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RESEARCH ARTICLE

SPATIAL DYNAMICS OF THE CITY OF AZOVE (BENIN)

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ABSTRACT

In the midst of space-time mutation, the city of Azovè is characterized by galloping population growth and horizontal dynamics of agglomeration zones. This research presented the city's spatial dynamics between 2005 and 2023 using cartography. Data were first collected through individual interviews with 120 households and by taking geographical coordinates of existing infrastructures. Cartographic production was based on Landsat TM 2005 and Landsat Oli-Tirs 2023 images downloaded from www.earthexplorer.com using ArcGis 10.7 software. The Excel 2016 spreadsheet was used to calculate proportions and produce figures of the interviewees' responses. The results showed that the land-use units in the urban space are forests and savannas, forest and fruit plantations, crops and fallow land, crops and fallow land under oil palms and agglomerations. Field mosaics and fallow land under oil palms have lost 310 ha to fields and agglomerations. This dynamic is the direct cause of the increase in the built-up land linked to subdivisions (23.12%), the reduction in traditional housing (22.31%), and in farmland (21.10%), the presence of foreigners from Togo with cross-border trade (18.46%) and the increase in infrastructure (15.01%). From 2005 to 2023, the city's socio-community infrastructures evolved with the agglomerations, making the city a center for goods and people exchange.

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INTRODUCTION

Large cities are undergoing profound and rapid changes linked to both internal and external interactions (F. Eddazi, 2011, p. 37). These transformations are perceptible in the spaces that these cities occupy and are due to demographic growth, migratory and commercial flows. These are the key factors of development (V. Azandégbé *and al*., 2019, p. 77). The spatial dynamics of cities in the developing countries of sub-Saharan Africa have a number of distinctive features. It is recent and is taking place at an increasingly accelerated pace; it is manifested by the spread of its urbanized surface (D. M. Baloubi, 2018, p. 120). At the level of state borders between two countries, this dynamic is particular and is observed through movements at border level, creating connection points and contact between two different socio-economic systems (A. Vigani, 2011, p. 98; A. C. AGBON, 2015, p. 23). In the case of Africa, the urban population grew from 27 to 567 million between 1950 and 2015, with almost half of them living in agglomerations of more than 10,000 inhabitants (P. Heinrigs, 2021, p. 19). Spatial mutations thus appear as major facts in the contemporary history of sub-Saharan Africa, especially from 1960, the year of independence (D. S. Claude and *al*., 2021, p. 68). However, these mutations have consequences on the occupation of space in cities, contributing to the degradation of plant cover (F. Moriconi-Ebrard, 2020, p.3) and the disappearance of traditional dwellings in favor of modern and semi-modern dwellings. Benin, for its part, is experiencing very noticeable urban growth, with the urbanization rate rising from 35.7% in 1992 to 38.9% in 2002, before reaching 44.6% in 2013 (D. Houssou, 2016, p.6). This increase observed between 2002 and 2013 is due to the fast development of certain cities, particularly in the south of the country, such as Cotonou, Abomey-Calavi, Porto-Novo, Ouidah, Grand-Popo, Lokossa, Aplahoué and Bohicon. The growth of these cities is achieved by extending into the outskirts, creating new neighborhoods (T. Agossa, 2021, p. 112). Cities then extend beyond their initial boundaries and infiltrate the rural world. The district of Azovè, located in the commune of Aplahoué, has not been spared this urban sprawl into rural areas (INSAE, 2005, p.16). Indeed, Azovè's geographical position makes it a crossroads for flows from the Republic of Togo to the west, the Department of Zou to the north, the Department of Mono to the south, and agricultural products from the rural areas of the commune of Aplahoué to the east, making it a truly dynamic cross-border economic and social space (S. A. Vissoh, 2021, p.575).

These findings raise the following question: what are the spatial dynamics of the city of Azovè between 2005 and 2023? The aim is to analyze the dynamics of Azovè's urban space using maps.

MATERIALS AND METHODS

Study environment: Located in the south-east of the commune of Aplahoué in the Department of Couffo, the town of Azovè lies between 6° 55' 16" and 7° 00' 14" north latitude and between 1° 41' 26" and 1° 43' 56" east longitude. It extends over an area of 51.56 km2 (figure 1).

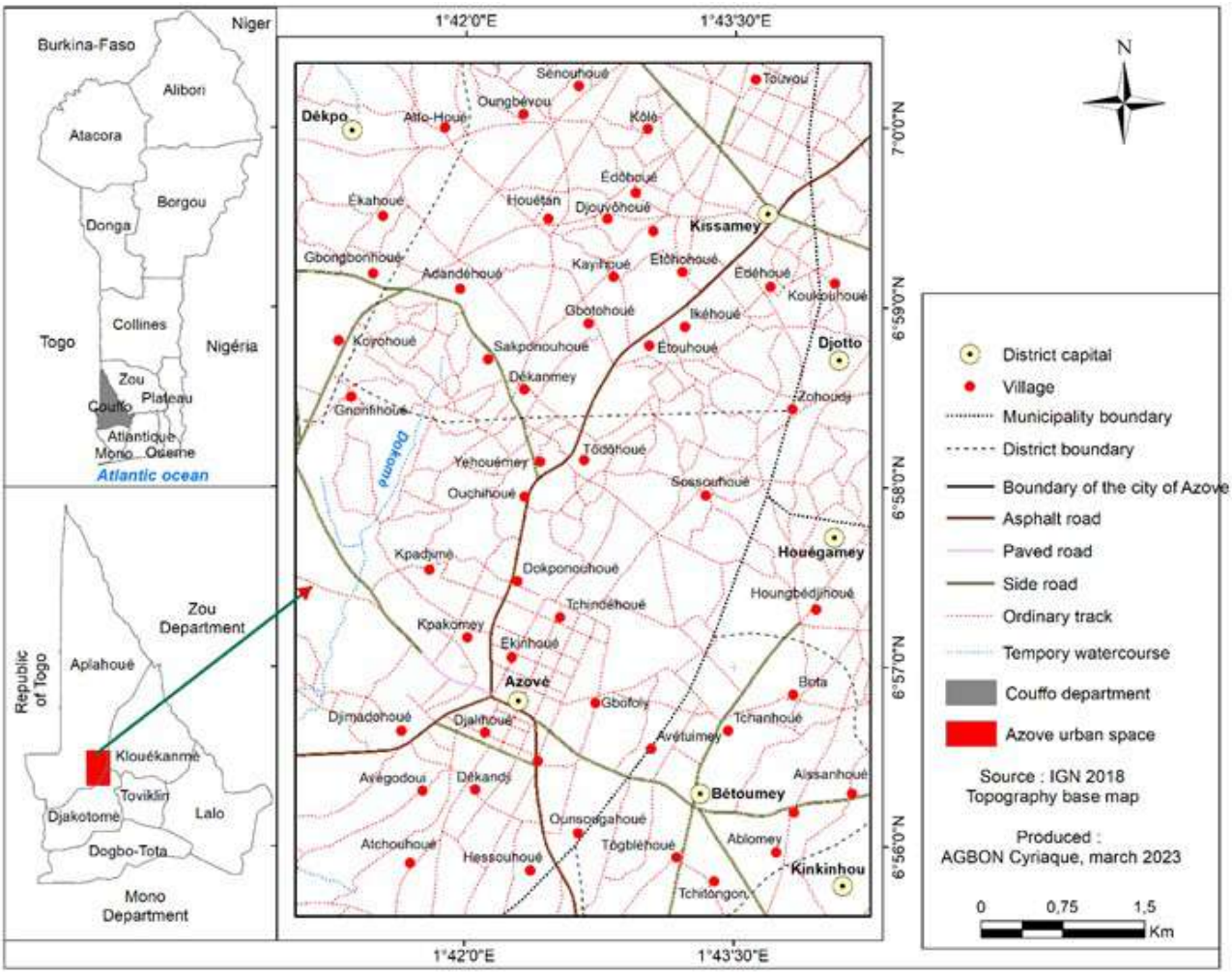

Figure 1. Geographical and administrative location of the town of Azovè

Data collection techniques: Two data collection techniques were used: the collection of documents, planimetric and demographic data, and field surveys based on sampling.

Documents, planimetric and demographic data collection: Two (02) satellite images were used for cartographic production. These were Landsat TM images (15 m resolution) from 2005 and Landsat Oli-Tirs images (10 m spatial resolution) from 2023, all downloaded from earthexplorer.usgs.gov in Geotiff format, to analyze spatial dynamics. Vector data (shapefile) of the road network, hydrographic network, localities and administrative boundaries of the city were extracted from the National Geographic Institute's 1/50,000 topographic map of 2018. Documents relating to the research topic were collected and read (see bibliographic reference). Data on population trends in the city's localities were extracted from the INSTaD (*National Institute of Statistics and Demography*) database, formerly known as INSAE (*National Institute of Statistics and Economic Analysis*) from 1979 to 2023. Files on the town's subdivision operations were also taken from Aplahoué city hall.

Field data Collection: Data was collected in the field by means of questionnaire surveys and geographical coordinates. Questionnaire surveys were carried out by means of individual interviews with people from several socio-professional categories resident in the town. These included farmers, traders, transporters and town planning officials. Survey sheets and interview guides were designed to guide these exchanges. The sample size was determined using the formula of J-P. Beaud and B; Marien (2003): n = N x 400/N + 400; where n = sample size; N = total number of households in the town of Azovè; n = 9920 x 400/9920 + 400; n = 384.49; a rate of 30% was applied, giving: n = 384.49 x 0.3 = 115.34 or 115 people interviewed.

The data collected are essentially people's perceptions of the factors driving the city's spatial dynamics, the problems associated with these dynamics and the level of land transformation. In addition to these surveys, the geographical coordinates of the existing infrastructures with the date of installation were taken using Locus Map.

Data processing techniques: Data processing followed several stages: the production of land-use maps over two dates, population trends, subdivision trends, and the dynamics of Azovè's socio-community infrastructures. The cartographic processing method used to analyze land-use dynamics was on-screen digitization. A digital interpretation of the 2005 and 2023 images was carried out, enabling the attribute table and area calculation for each year to be brought out, and the transition matrix to be produced. Next, the geographical coordinates of the socio-community infrastructures were downloaded onto the computer and used to create a database containing the dates of installation and categorized into two periods (2005 and 2023). Data on the population of the city's districts from 1979 to 2013 obtained from INStaD, together with a simulation of the population in 2023, were inserted into the attribute table for the localities of the city of Azovè. Categorization was performed using the *Graduted symbols* tool in *Quantities* under ArcGis 10.7. Population density was also analyzed. Subdivision operations were carried out in 1984, 1998 and 2007. The map was produced using two time periods: subdivisions made before 2005 and subdivisions made after 2005 to standardize the maps. Data on topography, buildings, agricultural area, natural degradation and human actions were superimposed to present a synthesis of the spatial dynamics of the city of Azovè. A cartographic correlation was made between land use, housing developments, demographic evolution and the town's spatial dynamics. This made it possible to analyze the spatial dynamics of the city of Azovè. The ArcGis software was used to carry out all these cartographic analyses.

The survey forms and interview guides submitted to the populations were stripped and coded to form a database on the Excel 2016 spreadsheet. Using the same spreadsheet, response frequencies were automatically calculated to analyze the population's perceptions by producing graphs.

RESULTS

The spatial dynamics of the city of Azovè have been analyzed based on a synthesis of population dynamics, subdivision operations, land use and socio-community infrastructures.

Population dynamics in Azovè from 2002 to 2023: The population of Azovè rose from 76,557 in 1992 to 109,647 in 2002, and from 162,178 in 2013 to 257,820 in 2023. These figures testify to a rapidly growing population. Population density has also varied across the city (Figure 2).

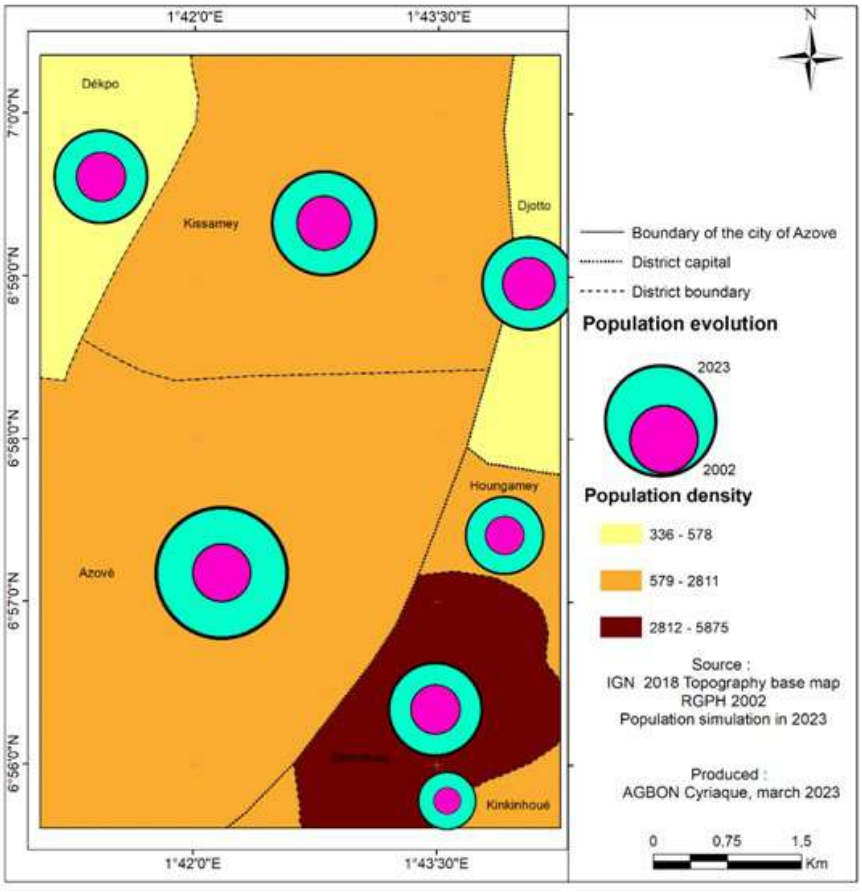

Figure 2. Population density in 2023 and population trend from 2002 to 2023

Analysis of figure 2 shows that population density is high in the Bétoumey district, average in the Kinkinhoué, Houngamey Azovè and Kissamey districts, and low in Djotto and Dékpo. Although density is average in the Azovè district, strong demographic growth has been recorded and the city's urban center is expanding to occupy the rest of the district.

Development of subdivisions in Azovè: Pre-1910 subdivision operations were carried out in the Aplahoué center district. Those for the city of Azovè and surrounding areas were carried out successively in 1984 in Azovè, and in 1998 in Zohoudji, Aplahoué, Kpakomey and Avégodui-Djimadohoué. In 2007, they were carried out in Gbofoly and Ouchihoué, before being repeated in 2025 (Figure 3).

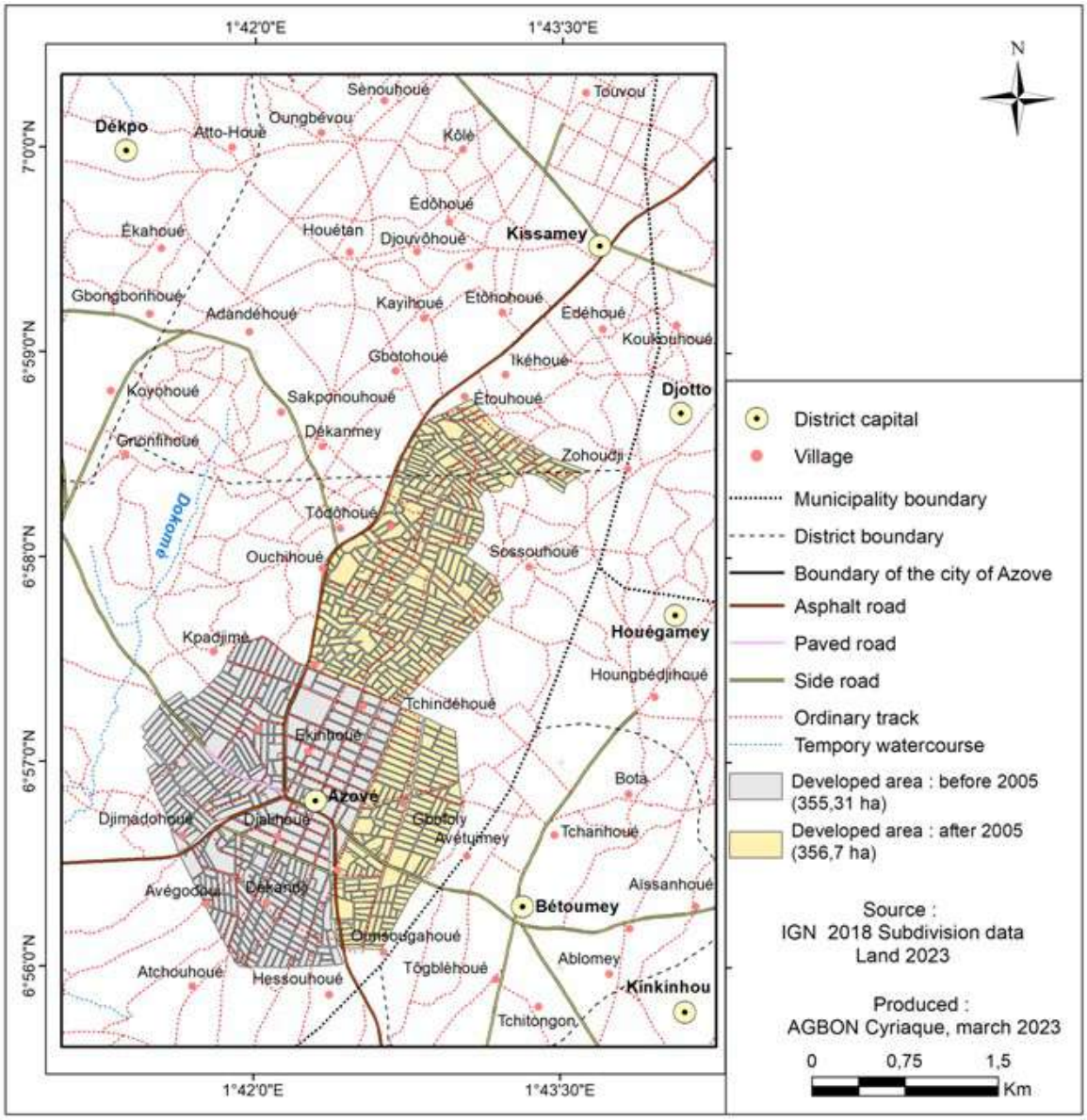

Figure 3. Subdivisions dynamics in the town of Azovè

According to Figure 3, subdivisions that took place before 2005 cover an area of 355.31 ha. They were made in the center of Azovè and from 2005 to the present day, they cover an area of 356.7 ha and occupy the north and east of the city. These operations have continued right up to the present day, and played a significant role in the city's urbanization process. These subdivisions are currently underway in Todôhoué, Dékanmè and Gbotohoué.

Land use dynamics in Azovè between 2005 and 2023: The results of the interpretation enabled to distinguish six (6) land-use units in the city between 2005 and 2023. These are swamps, forest and fruit plantations, crops and fallow land, crops and fallow land under oil palms and agglomerations (figure 4). Land-use units have undergone a dynamic change in surface area, with a major shift observed in agglomerations, crops and fallow lands. These changes have reduced the area of other units, in particular fields and fallow lands under oil palms. However, some of the fields and fallows have been transformed into forest plantations. The significant evolution of the agglomerations is recorded during this period due to the population growth described above. This development took place mainly in the heart of Azovè center towards the outskirts of the town (table 1). The content of this table confirms that some occupancy units regressed during this period. Crops and fallow land under oil palm have lost 307 ha and 3 ha respectively to crops and agglomerations.

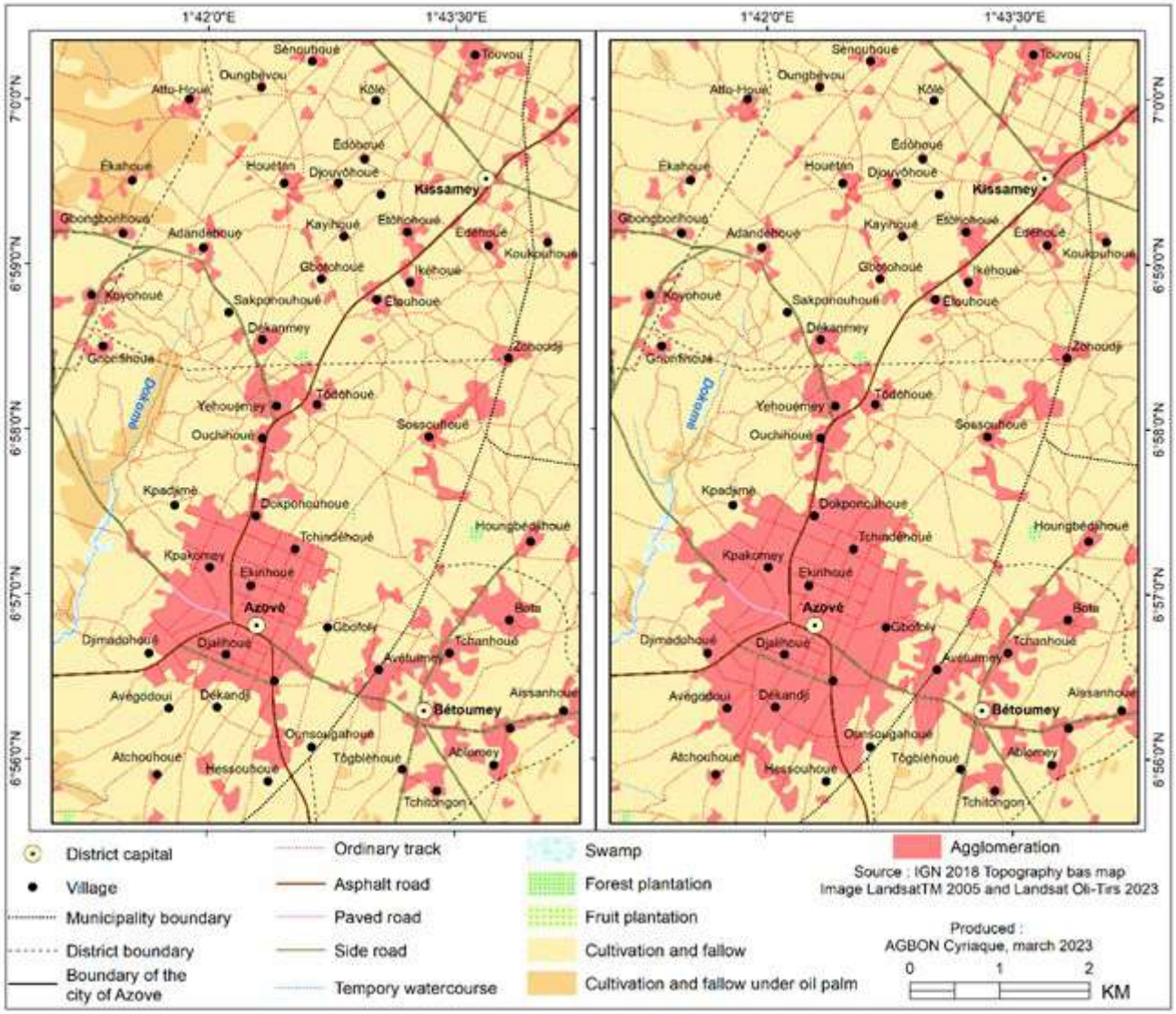

Figure 4. Land use units in the city of Azovè between 2005 and 2023

Table 1. Conversion of land-use units

Land use	M	PTFR	PTFT	CJ	CJP	HA	Total in 2005	Loss
M	15	0	0	0	0	0	15	0
PTFR	0	8	0	0	0	0	8	0
PTFT	0	0	1	0	0	0	1	0
CJ	0	0	0	3646	2	321	3969	323
CJP	0	0	0	307	44	3	355	311
HA	0	0	0	0	0	809	809	0
Total in 2023	15	8	1	3953	46	1134	5157	
Gain	0	0	0	307	2	325		

Legend: FSM: Swamp, PTFR: Forest plantation, PTFT: Fruit plantation, CJ: Crop and fallow, CJP: Crop and fallow under palms, HA: Agglomeration

Fields and fallow land lost 323 ha to agglomerations. Between 2005 and 2023, the agglomerations' areas increased by 325 ha. This dynamic is linked to the galloping growth of the population, the infrastructures available in the city and the various subdivisions. A comparative analysis of figures 3 and 4 shows that the urban agglomerations are concentrated in the areas where the subdivision operations have taken place. These figures confirm the surface area gained by agglomerations between 2005 and 2023. These subdivisions have contributed to the rapid urbanization of the city, the rise in plot prices and the modernization of buildings by foreign buyers of plots from outlying cities.

Spatial dynamics of Azovè's socio-community infrastructures: Azovè's socio-community infrastructures have also evolved (Figure 5), as have its population and land use, making the city a center for the exchange of goods and services. Trading infrastructures are the real foundation of these dynamics. A total of 86 infrastructures were recorded in the city, including 37 in 2005 and 49 in 2023. Road infrastructure underwent a number of changes during this period. The main road linking Azovè to the city of Aplahoué and the Republic of Togo has been upgraded, and is the main and most popular road for the movement of goods and people, along with the Azovè-Lokossa and Azovè-Abomey routes.

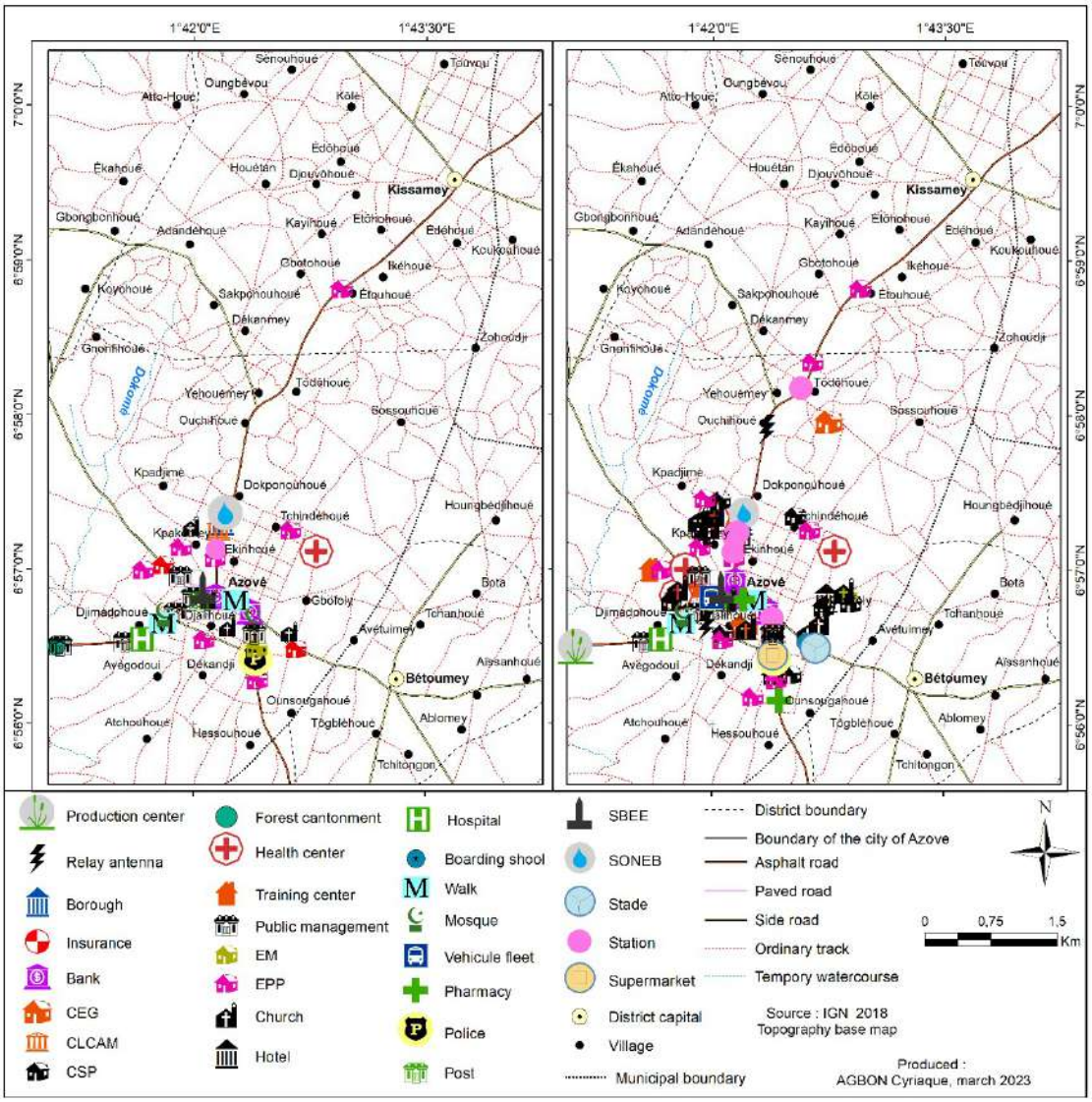

Figure 5. Spatial distribution of infrastructure dynamics in the city of Azovè

In terms of commercial infrastructure, a new market and a fleet of vehicles have been installed, making life easier for residents and foreigners from Togo, Zou and Cotonou and surrounding areas. School, health, administrative and water infrastructures, police, hotels, pharmacies, petrol stations, banks, savings offices, agricultural production centers and soccer stadiums have all been inventoried, and several have been refurbished, while others have been added.

Summary of the spatial dynamics of the city of Azovè: The dynamics of building space, population, socio-community infrastructures and subdivisions have changed the urban landscape of the city of Azovè. Between 2005 and 2023, there has been a steady shift in the built-up land towards fields and palm groves (figure 6). Figure 6 shows that, in 2005, the urban area was concentrated in the Azovè district, but by 2023 had expanded to the other neighborhoods, especially to the south and east. A total conversion of palm groves into fields and fallow land is observed in the north-west and center-west of the city, while small patches of plantation formation are observed in the center. This is one of the anthropogenic changes of this period. The natural changes observed are linked to rain erosion due to the difference in the slope, which varies between 140 and 240 meters in altitude. Although the progression of agglomeration contributes to spatial dynamics, the difference in altitude to the north and north-east of the city has halted the city's expansion to the north. It should be noted that most of the roads in this area are still undeveloped and are mostly rural tracks.

The population's perceptions of spatial dynamics factors in Azovè: Spatial dynamic factors include population growth, urbanization, subdivision, local markets (Azovè and Kissamey) and road asphalting. Figure 7 shows how people perceive these factors. According to field investigations, people's perceptions vary with regard to the factors of spatial dynamics. According to them, the most important factors are population growth (96.72%), urbanization (86.07%) and subdivision (34.43%). They believe that demographic growth is the most important factor, due to the large influx of people from Togo, Aplahoué, Djakotomey and other communes in the Couffo and Mono departments. This movement is facilitated by the asphalting of the main roads (16.39%) into and out of the town. The local market (10.56%) also contributes to this dynamic, prompting the government to develop the Azovè market to meet the standards and requirements for consumption and marketing in the city of Azovè.

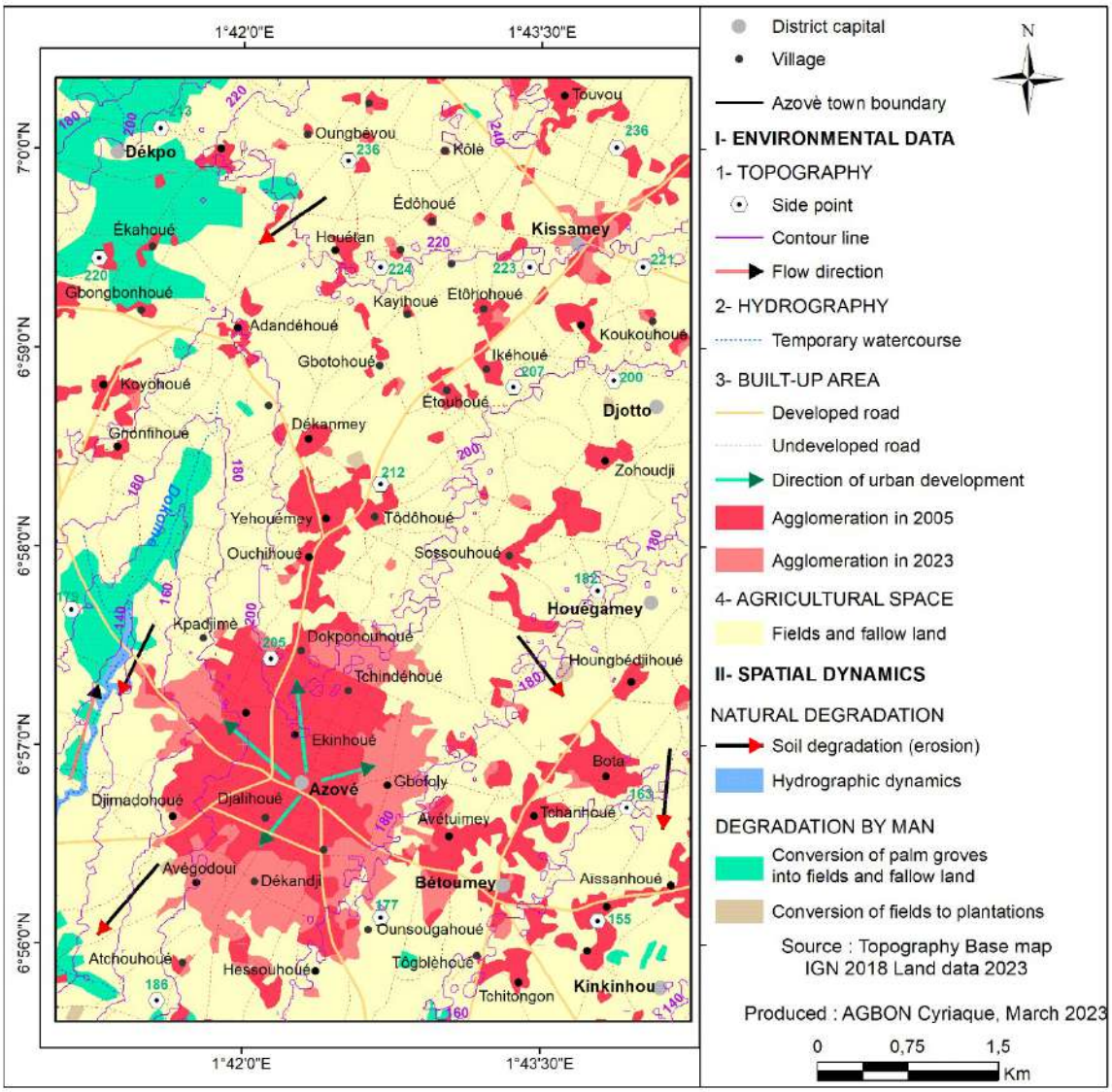

Figure 6. Synthesis of the spatial dynamics of the city of Azovè between 2005 and 2023

Level of change generated by spatial dynamics in Azovè: The changes observed in the city of Azovè are linked to the presence of more and more foreigners, the increase in infrastructure, the change in housing types, the reduction in agricultural land and the increase in built-up land (Figure 8). Spatial dynamics in the city of Azovè have brought about changes in the structure and organization of the city. According to the perception of those interviewed, the increase in the built-up land (93.4%) is the main change observed. This is followed by the evolution of housing (90.2%), reflected in the modernization of the city's traditional dwellings, the reduction of agricultural land (85.2%) through the growing consumption of land for building, the presence of foreigners through the rural exodus phenomenon (74.6%) and the increase in infrastructure (60.7%).

DISCUSSION

This study analyzed the spatial dynamics of the city of Azovè using cartography. Cartographic processing on two satellite images using the on-screen digitizing technique was used to carry out this analysis. This approach is recognized by several authors (A. Mama and *al*., 2013, p. 80; B. Mamane and *al*., 2018, p. 1670; S. Biaou and *al*., 2019 p. 14), for its performance and the quality of its results on image processing, because human brain is a good interpreter (O. A. Bah and *al*., 2019, p. 7), unlike supervised classification, which confuses the spectral signature of certain classes. There has been an increase in the core area of the city, with the expansion of urban areas rising from 809 ha to 1134 ha between 2005 and 2023. There was also a reduction in fields and fallow land under oil palms, with 311 ha lost. These results are in line with the work of S. A. Chaffra and *al*, (2022, p. 41) in the commune of Bopa and O. Tente et *al*, (2019, p. 144) in the commune of Zè with a similar mapping approach. Using the image-based classification method, O. E. Edea and *al*., (2022, p. 1) proved that an extension of the built-up land was recorded in the city of Parakou between 1990 and 2015, as did M. Boni and *al*., (2001, p.23) in southwest Burkina-Faso. This is also the case for the work of A. Amal and *al*, (2014, p. 139 and M. El Hadji and *al*, (2021, p.76) and P. Roel and *al*, (2021, p. 10) who have demonstrated an enormous loss of agricultural land, with demographic growth accentuating the urbanization process.

The spatial dynamics of land-use units are a direct consequence of ever-increasing population growth, the expansion of health infrastructures, subdivision operations in the city, local markets and the urbanization process. Indeed, the population of Azovè is growing in every neighborhood, as is the socio-community infrastructure. Azovè's population, estimated at 54,154 in 1979, rose to 76,557 in 1992, before reaching 109,647 in 2002. It will grow from 162,178 inhabitants in 2013 to 257,820 in 2023. In the Senegalese town of Keur Massar, O. M. A. Diop (2020, p. 28) made the same observation. This situation of population growth is also observed in the south of the Sakété Plateau (Benin), characterized by strong demographic growth accompanied by unprecedented spatial expansion (A. F. Djogbénou (2014, p. 9; S. Dahandé et *al*., 2021, p. 67). It should be added that this expansion has led to the shrinking of agricultural areas and the bursting of agglomerations. The city of Azovè has undergone changes in structure and organization, with an increase in the built-up land (23.12%), modernization of traditional dwellings (22.31%), a decrease in farmland (21.10%), the presence of foreigners (18.46%) and an increase in infrastructure (15.01%). This corroborates the work of S. Dansou (2021, p. 86) on the structuring and dynamics of the cities of Ouidah and Grand-Popo. For him, the geographical location of the two cities, their proximity to the Cotonou metropolis, and the presence of infrastructure and land are the main factors favoring spatial dynamics. This is also the case for the findings of F. Bendraoua and *al*, (2011, p. 104) who focused on land pressure in the urban periphery of Oran in Algeria. This study identified other factors influencing the spatial dynamics of the city of Azovè, such as the local market, road asphalting, urbanization and population growth. A synthesis map of the city's spatial dynamics showing the direction of evolution of the urban core, environmental elements, natural and man-made degradation is presented as a decision-making tool.

CONCLUSION

The city of Azovè has experienced dynamics in time and space. To analyze these spatial dynamics, a diachronic interpretation was carried out between 2005 and 2023. The results showed that several elements have contributed to these dynamics. These include fields and fallow land under oil palms, agglomerations, population, infrastructure and subdivision operations. In fact, fields and fallow land under oil palms have lost 307 ha and 3 ha to fields and agglomerations, while built-up lands have seen a fairly marked increase in surface area between 2005 and 2023, i.e. over 325 ha. These dynamics are linked to the galloping growth of the population, the infrastructures available in the city and the subdivision operations that have evolved with the city's urban core. Azovè's population, estimated at 54,154 in 1979, rose to 76,557 in 1992, before reaching 109,647 in 2002. Between 2013 and 2023, it grew from 162,178 to 257,820 inhabitants. All these have been used to produce a synthesis map that will enable local authorities to make sound planning decisions for the city's urban bloom. This cartographic approach is essential for analyzing changes in the landscape. According to local perceptions, the determining factors in these changes are population growth, urbanization, subdivision, road development and local markets. It will therefore be very important to take all these elements into account in future planning for the city of Azovè.

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