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Spatial Dynamics in Tenghory Commune (Bignona) and Their Effects on Vegetation

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Abstract

With the growth of urban populations, the regressive dynamics of the world's forest areas, particularly in Senegal, have been observed. This situation is manifested in precarious, spontaneous and unplanned housing, leading to urban sprawl. This urban growth also has repercussions on riverside communities, which tend to accommodate more housing due to the availability of land. As a result, urban sprawl affects natural areas, degrading forest massifs. With this in mind, we are studying the commune of Tenghory in the south of the country, in order to understand its development and the factors that could affect the town of Bignona, which borders it. The aim is to show that urban growth has an impact on forest and agricultural areas. The study of the spatial dynamics of habitat and vegetation in the Tenghory commune from 1990 to 2020 was carried out using geomatic tools such as ENVI and ARCGIS software. The methodology consisted of year selection, cartographic processing and statistical analysis. The results obtained show a progression of the built-up area in different, sometimes contradictory phases, making this study interesting, but also a vegetation cover that changes with time. Several factors have favored the evolution of the habitat, with direct repercussions on the vegetation structure.

Subject Areas

Geography

Keywords

Spatial Dynamics, Habitat, Vegetation Cover, Land Use, Forest Area

1. Introduction

Throughout the world, and in Africa in particular, strong urban growth is a fact of life. This is reflected in the spread of urban centers to the benefit of rural areas and forest ecosystems. This global situation does not spare our country. Senegal, for example, has been experiencing the same phenomenon of rapid urbanization for several years, with a rate of over 45% in 2015 [1]. However, this strong urbanization is not without consequences for forest space. It translates into rapid, uncontrolled urban growth in most cases. It also manifests itself in spontaneous and unplanned settlements, resulting in urban sprawl that reduces the space occupied by vegetation. Urban sprawl is also having a major impact on the country's forest areas, contributing to the degradation of plant resources (forest massifs) which are veritable nature reserves, made up of a variety of ecosystems. Urban expansion causes the destruction, degradation and fragmentation of biodiversity in peri-urban areas [2]. This phenomenon of urbanization alters the ecosystem functions offered by the forest to local populations. Also, through the fragmentation and sprawl of the vegetation cover, residential sprawl contributes to the disappearance of rich agricultural land, which affects farmers' yields.

With the communalization of rural areas, this urban growth is bound to create negative repercussions on these bordering territorial entities, particularly in the southern part of the country [3]. These reforms have weakened the governance of the land tenure system, especially in rural areas. In addition to its position and the prevailing security situation in the area, the town of Bignona is growing due to insecurity in remote areas. As a result, the repercussions of the movement of people to more secure areas (Bignona and its surroundings) are felt in the small rural communes bordering the town. The impact of this phenomenon can be seen in the neighboring commune of Tenghory. For these reasons, we have targeted this commune to see the consequences of the expansion of small villages and the town of Bignona on the forest area. The research carried out focuses more on population and housing growth, leaving aside the vegetation structure. As a result, the increase in housing creates problems for agricultural areas and the destruction of forest features.

Tenghory is a commune in the Department of Bignona, in the Ziguinchor Region of Lower Casamance. It is a semi-urban area with abundant forest formations. The commune boasts several classified forests (FC Kalounaye, FC Bignona, etc.) and other forest areas. Moreover, these forest massifs tend to suffer from the effects of urban sprawl. The latter is marked by the establishment of precarious and spontaneous housing, leading to an expansion of dwellings in the commune. This situation could have an impact on the forest area and also affects Tenghory's agriculture. It is in this context that the spatial dynamics of habitat on the vegetation of the Tenghory commune need to be studied. The aim of this work is to study the evolution of land use (dwellings and vegetation cover) in order to see the changes that have taken place and to analyze the factors behind them.

2. Presentation of the Study Area

The Tenghory commune is located in the Bignona department (**Figure 1**). It covers an area of 302 km^2 and comprises thirty-four (34) administrative villages. It is bordered to the north by the communes of Suelle (part) and Sindian, to the south by the commune of Niamone, to the east by the communes of Oulampane, Ouonk and Coubalan, and to the west by Balingore, Diégoune and part of Suelle. Its population was 30,743 in 2013 according to the 2013 RGPHAE [4]. The Tenghory commune is predominantly made up of Diolas, followed by Mandingues and Peuls.

Tenghory's relief, like that of the Ziguinchor regional territory, is generally flat (ANSD, 2017) [5]. In addition, the commune fits well into a watershed whose divide is located north of the village of Sindian [6]. According to the ANSD, several soil types are present in the region [7]. These include hydromorphic soils in the valleys and tropical ferruginous and ferralitic sandy or clayey-sandy soils on the basins and terraces [8]. The diversity of soils is conducive to the development of agriculture, an important sector for the Tenghory population. The relatively flat terrain contributes to good drainage of the rice-growing valleys, which are flooded in winter by the Bignona marigot and its tributaries. In addition to the marigot, the commune has a number of winter ponds, which dry up rapidly after the rainy season.

Like the rest of the Ziguinchor region, Tenghory has a Sudano-Guinean climate, with two seasons: a rainy one (June-October) and a non-rainy or dry one (November-May). Rainfall can reach 1200 mm, with an average of more than 65

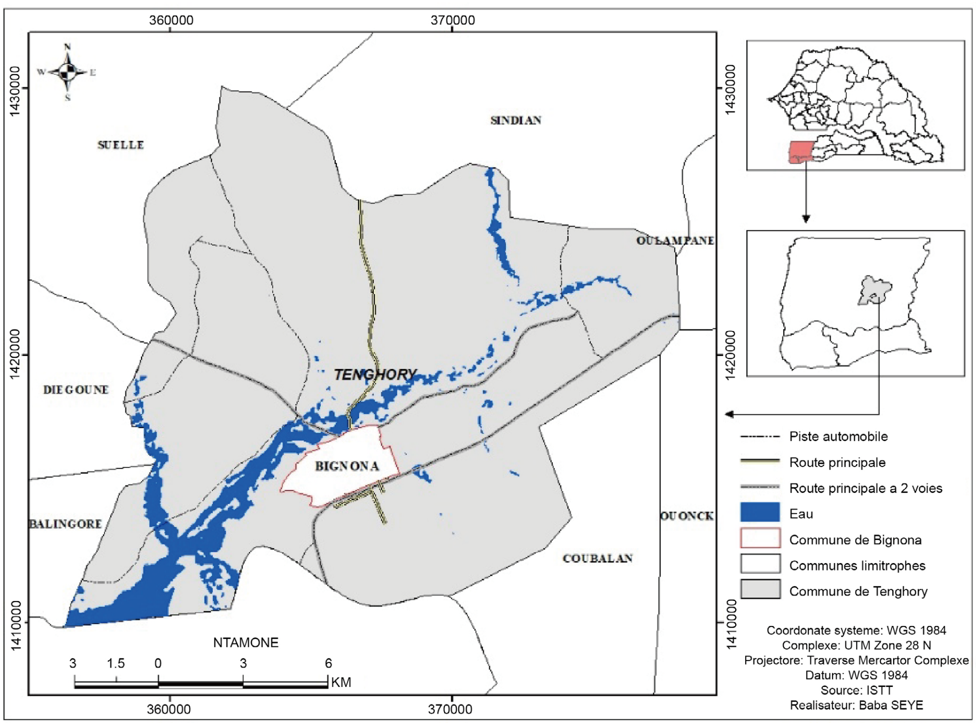

Figure 1. Location of the Tenghory commune.

rainy days, which favors abundant vegetation in the commune [9].

The region's vegetation is sub-Guinean in character. The forest estate is made up of dense forests, dry forests and gallery forests located mainly in the southern part [5]. The vegetation is made up of characteristic species such as *Parkia biglobosa*, *Khaya senegalensis*, *Azadirechta indica*, *Pterocarpus erinaceus*, *Élaeis guineensis*, etc. In addition, the commune has significant forest massifs characterized by dense forests, open forests in places and shrub savannahs [9]. Tenghory also boasts numerous classified forests, including the FC de Bignona, FC Boutolate, FC Kalounaye and FC kourouck.

3. Methodology

In order to assess the impact of habitat sprawl on the commune's forest area, the methodological approach adopted is based on documentary research and diachronic study through the selection of study years, cartographic processing and statistical analysis.

3.1. Documentation

This consists of a search for information through documentary review. In order to achieve the objectives set for this study, documentary research took us to various libraries and research centers. The amplified list is made up of documents from research centers such as the consultation of work carried out in the area but also elsewhere where this type of work has been done.

3.2. Diachronic Study

3.2.1. Selection of Study Years

The diachronic study was carried out on the basis of four (4) satellite images. The images provided by the Centre de Suivi Écologique (CSE) were acquired from the USGS site (Unites States Geological Survey, http://earthexplorer.usgs.gov). The four years selected are 1990, 2000, 2010 and 2020 (**Table 1**).

The years are chosen according to the availability of images, taking into account several factors (drought years, the Casamance conflict, the return of rainfall, etc.). The aim of the study was to start with the 1970s, a year marked by the drought of 1970-1980, but the poor quality of the 1979 image we obtained from the CSE meant that it could not be processed properly. For this reason, 1990 was used as the starting point for our land use study. The year 1990 was chosen because it gives us a view of the post-drought period of the 70s and 80s. It also allows us to see land use after a decade of conflict in Casamance, which began in 1982. A 10-year gap is maintained from 1990 for the rest of the years. The year 2000, marked by a period of calm in the Casamance conflict and a timid return of rainfall to the region, shows the evolution of land use during this period. The year 2010 shows the dynamics of vegetation, with rainfall averaging over 1000 mm. It also allows us to measure the evolution of buildings in the commune.

Table 1. Choice of images used for the land cover study.

Year	Image date Image type	Types d'image	Resolution
1990	November 1990	Landsat	30 m
2000	December 2000	Landsat	30 m
2010	November 2010	Landsat	30 m
2020	November 2020	Landsat	30 m

Source: USGS, CSE 2020.

The final year (2020) has been chosen as the reference year for our study, allowing us to see the evolution of both buildings and vegetation.

All these images were taken during the dry season to avoid any exaggeration of the vegetation. However, the month of November, corresponding to the month in which the images were taken, although close to the wintering period, allows a fair assessment of the vegetation, with the existence of a herbaceous carpet that remains for the rest of the dry season.

3.2.2. Cartographic processing

Cartographic processing was carried out in two stages (unsupervised and supervised classification and GIS processing) using two software packages (ENVI and ARCGIS). ENVI was used to classify land use units. An unsupervised classification was first carried out. This approach was justified by the absence of a reference sample of old images. It consists in asking the software to group pixels with the most uniform spectral signatures into land use classes. Using the K-means classification algorithm, it has the advantage of assigning pixels to the closest class [10]. Unsupervised classification was run on 10 classes. The classes obtained served as the basis for the supervised classification. The latter was carried out by first determining the training units or ROIs (Region Of Interest), based on their spectral signature of the images and the units defined in the unsupervised classification. ROIs are samples of pixels selected to classify the different units. The number of pixels was taken at random for each year of study. Classification was then carried out using the maximum likelihood algorithm, resulting in the different land use units obtained. Seven classes were selected. They are: water, built-up area, bare soil (including agricultural areas), tannage, dense vegetation, medium-dense vegetation and sparsely dense vegetation. To refine the classification, a test of the ROIs' separability was carried out to assess the possibility of distinguishing them correctly. The value of the class separability test averaged between 1.85 and 2, indicating acceptable classification. Post-classification processing was carried out to eliminate isolated pixels and homogenize the classes.

Finally, the classification was validated by analysis of the confusion matrix based on Using Ground Truth ROIS to check the degree of reliability of the classified image. The interpretation of the Kappa coefficient obtained from this process showed that the supervised classification was good.

Table 2 shows that the Kappa coefficient is between 0.82 and 0.89 for 1990, 2000, 2010 and 0.73 for 2020. The overall accuracy obtained is 86.7% for 1990, 91.3% for 2000, 86.1% for 2010 and 78% for 2020.

Following validation of the results, we then proceeded to GIS processing of the resulting rasters. This involves converting raster data into vector data. Identical polygons, *i.e.* those belonging to the same class, were merged into a single layer. This process enabled us to make a final correction of the land use units by superimposing them on high-resolution images (Google Earth and Sentinel 2) with the help of Arcgis software. Validation was completed by field observations and interviews with resource persons on the evolution of land use in the commune.

Arcgis software was used to format the various land use maps and their colors. *Buildings are represented by dark grey. Tans are light grey. Bare soil is characterized by yellow. Water is represented by dark blue. The gradient color of green* (from darkest to lightest) was used to represent dense *vegetation*, *moderately dense vegetation and sparsely dense vegetation*. Arcgis was also used to calculate the surface area of the area's occupancy units.

3.2.3. Statistical Analysis

This concerns the analysis of the surface areas of the land use classes and their coverage rates in the commune. This makes it possible to determine the share of each unit and measure their importance in the area for each year. The rates of change of each land use unit are also calculated, in order to study their progression over the years. It is calculated as follows:

$$T = \frac{S2 - S1}{S2} * 100$$

S1: equal to the starting year.

S2: corresponds to the year of arrival.

A positive value of T means an increase in the area of the land use class, and a negative value of T, a loss or regression of area [10]. The evolution of the expansion rate has thus made it possible to see the changes for each land use class for the different periods.

4. Results

4.1. Diachronic Study of the Local Area

The aim is to see how the commune has evolved over this period, enabling us to

Table 2. Classification accuracy statistics for Landsat images.

Image sources	Years	Kappa coefficients	Overall accuracy
Landsat	1990	0.82	86.7%
Landsat	2000	0.89	91.3%
Landsat	2010	0.82	86.1%
Landsat	2020	0.73	78%

Source: FAYE B., SEYE B., LANDSAT image processing 1990, 2000, 2010 and 2020.

assess the dynamics and draw conclusions.

4.1.1. Land Use in 1990

During this period, the work consists of studying land use, which allows us to see how the land is used (agricultural or natural) and to deduce the factors behind these changes. The map and figure below show the different types of land use and their surface areas.

Figure 2 shows the distribution of land use in 1990. It shows significant vegetation in varying degrees. Indeed, it reveals a predominance of sparsely populated vegetation. Table 3 shows that the surface area occupied by this entity is estimated at 13,067 ha, *i.e.* half the surface area of the study area, compared with 6477 ha for dense vegetation and 3086 ha for moderately dense vegetation cover. This mapping study also shows that dense and medium-dense vegetation are located in areas where protected areas (PAs) are established, such as the Bignona PA to the south, the Kalounaye PA to the southeast and the Boutolate, Kaparan and Tendième PAs to the north. The map also provides information on the surface area occupied by buildings and bare soil. In 1990, built-up land occupied a small proportion of the communal area (304 ha). Thus, land use shows that housing did not have a significant impact on the forest area during this period. Furthermore, bare soil, represented by agricultural land and empty spaces, occupies 7% of the commune.

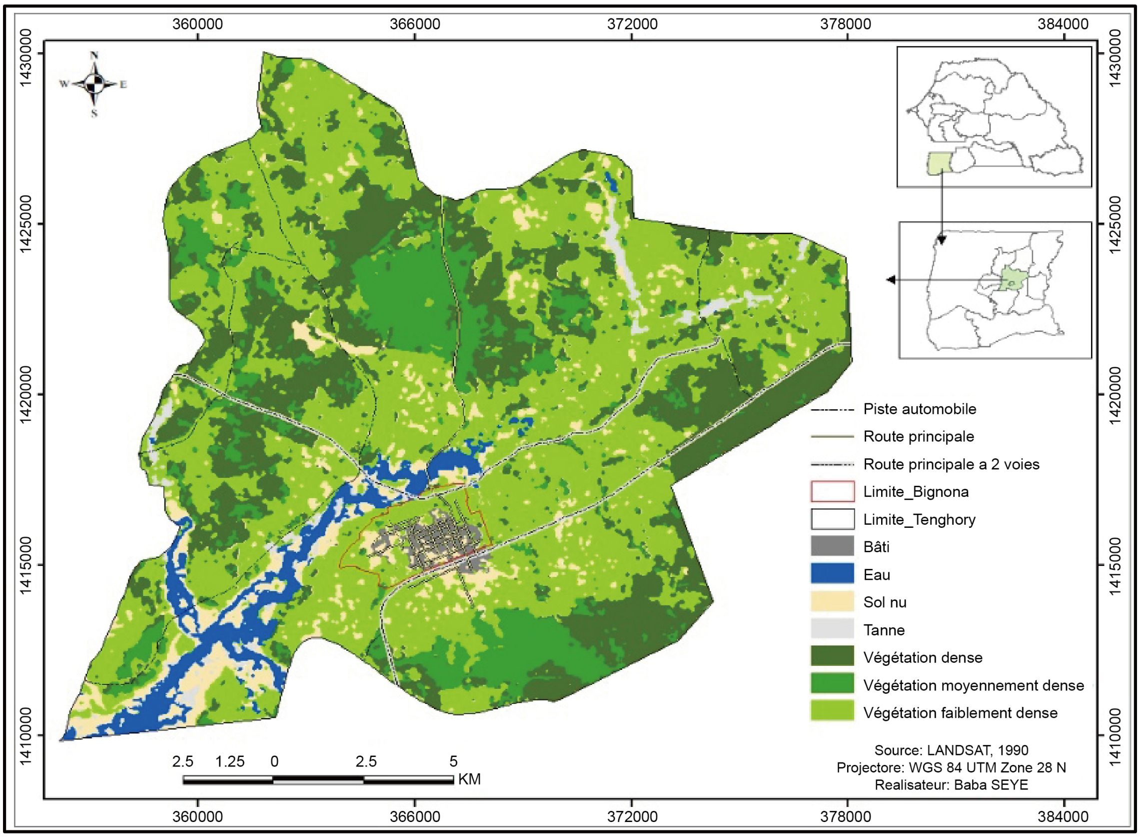

Figure 2. Land use in 1990.

Table 3. Characteristics of land use units in Tenghory Commune in 1990.

Units	Areas in (ha)	Values in (%)
Water	1069	4
Built-up	304	1
Bare soil	1891	7
Tanne	377	1
Dense vegetation	6479	25
Medium-dense vegetation	3086	12
Low-density vegetation	13,067	50
Total	**26,272**	**100**

Source: FAYE B., SEYE B., LANDSAT image processing 1990.

The map thus reflects the importance of agricultural land around residential areas.

In short, the low impact of housing and bare soil shows that the vegetation cover is not threatened, which translates into a regeneration of the plant cover, which could explain the presence of a large, sparsely populated vegetation cover.

4.1.2. Land Use in 2000

Land use in 2000 (Figure 3) shows the dynamics of urban space compared to 1990. On this date, there was a significant increase in vegetation cover, which occupied an area of 9038.8 hectares, accounting for 34% of the total area. This density was more pronounced in the northern and western parts of the city. The area covered by moderately dense vegetation was 2900 hectares, while low-density vegetation covered 40% of the total area (Table 4). The growth of dense forests may have been caused by various factors. Similarly, the growth of residential areas was relatively small, mainly concentrated in the southern part of Bignona near the village of "Tenghory Compliqué". It occupied 2% of the total area of the city. However, the area of bare land decreased to only 4% compared to 1990.

Therefore, it is worth noting that the vegetation cover density in the city increased while the growth of residential areas was slow. Observing the map, it can be seen that there was minimal, or even negligible, growth in residential areas in 2000, making it difficult to measure its impact.

4.1.3. Land Use in 2010

Land use in 2010 (Figure 4) shows an increase in the surface area of housing and bare soil. Table 5 shows a significant increase in built-up area. In fact, the surface area occupied by housing has more than doubled. It rose from 512.9 ha in 2000 to 1270.6 ha in 2010, covering 5% of the commune's territory (Table 5). Settlement is moving into forest areas, particularly in villages close to the commune of Bignona such as Tenghory Compliqué. To the south and east of Bignona, we note a regression in vegetation cover in favor of housing and bare

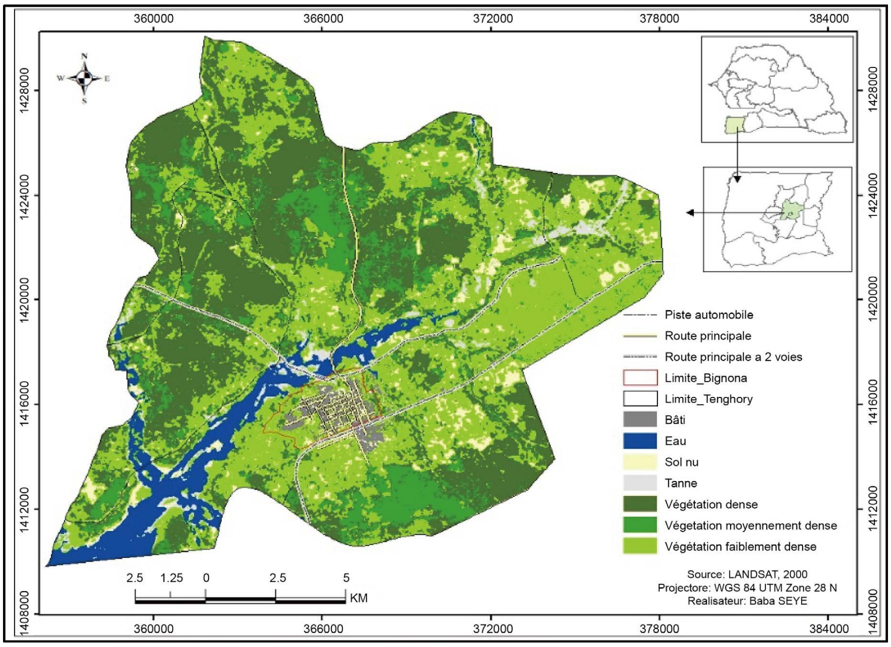

Figure 3. Land use in 2000.

Table 4. Characteristics of land use units in Tenghory Commune in 2000.

Units	Areas in (ha)	Values in (%)
Water	1642	6
Built-up	526	2
Bare soil	1059	4
Tanne	613	2
Dense vegetation	9039	34
Medium-dense vegetation	2900	11
Low-density vegetation	10,514	40
Total	**26,293**	**100**

Source: FAYE B., SEYE B., LANDSAT 2000 image processing.

Table 5. Characteristics of land use units in Tenghory Commune in 2010.

Units	Areas in (ha)	Values in (%)
Water	1543	6
Built-up	1271	5
Bare soil	2177	8
Tanne	361	1
Dense vegetation	8369	32
Medium-dense vegetation	3486	13
Low-density vegetation	8846	34
Total	**26,053**	**100**

Source: FAYE B., SEYE B. LANDSAT 2010 image processing.

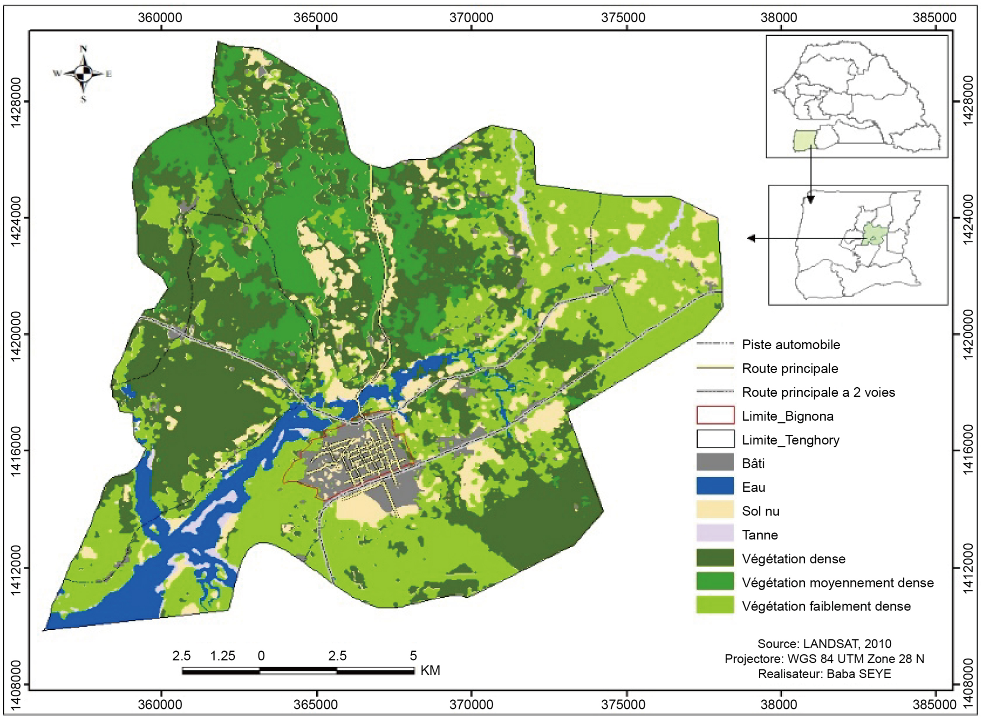

Figure 4. Land use in 2010.

soil (agricultural land). The latter also cover a significant area, with 2177.1 ha in 2010.

In contrast, the western and northern parts of the commune are dominated by dense vegetation (32%) and medium-dense vegetation (13%). The state of vegetation evolution in this area can be attributed to a number of factors.

All in all, 2010 was marked by an increase in housing, the expansion of Bignona and an increase in bare soil (agricultural land) in favor of plant cover in the south and east of the commune, dominated by sparsely planted vegetation.

4.1.4. Land Use in 2020

The trend in housing development is more marked in the commune in 2020. Figure 5 shows their distribution and level of expansion. Table 6 also shows the reduction in the surface area of dense and sparsely populated vegetation.

The surface area occupied by housing continues to grow. In fact, the built-up area is expanding rapidly throughout the commune, with a total surface area of 3018.4 ha, covering 12% of the Tenghory territory. This expansion is taking place in villages both near and far from Bignona. However, observation of the map shows that settlement growth is most pronounced in the village of "Tenghory Compliqué", located to the south and closer to the commune of Bignona.

In this zone, habitat extension covers almost all bare ground. Some habitats are even found inside forest massifs, particularly in the south in the FC de Bignona. Figure 5 also shows a gradual deterioration in vegetation cover. The increase in the area of medium-dense vegetation, from 3485.7 ha in 2010 to 5247 ha, is favoured by the reduction in dense vegetation cover. Dense vegetation is

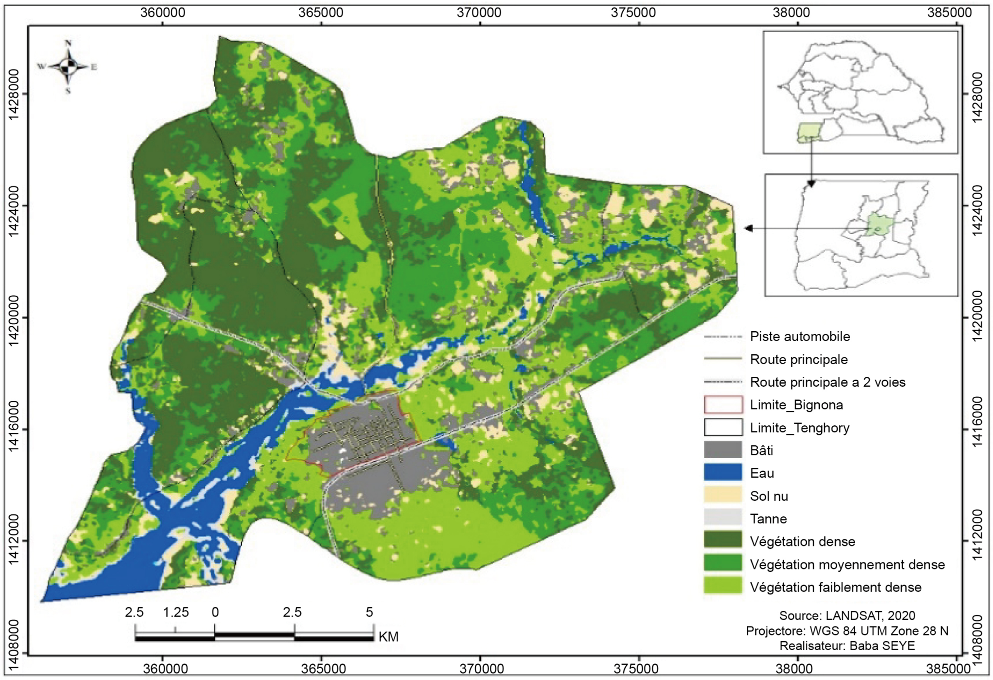

Figure 5. Land use in 2020.

Table 6. Characteristics of land use units in Tenghory Commune in 2020.

Units	Areas in (ha)	Values in (%)
Water	1756	7
Built-up	3018	12
Bare soil	1570	6
Tanne	480	2
Dense vegetation	7056	27
Medium-dense vegetation	5248	20
Low-density vegetation	7088	27
Total	**26,216**	**100**

Source: FAYE B., SEYE B., LANDSAT 2010 image processing.

only significant to the west of the commune. However, there is some reforestation in certain areas, such as near Badiouré in the east.

Thus, the map illustrates a sprawl of dwellings towards the forest area, particularly to the south in the village of "Tenghory Compliqué". However, the expansion of settlements is affecting vegetation and increasingly leading to the disappearance of arable land around housing areas.

4.2. Comparative Study and Discussion of Spatial Dynamics

After reading the individual years, it's time to look at the trends revealed by the mapping. The comparative study allows us to see the evolution of the different land use units. It helps to analyze the spatial dynamics of different years in order to get a glimpse of the changes that have taken place. The units where the emphasis has been placed are buildings, bare soil and vegetation with its different facies. **Figure 6** shows the spatial dynamics from 1990 to 2020. It compares land use over the entire mapping period and examines how it has changed.

For greater analysis, the table of evolution rates for the various units (**Table 7**) is complemented by a graph that provides a clearer view of both positive and negative rates for the different entities.

4.2.1. Analysis of Spatial Dynamics 1990-2000

Observation of the 1990 and 2000 maps shows changes in the various spatial units. It shows changes in the areas of vegetation cover, built-up areas and bare soil. Changes in vegetation density are perceptible. The rate table shows the dynamics of the different units. It shows evolution rates of 28% for dense vegetation, −6% for moderately dense vegetation and −24% for sparsely dense vegetation. These rates express a densification of vegetation between 1990 and 2000. Indeed, dense vegetation increased from 6479 ha in 1990 to 9039 ha in 2000.

Figure 6 illustrates the regression of medium and sparse vegetation cover in favour of dense vegetation. Density is most noticeable to the north, south and west of the commune. The built-up area is also on the increase. In fact, the number of dwellings in the commune has increased considerably, with a growth rate of 48%. The surface area of housing increased from 304 ha in 1990 to 526 ha

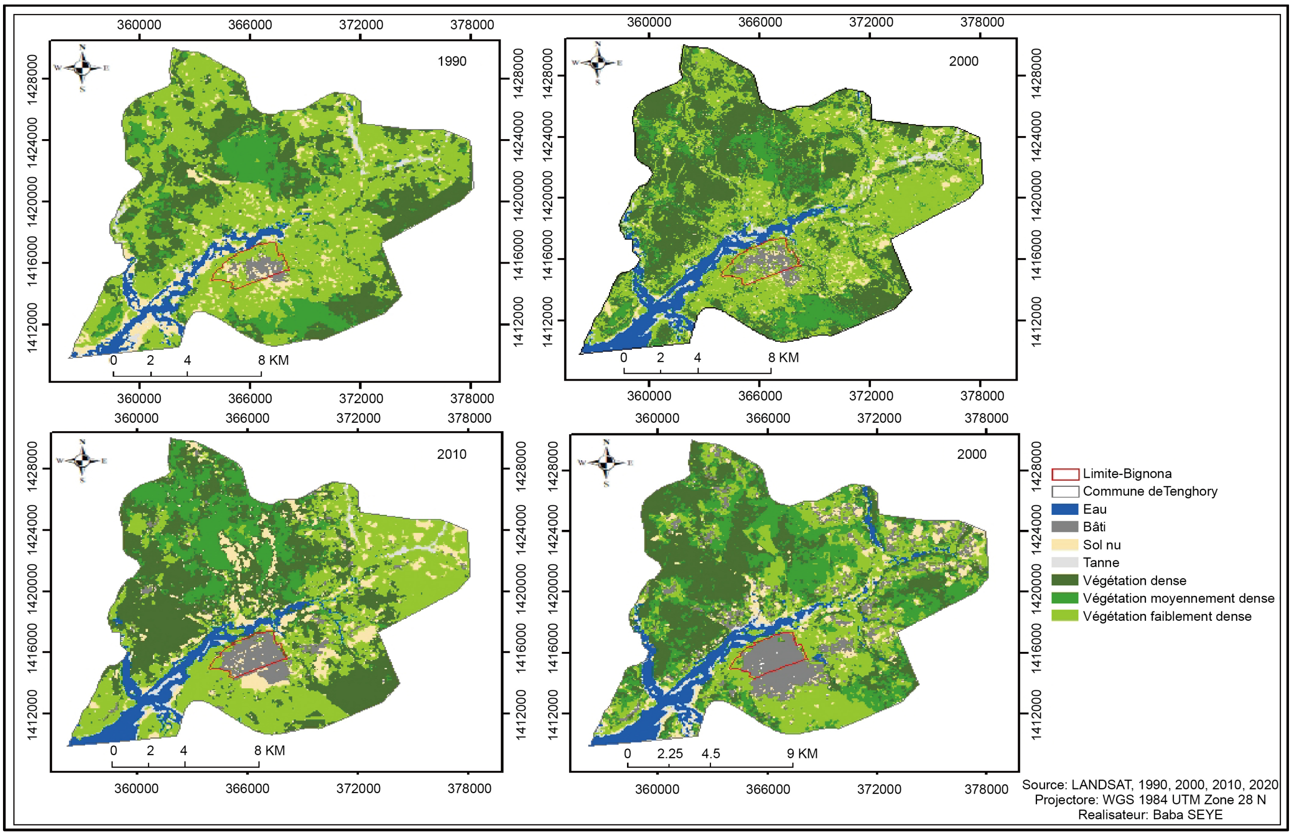

Figure 6. Dynamic map of land use from 1990 to 2020.

Table 7. Evolution rate of land use units from 1990 to 2020.

	Rate of change (%) 1990-2020			
Unit	**(1990-2000) Rate**	**(2000-2010) Rate**	**(2010-2020) Rate**	**(1990-2020) Rate**
Water	35	−6	12	39
Built-up	42	59	58	90
Bare soil	−79	51	−39	−20
Tanne	38	−70	25	21
Dense vegetation	28	8	−19	8
Medium-dense vegetation	−6	17	34	41
Low-density vegetation	−24	−19	−25	−84

Source: FAYE B., SEYE B., LANDSAT image processing 1990, 2000, 2010 and 2020.

in 2000, covering 2% of the total surface area. However, its rate of coverage makes it impossible to measure its impact on vegetation. In contrast to the built-up area, the surface area occupied by bare soil has decreased significantly. The figure above shows a negative evolution rate of around −79%. The map above shows that most of this lost surface area has been colonized by plant cover.

4.2.2. Analysis of Spatial Dynamics 2000-2010

An analysis of the data in the evolution rate table reveals the dynamics of land use on both dates. It shows that dense vegetation is in slight decline. In Table 7, for example, the rate of change is 8%, which represents a 20% reduction on the previous 1990-2000 series. Examination of the dynamic map shows that the densities observed in the North in 2000 are deteriorating, resulting in a shift from dense to moderately dense vegetation, with the latter showing a slight increase. Figure 7 shows a positive transformation, with an evolution rate of 17% compared with −6% for the previous series (1990-2000). Its surface area increased from 2900 ha in 2000 to 3486 ha in 2010. The expansion of moderately dense vegetation is also taking place at the expense of sparsely dense vegetation. The rate of change in sparsely-covered vegetation remains negative. It was −19%, compared with −24% in 1990-2000. It covered 40% of the study area's total surface area in 2000, compared with 34% in 2010. This indicates a decline in surface area. It is particularly important to the east and south-west of Tenghory. In this sector, it is under pressure from the expansion of the built-up area. However, the high rate of building expansion (59%), illustrates the significant dynamics of the habitat. Its occupied surface area was 1271 ha in 2010, compared with 526 ha in 2000. The figure above gives a clearer idea of the level of development. This trend is most marked in the south, near the commune of Bignona. This progression is towards bare soil and wooded areas.

With regard to bare soil, a significant change was observed between 2000 and 2010. The rate of change went from −79% in 1990-2000 to over 51% for this series. They cover 8% of the commune's surface area, compared with 4% in 2000.

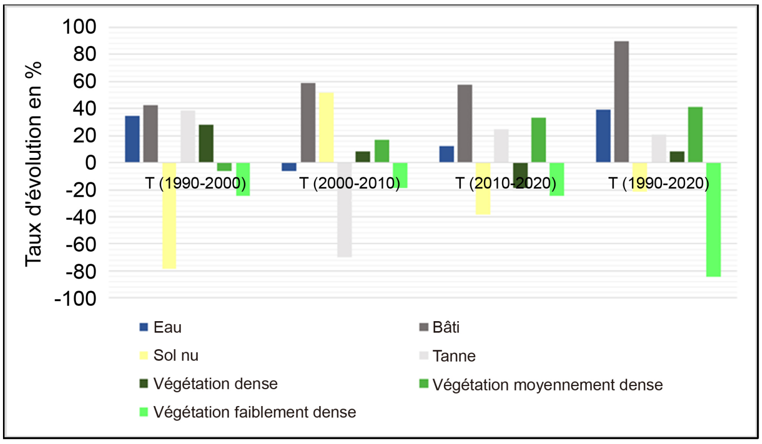

Figure 7. Distribution of land use unit evolution rates from 1990 to 2020. Source: FAYE B., SEYE B., LANDSAT image processing 1990, 2000, 2010 and 2020.

This progression may be an indicator of the importance of agricultural activities during this period. It also shows its influence on the forest area, which has retreated in some places.

4.2.3. Spatial Dynamics Analysis 2010-2020

With regard to the analysis of spatial dynamics 2010-2020, Table 7 and Figure 7 show the same trends in land use unit rates observed in the previous series, with the exception of bare soil. Built-up area is steadily increasing, as in 2000-2010. In fact, its evolution rate is 58%, which represents a strong increase in dwellings. Its surface area has increased from 1271 ha in 2010 to 3018 ha in 2020. This means that the area occupied by housing has grown by 1747 ha in 10 years. Housing growth is observed in all sectors of the commune, but is most pressing in the south, in the village of "Tenghory compliqué". The increase in housing is having an impact on bare soil (agricultural land) and plant cover. Its dynamics result in the retreat or elimination of agricultural land and the loss of forested areas. As a result, bare soil is declining sharply in the commune. Its surface area fell from 2177 ha in 2010 to 1570 ha in 2020, reflecting the downward trend in the evolution curve (Figure 7). Its rate of change, which is −39%, represents only 6% of the overall surface area. The amount of bare land in 2010 will have been largely colonized by housing by 2020.

Dense vegetation continues to regress, resulting in a decline in the density of plant cover. The rate of change is negative. It fell from 8% in 2000-2010 to −19% in 2010-2020, resulting in a reduction in its surface area estimated at 1313 ha. The deterioration of the dense vegetation is most visible in the south. However, moderately dense vegetation is increasing sharply. It has risen from 3486 ha in 2010 to 5248 ha in ha 2020, an increase of 1762 ha. Spaces occupied by low-density vegetation show an evolution rate of 34%, while low-density vegetation is in continuous reduction. The dynamic shift from habitat to forest has resulted in the loss of low-density vegetation in the south and east (Figure 5). The development of medium-density vegetation is also taking place at the expense of low-density vegetation. All these factors point to a negative rate of change (−25%), with the surface area falling from 8846 ha in 2010 to 7088 ha in 2020.

4.2.4. Spatial Dynamics Analysis 1990-2020

A study of the 1990-2020 spatial dynamics map enables us to better characterize the various changes in land use units that occurred in this study.

The results of the map processing observed reveal a real change in the environment between 1990 and 2020 as shown in **Figure 8**. Indeed, with the exception of sparsely populated vegetation, which dominated in 1990, and bare soil, all occupancy classes have progressed. Built-up areas, which were virtually non-existent in 1990 (**Table 3**), show the strongest increase, rising from 304 ha in 1990 (1% of the commune) to 3018 ha in 2020, *i.e.* an evolution rate of 90%. Housing expansion is most significant to the south and east of Tenghory. The southern part of the area is more affected by the expansion of human settlements, resulting in the loss of the dense vegetation observed in this area in 1990.

The dense vegetation is well preserved to the north and west of the commune. It increased by 8% between the two dates. The increase in moderately dense vegetation is greater after the built-up area. It rose from 3086 ha in 1990 to 5248 ha in 2020, a change of 41%. This strong progression is the result of the conversion of low-density vegetation to medium-density cover. The lowest rate of change is recorded by sparsely dense vegetation. It has been in continuous decline since 1990, with a loss of 6012 ha. Bare soils also showed a slight decline, with an evolution rate of −20%. Most of the bare soil observed in 1990 has been colonized by buildings.

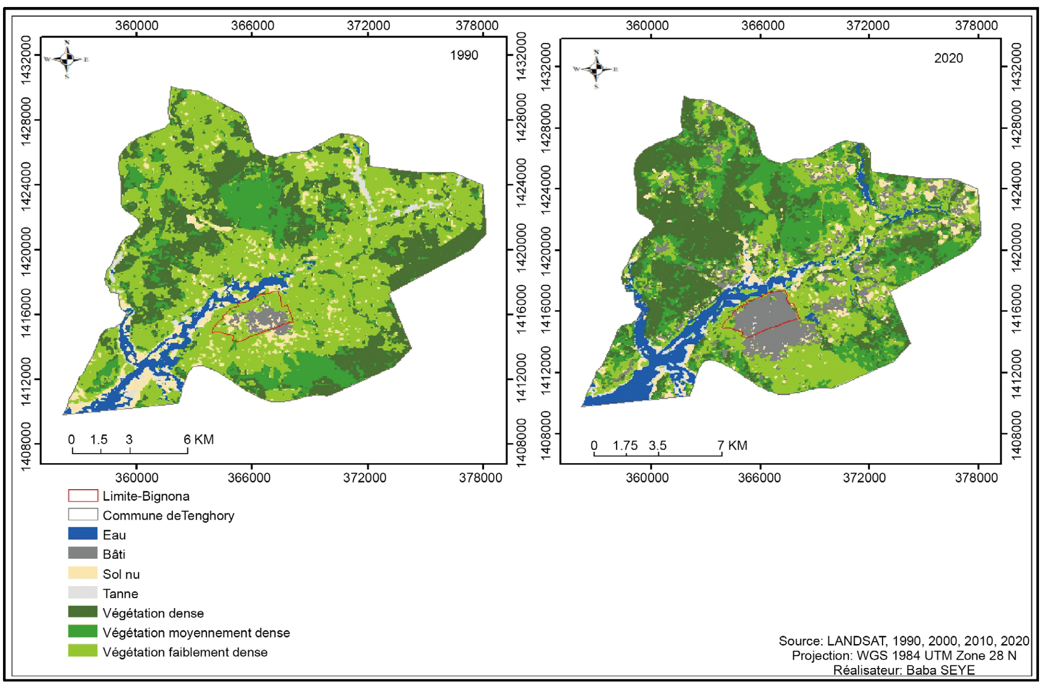

Figure 8. Dynamic land use map 1990-2020.

In view of these differentiated changes, it is necessary to specify the reasons for these variations in the communal area.

4.3. Habitat and Vegetation Dynamic Factors

4.3.1. Factors in Spatial Habitat Dynamics

Figure 9 shows a continuous expansion of the built-up area from 1990 to 2020. The shaded red color shows the expansion of the built-up area over 3 decades. It reveals that this evolution is more significant near Bignona. This growing expansion is the result of several factors.

Population growth: As in the rest of the country, the commune of Tenghory has experienced strong demographic growth in recent years. The population rose from 3518 in 2002 to 30,743 in 2013 according to the RGPHAE [4]. It is expected to reach 38,290 inhabitants in 2020 and 40,865 inhabitants in 2022 according to the Senegal population projection [1]. The fertility rate in the Ziguinchor Region is 5.5 children per woman [4]. Similarly, 84.7% of the population originate from the commune according to the results of field surveys as shown in Figure 9. However, the increase in the population is increasing the need for housing, thus favoring the fragmentation of agricultural areas and vegetation. It also puts pressure on forest resources to meet household needs for charcoal, firewood, etc. According to the municipal secretary at Tenghory town hall, "administrative housing estates are being built inside forest massifs to satisfy the demand for land for housing purposes".

The expansion of the commune of Bignona: The expansion of housing in Tenghory is also due to the effects of the expansion of the commune of Bignona. Bignona is a commune of around 686 ha, and forms an enclave within Tenghory.

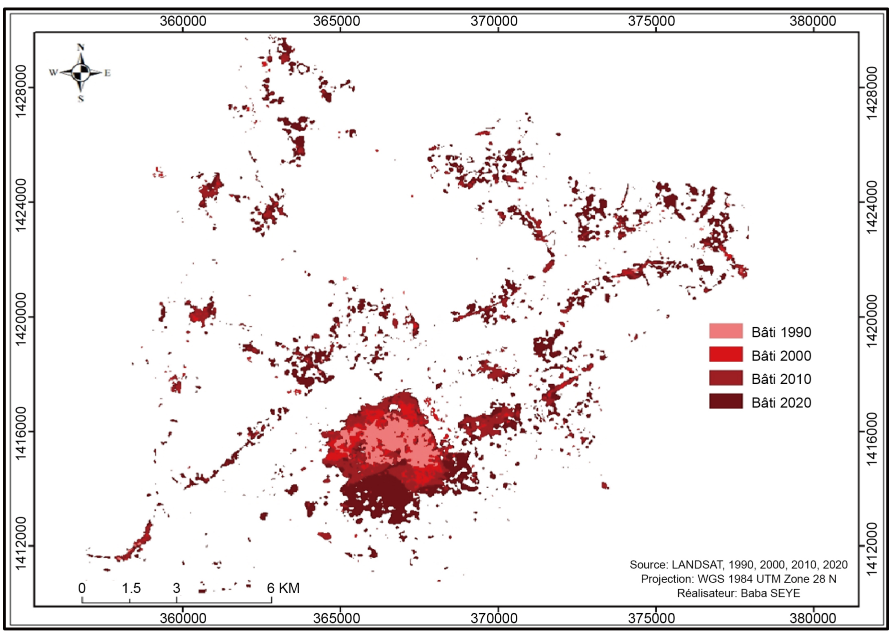

Figure 9. Building development from 1990 to 2020 in the commune and surrounding area.

The commune's small size, combined with population growth, is forcing the town of Bignona to expand towards the outskirts, encroaching on Tenghory. Indeed, 25.30% of Tenghory's population originate from other communes, mainly Bignona, and 88.4% of them have left their place of origin in search of land to live on. According to the population of Tenghory, 73.52% of the high demand for housing is due to its proximity to Bignona. However, Bignona's expansion is directed towards the south, particularly Tenghory Compliqué. In addition, the lower cost of land on the outskirts of the town is also a major factor in housing sprawl. The more affordable cost of land in Tenghory is attracting more and more people to leave Bignona to escape the high cost of land in the urban environment, causing residents to migrate from the center to the outskirts.

Proliferation of irregular housing and land speculation: In Senegal, strong demographic growth has led to housing sprawl, reflected spatially by the existence of unplotted areas, representing 30 to 40% of occupied space [11]. Indeed in Tenghory, many dwellings are built in unlotted areas, with 65.29% of the population stating that there are dwellings that are built irregularly. In the commune, 55.29% of residents confirm that housing is being built in forest areas. The 2020 land use map (**Figure 5**) reveals the presence of scattered dwellings within the forest area. Numerous housing estates and subdivisions are located in forested areas. These areas are subject to considerable land speculation. This leads to subdivisions and, in some cases, irregular appropriation of certain areas. Land speculation also means that many people flock to forest areas in search of land on which to live. The image below shows the fragmentation of forest land for housing.

As shown in **Figure 10**, population growth, irregular settlement patterns, etc. are among the factors contributing to the spread of housing, leading to the degradation of vegetation and fertile farmland on the outskirts.

4.3.2. Factors Explaining Vegetation Dynamics

The diachronic study from 1990 to 2020 revealed an overall regressive vegetation dynamic, although there was some progress in places. Vegetation evolution is

Figure 10. Parcel of land for housing in the Tenghory Compliqué forest. Photo: FAYE B., SEYE B., field study, 2021

the result of several factors:

Vegetation regression is due in most cases to anthropogenic factors. It is more marked to the south and east of the commune. Regression is due to the increase in human settlement, which has been growing steadily in recent years. It covered 12% of the commune's surface area in 2020, compared with 5% in 2010. However, this expansion is directed towards the forest area, causing the latter to shrink. The high demand for housing and the increase in population have led to the sprawl of wooded areas, resulting in the degradation of vegetation. Added to this is the exploitation of forest resources. They are the main source of food for the local population. They provide the population with firewood and charcoal for cooking, and are also their main source of income, which is putting considerable pressure on forest areas, particularly in the south. In addition, land clearing for agricultural purposes and abusive logging are accentuating the degradation of vegetation in the south and east of the commune. The photos below show the two types of felling used, both contributing to the deterioration of wooded areas.

According to the SN/PNAB, the irrational exploitation of energy wood (firewood and charcoal) and timber leads to the degradation of numerous plant species and forest ecosystems [12].

In addition, bushfires, which are increasingly frequent in the commune's localities and are mostly caused by farmers slash-and-burn in cultivated areas that

Figure 11. Wood cut with a chainsaw Photo 3: Wood cut with an axe. Source: FAYE B., SEYE B., field survey June (2021).

Figure 12. Degradation of vegetation by bush fires at Badiouré. Source: FAYE B., SEYE B., field survey June (2021).

encroach on forests, lead to the degradation and destruction of natural habitats as shown in Figure 11. Their impact on the forest is harmful.

Agriculture also affects forest areas. Clearing is a factor contributing to the degradation of vegetation in agricultural areas as shown in Figure 12. In the commune, this is most often done by axe. The demand for arable land is driven by the colonization of agricultural land by new settlers, prompting farmers to turn to the forest, resulting in the retreat of forest areas in some places.

The progression of vegetation is most visible to the north and west of the commune (Figure 6). As shown in Figure 13, the densification observed in these areas is the result of several factors.

Variations in rainfall play a key role in vegetation regreening. It is well known that rainfall patterns influence vegetation by influencing soil formation and development. Above all, however, it has a direct impact on plant formations, conditioning their spatial distribution [13]. Analysis of rainfall data at the Ziguinchor station from 1991 to 2020 reveals an average of over 1200 mm of rainfall/year. Figure 14 below shows rainfall in the area.

Figure 13. Clearing of an agricultural area at Koutenghor. Source: FAYE B., SEYE B., field study June (2021).

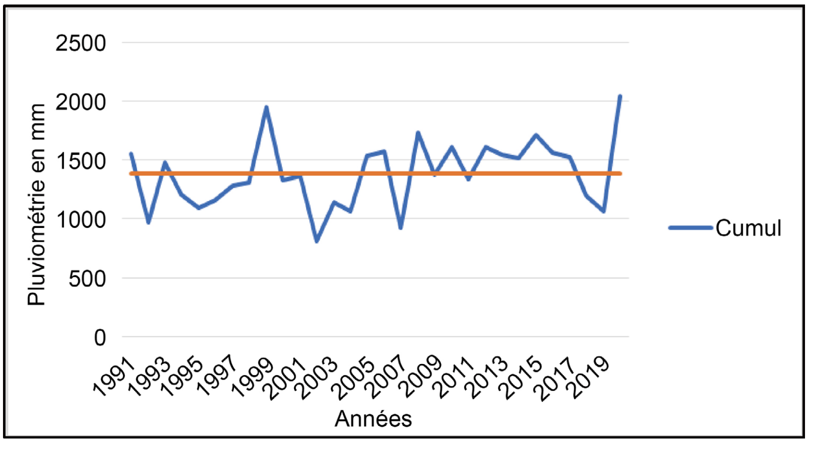

Figure 14. Interannual rainfall trends at Ziguinchor station from 1991 to 2020. Source. FAYE B., SEYE B., (2021), ANACIM data.

Figure 14 shows abundant rainfall for most years. The trend curve shows that rainfall has remained constant over the last 10 years. It shows that surplus years are more important than deficit years. Only three years are in deficit: 2011 (1341.7 mm), 2018 (1200.7 mm) and 2019 (1068.2 mm). This trend in rainfall is an essential factor in the development of vegetation, with abundant rainfall.

The densification of vegetation, under the effect of abundant rainfall, is also favored by the low population density in northwest Tenghory. The low population concentration in these areas favors good vegetation development, as it is not subject to great pressure. This area is also marked by the presence of classified forests such as the Kaparan FC, the Boutolate FC, etc.

In addition, the lull in the Casamance conflict is an important factor. Indeed, the climate of security that has prevailed in the region since the 2000s has enabled the Water and Forestry Service to exercise greater control over forest areas. This has helped to combat illegal logging, particularly of Vene (*Pterocarpus erinaceus*), a species highly prized for the quality of its wood. The presence of mines also prevents the population from gaining access to certain forest areas.

4.4. Discussion

Several studies have examined the spatial dynamics of settlement and vegetation. Many of these studies have revealed an increase in housing in towns and their outskirts, and a regressive dynamic in wooded areas.

In fact, the development of housing in the Tenghory commune has accelerated in recent years. Its surface area has increased from 1271 ha to 3018 ha between 2010 and 2020, *i.e.* an evolution rate of 58%. It is marked by rapid, spontaneous and unplanned progression, as in most low-income countries according to the FAO [2]. Like the current dynamics of Ziguinchor, which is constrained in places by the physical environment, growth is taking place in the direction of communes such as Bourofaye, Boutoute, etc. [14].

The expansion of housing in Tenghory is also moving towards the south and east of the commune particularly in the locality of Tenghory Compliqué (to the south). The sprawl of housing in this area is the result of population growth and strong housing demand, increasing the surface area occupied by housing. It is similar to that observed in the commune of Tambacounda. In this commune, we are increasingly witnessing the fragmentation of forest areas as part of the housing program to satisfy the growing demand for housing, pushing the municipality to free up more space to satisfy the population. This situation accentuates the extension of the municipality, representing a danger for the forest [15]. The evolution of housing has effects on the periphery particularly on vegetation just like that noted in France, where peri-urban natural spaces suffer the effects of city growth [16].

The impact of habitat dynamics on vegetation in Tenghory is identical to that observed in Abidjan, where urbanization of the city has been to the detriment of forest cover [17]. The metropolis exerts a strong influence on agricultural production areas and thus contributes to the degradation of the Ivorian forest environment. The same phenomenon can be seen in Tenghory, where settlement has led to the retreat and degradation of vegetation and the disappearance of rich farmland.

Moreover, vegetation dynamics are generally regressive in the commune. The regression of forest areas is the most visible phenomenon [18]. Indeed, according to Ozenda, it is often excellent land and particularly important plant formations such as peri-urban forests that bear the brunt of urbanization, resulting in irreversible soil loss. The municipality's forests are characterized by low-density vegetation and medium-density vegetation. The adverse effects of urbanization are the most decisive factors in the degradation of Tenghory's vegetation, as in the sacred forests of Oussouye [19]. The negative impacts of urbanization have led to a reduction in the area of the city's sacred urban forests. In addition, the retreat of forest massifs is the result of pressure from the exploitation of forest resources (timber, charcoal, etc.), cutting and clearing for agriculture, as in the city of Pointe Noire. In this city in the Congo (formerly Zaire), pressure from human activity is increasing as Pointe Noire's need for wood for energy increases, leading to changes in the forest landscape [20].

5. Conclusions

The study of the spatial dynamics of habitat and vegetation has enabled us to observe their evolution in the communal area from 1990 to 2020, a period of 30 years. The evolution of housing in recent decades has been gradual. The spread of housing has been more visible since 2010, particularly to the south of the commune, affecting forest and farmland. A comparative analysis of the different vegetation types was also carried out, helping to define the characteristics of the vegetation, *i.e.* dense, moderately dense and sparsely dense vegetation. In addition, the comparative analysis of different years highlighted the various changes in vegetation cover. It reveals that settlement expansion first colonizes rich agricultural land, before nibbling away at the Tenghory forest massifs. These changes in vegetation are manifested by a decrease in density and the encroachment of wooded areas.

The study also analyzed the factors behind the spatial dynamics of habitat and vegetation. The analysis of explanatory factors shows that the increase in built-up areas recorded in recent years is the result of demographic growth, proximity to the nearby town of Bignona, the proliferation of irregular settlements and land speculation. It also showed that vegetation has a regressive and progressive tendency, depending on the location. The factors driving vegetation dynamics are both anthropogenic and natural (rainfall variation in the area).

Thus, it is important to see the impact of habitat dynamics on the forest area of the Tenghory commune in order to measure their consequences for the local inhabitants. The destruction of ecosystems disrupts the natural functioning of things, and this has repercussions on the living beings that use them to satisfy their needs.

Conflicts of Interest

The author declares no conflicts of interest.

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