The data used here comes from the census and geolocation of basic infrastructure and services in the Niakhar area carried out by the IRD in 2018. During this operation, the following information: GPS coordinates, type, date of implementation, state (functional/non-functional) of the infrastructure or service, name of the hamlet or village where it is located, were collected. The people surveyed are the village chiefs or their representatives. This choice is explained by the fact that these people, due to their status, often have a good knowledge of their village.

Transport infrastructure was excluded from this study due to the unavailability of reliable and exhaustive data over the reference period. Energy infrastructure could also not be selected due to their very scarcity in the area.

2.3. Description of the Spatial Structure of the Distribution and Its Evolution

In this subsection, the following steps will be observed.

2.3.1. Centrographic Measurements to Describe the Overall Spatial Distribution

The objective is to follow the evolution of the movement of the infrastructure and services, measure the overall spatial dispersion and clearly visualize the orientation of this distribution. For this, centrographic measurements, including the mean point, the standard distance and the dispersion ellipse are used. They make it possible to globally display changes in the spatial distribution of a phenomenon ([21] [22]), by providing information on the degree of concentration or spatial dispersion and its orientation in time.

The average point was used to follow the evolution of the movement of infrastructures and services, because it allows the spatial distribution to be summarized. Its x_g and y_g coordinates are calculated as follows:

$$y_g = 1/N \sum_{i=1}^{N} y_i$$
$$x_g = 1/N \sum_{i=1}^{N} x_i \quad (1)$$

With N: number of points, x_i: longitude of the given point i and y_i: latitude of the given point i.

To determine the overall spatial dispersion of infrastructures and services around the average point, the standard distance is chosen. It measures the average variability of the positions of the points around the center of gravity. Its formula is as follows:

$$\sigma_{x,y} = \sqrt{1/N \sum \left(x_i - x_g\right)^2 + \left(y_i - y_g\right)^2} = \sqrt{\sum 1/N \left(d_{iG}^2\right)} \quad (2)$$

With N: number of points, x_i: longitude of point i and y_i: latitude of point i; x_g: longitude of the midpoint and y_g: latitude of the midpoint; d: distance between point i and the mean point. To facilitate the calculation of distances, the projected coordinates in metric units are preferred.

The use of the dispersion ellipse helps us to clearly visualize the orientation of the spatial distribution of infrastructure and services which does not appear evident enough on the map. It enables us to represent the intensity of the minimum and maximum dispersion of a series of points in relation to their average center [23]. The two standard deviations (σ_x and σ_y), in the X and Y directions, are orthogonal and form, by construction, an ellipse which indicates the orientation of the distribution of the phenomenon. The latter are calculated, one, along the transposed axis X and the other, along the transposed axis Y (Levine N., 2010) as follows:

$$\sigma_x = \frac{\sqrt{\sum_{I=1}^{n} \left(\left(X_i - \bar{X}\right)\cos\vartheta - \left(Y_i - \bar{Y}\right)\sin\vartheta\right)^2}}{N-2}$$
$$\sigma_y = \frac{\sqrt{\sum_{I=1}^{n} \left(\left(X_i - \bar{X}\right)\sin\vartheta - \left(Y_i - \bar{Y}\right)\cos\vartheta\right)^2}}{N-2} \quad (3)$$

where N is the number of points, θ is the angle of rotation of the Y axis relative to the horizontal (axis X), X_i: longitude of the given point i and Y_i: latitude of the given point i,: longitude of the average point and: latitude of the average point.

2.3.2. Chi-Square Statistic to Confirm the Existence of a Preferential Direction of Distribution

Certainly centrographic measurements enable us to produce indicators which can be projected onto a map and thus visualize the preferential direction of the spatial distribution of infrastructures and services. However, they do not allow us to statistically confirm the existence of this direction. Also, directional statistics are used. The use of this statistic led us to observe three successive stages. First, the study area is divided into 4 angular sectors representing 4 cardinal directions, from the average point of sowing of infrastructures and services of the period before 1970, considered as the original focus. This hypothesis is relevant, because the average point summarizes the sowing of infrastructures and services. Then, in each direction and for each period, the new infrastructures and services are counted. Some years have a very low number of infrastructure and services. However, the use of aggregation makes it possible to have a sufficient number of infrastructures and services to carry out these analyses. Finally, a chi-square test ([24] [25]) was used to statistically confirm the existence of at least one preferred direction of the spatial distribution of infrastructure and services.

The chi-square equation is as follows:

$$\chi^2 = \frac{\left(f_i - \bar{f}_i\right)^2}{\bar{f}_i} \tag{4}$$

with $\bar{f}_i = \frac{E}{C}$ (theoretical number), with E = total number of the sample, f_i = number observed in direction i and C = number of categories.

2.3.3. Ripley Statistics to Verify the Existence of a Spatial Structure of Infrastructure and Services Seeding

There are several methods, in the field of spatial statistics, for describing the spatial structure of a pattern of points ([26] [27] [28] [29]). These methods have been used particularly in the field of forestry ([28] [30] [31]). Among the methods for analyzing the spatial structure of the seeding of points, those based on quadrats and those based on distances can be used. For quadrat methods, the data are numbers of individuals in quadrats [32], whereas for distance-based methods, the data are distances between points, individuals or positions.

Among the methods based on distances, one can note those which only require knowledge of the nearest neighbors of each point (such as the method of [33] used for small domains) and those more expensive requiring a map of the entire study area. The Ripley method is one of the latest methods and is used for large domains.

The advantage of the Ripley method over other distance-based methods (such as the method of [33] is that it allows the spatial structure of the distribution to be described simultaneously at several distances [28] and reveals the variation in the aggregation or spatial dispersion of features when the size of the neighborhood changes.

However, the Ripley function (K(d)) is always difficult to interpret, as the curve obtained for the null hypothesis is in the form of a parabola. Additionally, charts are very difficult to present. This is why a modified function L(d) proposed by [34] is chosen. This function is easy to use, standardized and thus makes it possible to compare the structure of seedlings having different sizes (different number of points). In addition, it is easier to interpret, because for a Poisson process, at all distances d, $L(d) = 0$. Above and below the x-axis are located respectively the aggregated (concentrated) processes and the regular (dispersed) processes. In addition, the $L(d)$ function has the advantage of having a much more stable variance than that of the $K(d)$ function. The equation of the function $L(d)$ is as follows:

$$L(d) = \sqrt{\frac{A\sum_{i=1}^{N}\sum_{j=1, j\neq i}^{N} k(i,j)}{\pi N(N-1)}} \tag{5}$$

where A represents the area, N is the number of points, d, the distance, and $k(i, j)$, the weighting.

If no boundary correction is applied, the weighting is equal to 1 when the distance between i and j is less than or equal to d; it is equal to 0 when the distance between i and j is greater than d. If boundary correction is applied, the weighting of $k(i, j)$ is slightly modified.

3. Presentation of Results

The results are structured around six points presented as follows:

3.1. An Evolution Characterized by a Constant Increase in the Number of Newly Created Infrastructures and Services

Figure 2 shows the evolution of the number of newly created basic infrastructures and services. The number of newly created infrastructures and services is generally constantly increasing. Two main phases can be identified: a first, between 1970 and 1999, with a slight increase and a second, from 2000 to 2018,

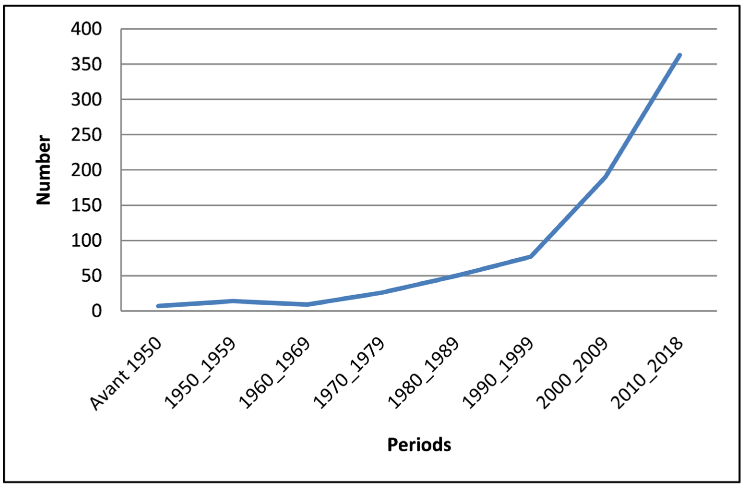


Figure 2. Evolution of the number of new infrastructures and services.

marked by a sharp increase in the number of new creations of infrastructure and services. So an overall trend towards an increase in the number of infrastructures and services can be noted; which illustrates the efforts undertaken by the State to equip the rural environment.

3.2. Infrastructures and Services That Increasingly Invest Space

Figure 3 highlights the evolution of the spatial distribution of basic infrastructure and services over six periods.

In the first period (before 1970), a very loose spatial distribution of basic infrastructures and services is observed. Indeed, **Figure 3** shows a very weak presence of infrastructures and services in the localities of the area. This global trend hides spatial disparities. Thus the localities housing more basic infrastructures and services are Ngayokhème (in the center-east), Diohine (in the south), Datel in the northeast and Nghonine in the northwest. The other areas are very poorly endowed.

The following period (1970-1979) was marked by the creation of basic infrastructure and services. However, only a few villages benefit from these new creations. The villages that have benefited the most from these basic infrastructures and services are Poultock-Diohine, Sass Ndiafadj, Diohine, Ngayokhème and Barry Ndondol, mainly located in the center, northwest and east of the area (**Figure 3**). The southern zone has benefited very little from the new creation of basic infrastructures and services.

In the period 1980-1989, basic infrastructures and services began to reach the north and the south, notably the villages of Datel, Kothiokh, Khassous and Diohine while consolidating their presence in the center, in Mboyenne, Lambanène and of Toucar (**Figure 3**). The east and west benefited from very little new creation of infrastructures and services during this period.

There is a continuous deployment of basic infrastructures and services in the center and the north in the period 1990-1999. Also during this period, basic infrastructures and services began to really reach the east and south-east of the area.

During the last two periods (2000-2009 and 2010-2018), basic infrastructures and services occupy almost the entire space of the Niakhar area, however with strong spatial concentrations in certain localities such as Ngayokhème, Toucar, Diokhine, Pouyène … (**Figure 3**).

3.3. South-West, Preferential Direction of Dissemination of Basic Infrastructures and Services

The results show an overall tendency for the spatial distribution of basic infrastructures and services to be oriented southwest, as illustrated by the dispersion ellipses (**Figure 4**). The analysis of **Figure 4** reveals a variation in the direction of the spatial distribution of basic infrastructure and services depending on the period.

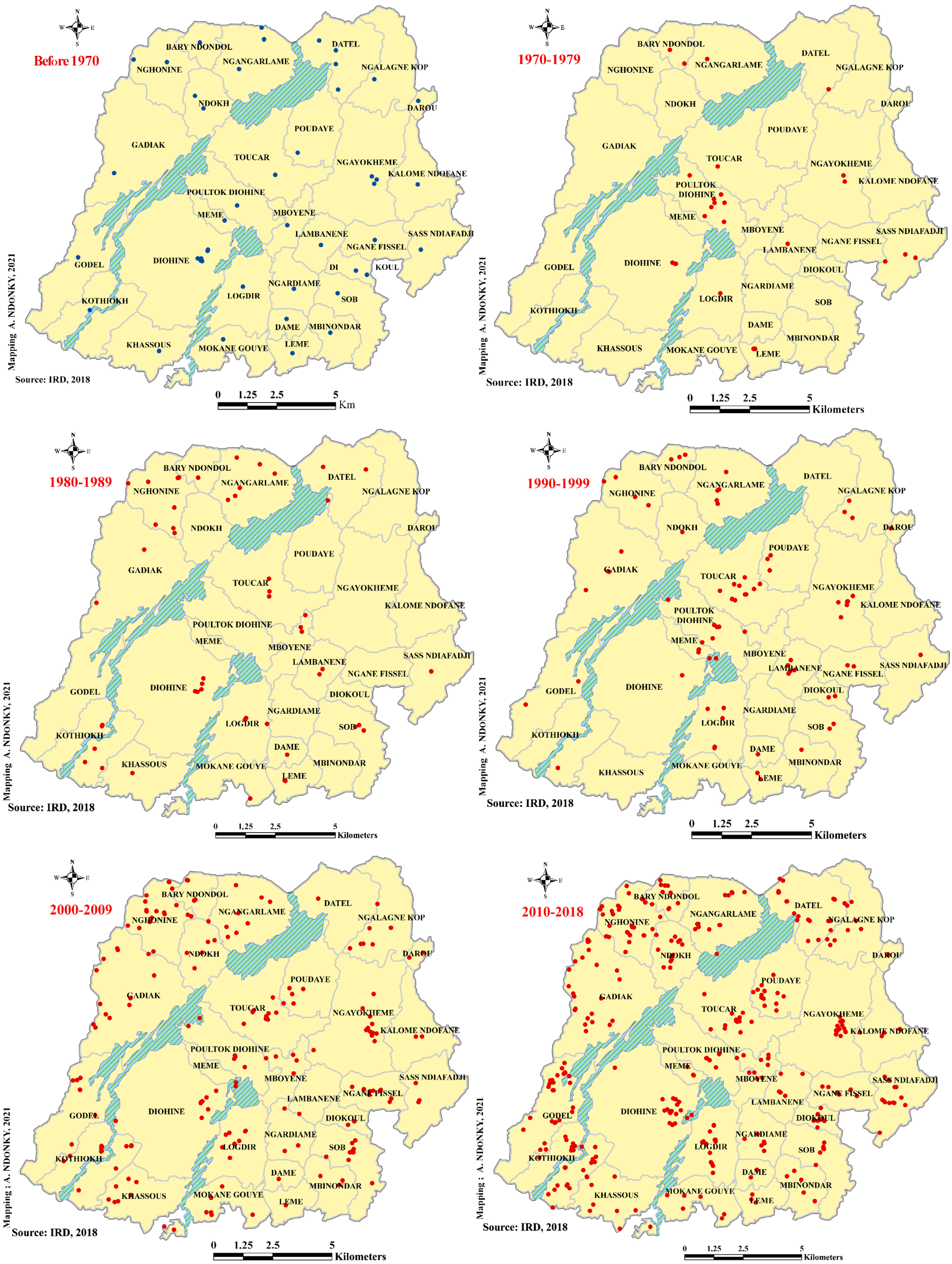


Figure 3. Evolution of the spatial distribution of infrastructure and services.

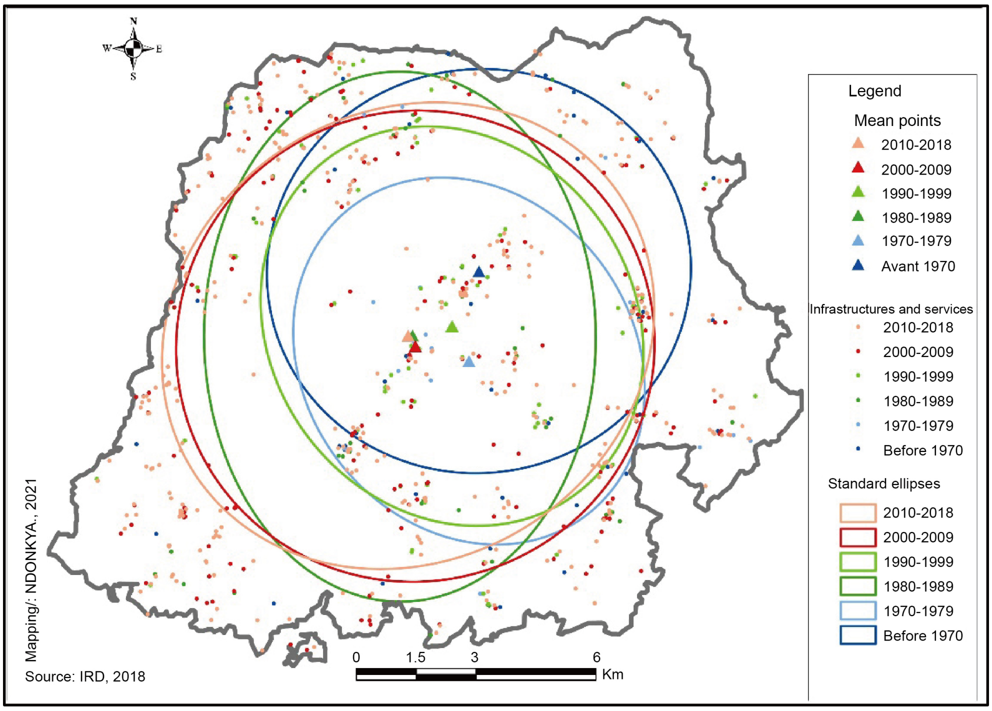


Figure 4. Summary of the evolution of the spatial distribution of infrastructure and services.

For example, for the first period, the spatial distribution is very weakly oriented, while for the following period, it is very oriented in a northwest/southeast direction; there is therefore a change of direction between the two periods. The 2010-2018 period is characterized by a change in orientation compared to the periods (1970-1979), (1980-1989), (1990-1999). Indeed, during the period 2010-2018, one can observe that the ellipse of the standard deviation is oriented northeast/southwest, while during the periods (1970-1979), (1980-1989), (1990-1999) it experienced a different orientation (Figure 4). Table 1 also illustrates this variation in the direction of the spatial distribution of basic infrastructure and services over time, since the long axis/short axis ratio has experienced an irregular evolution.

However, it is unclear whether these directions are statistically significant. This is what the results of the chi-square test contained in Table 2 allow us to know. These results confirm the existence of at least one preferred direction of the spatial distribution of basic infrastructures and services. Indeed, for a df = 3, the calculated chi-square 16> the theoretical chi-square (7.81) (Table 2); therefore there is a preferred direction of spatial distribution over time in the Niakhar area. These include the southwest direction.

3.4. Speed of Movement of the Center of Gravity of Infrastructure and Services Which Is Decreasing over Time

The results show that the speed of movement of the center of gravity of basic infrastructures and services varies from one period to another. Thus in the period 1970-1979, the center of gravity of basic infrastructure and services moved 2.3

Table 1. Evolution of global indicators of the spatial distribution of adopting villages.

Paramètres	Avant 1970 (1)	1970-1979 (2)	1980-1989 (3)	1990-1999 (4)	2000-2009 (5)	2010-2018 (6)
Distance standard (km)	5.17	4.5	5.81	4.9	5.92	6
Ratio Axe long/axe court de l'ellipse de l'écart-type	1.05	1.17	1.34	1.14	1.02	1.13
Vitesse moyenneannuelle de déplacement du point moyen (km/an)	NA (non applicable)	0.23	0.16	0.11	0.11	0.04

Table 2. Evolution of the number of infrastructures and services according to management.

Périodes	Nord-est	Nord-ouest	Sud-est	Sud-ouest	Total	Khi-deux
Avant 1970	7	7	7	9	30	5
1970-1979	1	3	8	14	26	4
1980-1989	3	17	12	18	50	4
1990-1999	7	17	24	29	77	1
2000-2009	17	46	52	75	190	1
2010-2018	44	83	90	147	364	1
Total	79	173	193	292	737	16*

*Significant at 5%, for a df = 3 and a theoretical chi-square = 7.81.

km southwards compared to the previous period, *i.e.* a speed of 0.23 km per year. In the period 1980-1989, it moved 1.6 km, or a speed of 0.16 km per year. The drop in speed continues during the following periods, as shown in Table 1.

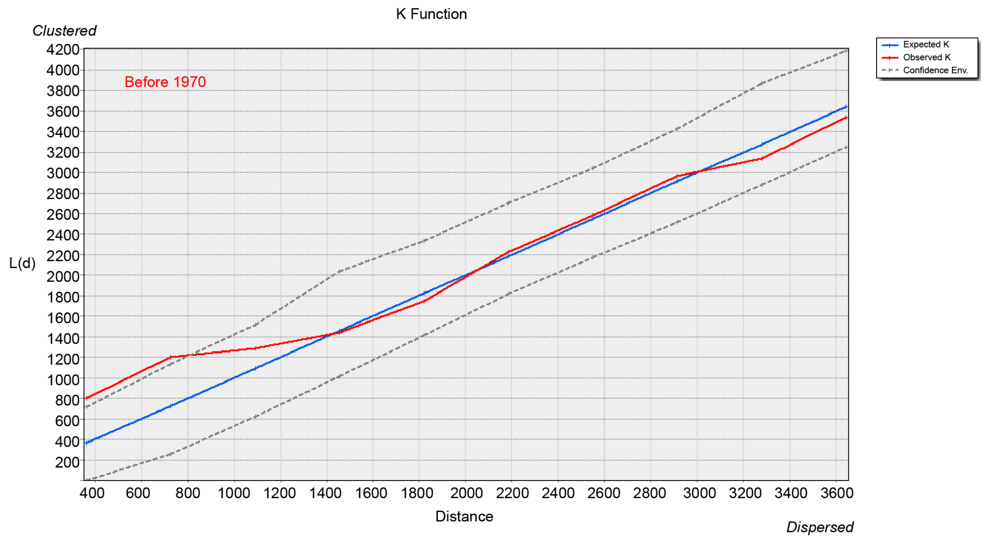
3.5. Spatial Disparities Which Tend to Increase

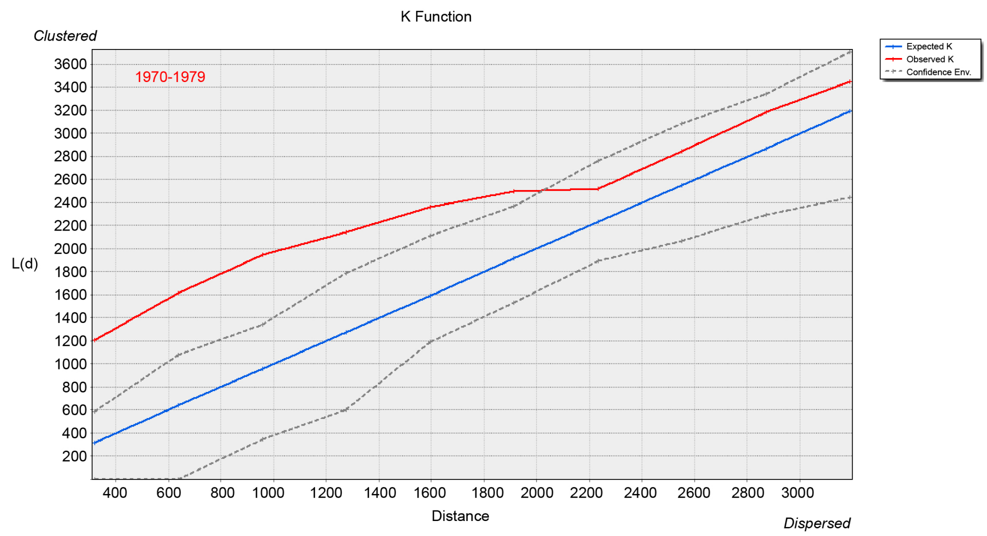
To describe spatial disparities, the standard distance, a measure of standardized difference is used (Table 1). Overall, there is a trend towards an increase in the standard distance; in other words an upward trend in spatial disparities in the spatial distribution of basic infrastructures and services. The increase in the number of basic infrastructures and services (Figure 2) has not resulted in a reduction in disparities, but on the contrary in an increase in them.

3.6. An Evolution of the Spatial Structure of Distribution of Infrastructures and Services Marked by a Tendency towards Concentration in Space

Figure 5 highlights the evolution of the spatial structure of distribution of basic infrastructures and services. Generally speaking, there is a trend towards spatial concentration of basic infrastructures and services. The analysis of the results by period, however, shows variations in the spatial structure over time.

In the first period (before 1970), the spatial structure of the distribution of basic infrastructures and services is heterogeneous. Indeed, one can observe a statistically significant spatial concentration over short distances (in the first 600


K Function
Clustered
Before 1970
L(d)
Distance
Dispersed
Expected K
Observed K
Confidence Env.


K Function
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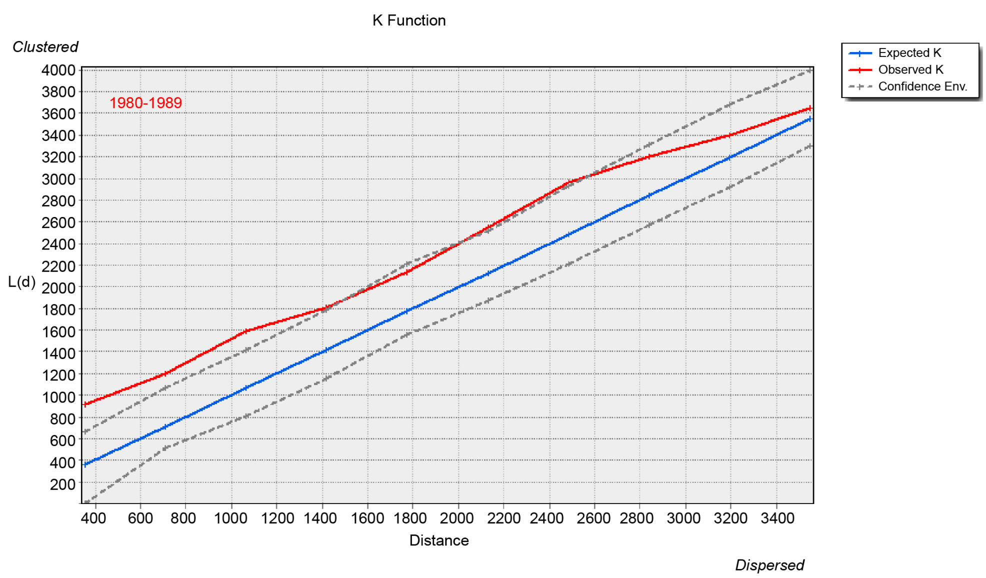
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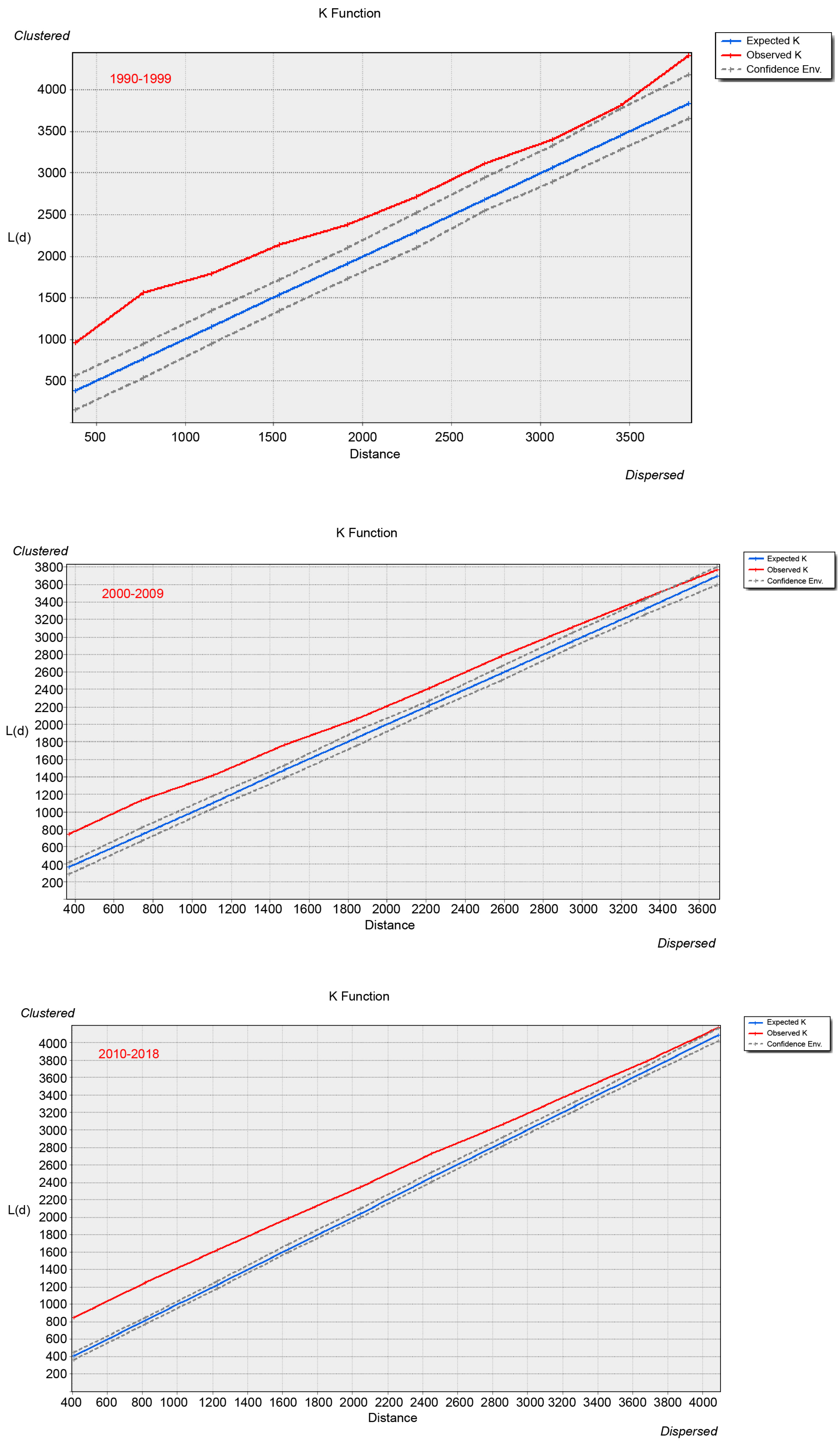

Figure 5. Evolution of the multi-distance spatial cluster of infrastructure and services in the Niakhar area.

meters), while between 600 and 3000, the distribution is random and beyond that, the distribution is more dispersed despite not being statistically significant (**Figure 5**).

During the following period, the spatial distribution still remains heterogeneous, although with differences, compared to the previous period. Indeed, a spatial aggregation in the first 2000 meters which is statistically significant is noted; but beyond that, spatial concentration is no longer statistically significant.

The period 1980-1989 is also characterized by a spatial concentration of basic infrastructures and services. But the spatial structure of this distribution is more complex than that of the previous period. Indeed, a statistically significant spatial concentration in the first 1400 meters is observed; between 1400 and 2600 m, this concentration is sometimes significant and sometimes insignificant; beyond 2600 m, a spatial concentration is still noted, which is however not statistically significant. Therefore, a statistically significant spatial centering over short distances during the first three periods can be noticed.

In the following three periods, there is a statistically significant spatial concentration of basic infrastructures and services, regardless of distance. This spatial concentration increases over time (**Figure 5**).

This upward trend towards the concentration of infrastructures and services shows that spatial disparities in the spatial allocation of basic resources have increased.

4. Discussion

Our results revealed a constant increase in the number of newly created basic infrastructures and services, a spatial distribution of the latter oriented towards the southwest. They also highlighted a decline in the shift in the center of gravity of basic infrastructures and services over time, a spatial structure of distribution of the latter marked by a tendency towards concentration in space.

In this study, demographic and socioeconomic data over the same period as data relating to the spatial distribution of basic infrastructure and services are not available. The availability of those data would have made it possible to verify the influence of population size and certain socio-economic factors on the temporal and spatial dynamics of the distribution of basic infrastructures and services. So, this situation limits the possibilities of analysis and the scope of the results. However, these limitations did not affect the quality of our results.

Thus, our results can be compared with those of the work of the [35] (relating to the census and mapping of basic socio-economic infrastructures), [36] (on medical services in the Senegal River delta), which revealed the spatial disparities in the distribution of such infrastructures. [37], in his study on the spatial dynamics and the evolution of health structures in Bouaflé (Côte d'Ivoire), he also revealed the spatial disparities in the distribution of health infrastructure and services. The work of [38] on access to and use of modern health care in urban Abidjan (Ivory Coast) also showed that despite the explosion of the private sector, spatial disparities in the distribution health infrastructure and services persist. These results are in line with ours and confirm the relevance of our approach.

The increase in the number of basic infrastructures and services, particularly from the 2000s onwards, is largely determined by State policy in terms of basic infrastructures and services. This policy has made it possible to improve the level of provision of territories with basic infrastructures and services, in particular through the national rural infrastructure project (PNIR), the drinking water for all project and support for community activities, the national rural infrastructure program and rural electrification (PNER) [5]. In addition, the role of private actors in increasing the number of basic infrastructures and services should be noted. Indeed, the location of certain infrastructures and services, such as shops, banks/insurance companies, teleservices, etc. is, in the context of a liberal economy as is the case in Senegal, linked to the action of private actors.

To try to understand the directions of the process of spatial distribution of basic infrastructures and services, it seems important to take into account the effect of the spatial organization of roads, weekly rural markets and the hierarchy of localities in the study area. Indeed, roads make localities more accessible and therefore more attractive for the exercise of several activities such as commerce. Weekly markets are meeting places that can make the localities in which they are located more attractive and therefore encourage the creation of infrastructures and services. Likewise, larger villages have greater potential for attraction than smaller ones. Therefore, they favor the creation of weekly rural markets and other types of infrastructures and services.

There is a diversity of forms of spatial distribution of basic infrastructures and services in the first two periods, revealing the differences in strategies of socio-economic actors in terms of location in the study area, levels of value of space: these levels are higher, particularly in the largest villages (Ngayokhème, Toucar, Diokhine). It suggests the existence of several spatial processes at work: contagion processes, random processes and hierarchical processes. This reflects the heterogeneity of the spatial distribution of basic infrastructures and services and socio-economic actors, contrary to what some authors such as [39] believe.

The originality of our study consists in producing diverse and complementary results combining several methods of spatial data analysis. This study may contribute to the knowledge of the phenomena of spatial distribution of basic infrastructures and services in the Niakhar zone, since so far, no study of this type has yet been carried out in this zone.

5. Conclusions

The objective of this study was to analyze the evolution of the spatial structure of the distribution of basic infrastructure and services. This objective was achieved, because the following lessons can be learned: the number of basic infrastructures and services has considerably increased; the presence of a preferred direction of the spatial distribution of basic infrastructure and services (the southwest, with a stronger spatial agglomeration). The results reveal a trend towards spatial concentration of basic infrastructures and services, particularly in larger villages.

From a methodological point of view, the use of several methods allows the production of rich and complementary results. Thus, the centrographic indicators revealed the spatial disparities, the direction of the spatial distribution, the speed of movement of the center of gravity of the sowing of basic infrastructure and services. The chi-square test helped statistically confirm the existence of this preferred direction of the spatial distribution of basic infrastructure and services. The Ripley method revealed the heterogeneity of the spatial structure of the distribution of basic infrastructures and services and especially the spatial concentration of the latter.

Our results can be useful for policies for the distribution of basic infrastructures and services in space. Indeed, the identification of different types of spatial aggregates, highlighting the preferred directions of the spatial distribution of basic infrastructures and services, providing information necessary for the correction of spatial disparities in access, to improve the spatial organization of social and economic life.

The production of these results constitutes an encouraging first step for the analysis of the spatial distribution of basic infrastructure and services. But improvements remain to be made in order to be able to measure the intensity of the effects of population size and socio-economic factors on the spatial distribution of basic infrastructures and services.

Conflicts of Interest

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

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