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Papers

The Construction of Maputo-KaTembe Bridge and The Dynamics of Land Occupation in The Municipal District of KaTembe – Mozambique

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Abstract
The present study analyses the influence of the Maputo-KaTembe bridge in changing the dynamics of land occupation in the municipal district of KaTembe. The bridge was inaugurated on November 10, 2018, and from there came the expectation of a new development scenario in the district and new dynamics of urban growth. Spatial patterns and the intensification of urbanization were shown using cartography tools. The study aimed to understand the dynamics before and after the construction of the bridge, in order to show new trends with the start of operation of the bridge, which was already expected. Images were visually interpreted in Google Earth at different times before and after the construction of the bridge, verifying the patterns of growth of the occupied area and validating of the manual classification of the images in the Google Earth platform. The Results and the map produced showed an intensification of land occupation in the district from the start of the operation of the bridge. Despite the expansion of the urban fabric, measures must be taken to prevent problems in the future, especially for the environmental problems (floods, pressure on natural resources, coastal erosion, etc.) and social problems (socio-spatial segregation, mobility). These measures include planning and managing the process of land use and occupation.

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INTRODUCTION

The search for better living conditions in cities by rural populations and the high rates of population growth are identified as the main factors that drive the growth of the urban fabric. Additionally, Alsaaideh *et al*. (2011) refers that large numbers of immigrants from neighboring countries and other socioeconomic changes are one of the factors contributing to population growth. In the case of Mozambique, the war that took place in the country for 16 years was another factor that created the rural exodus and boosted the growth of the urban population growth. In the words of Araújo (2003):

> In Mozambique, the 70s, 80s and 90s decades, were characterized by the occurrence of adverse circumstantial factors (colonial war, civil war, natural disasters) that altered the normal development of the territorial distribution of the population from urban centers (ARAÚJO, 2003, p. 168).

These characteristics played a role in the way the urbanization process took place in Mozambique. Urbanization, as explained by Ribeiro (2019), implies the transformation of land through the provision of infrastructure, equipment and buildings that ensure the physical settlement of populations in conditions to benefit from services of increasing level and quality of their life. In the occupation of land, as explained by Araújo (2003), there is a specific process of territorial organization of the population that takes place in its interrelation with the environment, creates a set of social, economic and cultural activities that result in the formation of a space with its own characteristics of concentration of the population, production, service and spatial organization.

Somantri and Nandi (2018) described Land use as a permanent human intervention to meet both material and spiritual needs, or in other words, an interaction between humans and their environment, where men strive to use the natural environment to successfully meet their life needs. According to the authors, among the various uses of land; agriculture, sports fields, housing, restaurants, hospitals and cemeteries have to be highlighted. "Land comprises the area on the surface of the earth that has certain characteristics, for climate (atmosphere), rocks and structures (lithosphere), relief and soil processes (pedosphere), vegetation and animals (biosphere) and humans (anthroposphere)" (SOMANTRI, NANDI, 2018, p. 4).

However, it is important to note that land occupation affects ecosystem processes, hydrology, biodiversity, climate, biogeochemical cycles, energy balance, and human activities as stated by Xiao *et al*. (2006). It is a consequence of the urbanization process that temporarily leads to the expansion of the urban population through the occupation of new areas. According to Srighar *et al*. (2019), the basic idea of urban sprawl is the gradual development of a low-density area to a high-density area or a temporally dispersed development, undergoing changes inland consumption in various ways.

Studies in land occupation processes currently involve the application of geographic information systems based on the images provided by remote sensors, especially onboard satellites. It is about digital land cover change detection, which according to Belal and Moghanm (2011) is a process of determining and/or describing changes in land cover and land use properties in multi-temporal remote sensing data from the identification of changes between two or more dates. Barow *et. al* (2018) for example, call attention that for the research of land occupation by urban sprawl, it is better to use the Geographic Information System (GIS) as a tool, due to its ability to deal with different categories of data, in addition to visualizing the urban sprawl in the study area and providing the corresponding maps. This tool also allows for in-depth analysis, providing the ability to examine all the data in a system, making it easier to measure urban expansion.

According to Gadal (2009), Remote sensing represents a technology that offers an essential avenue for the monitoring, modeling and analysis of urbanization processes, particularly in developing countries where it compensates for the scarcity of geographic resources, data and maps updated using satellite images to monitor the continuous development of urbanization over geographical areas of different sizes. Undoubtedly, the use of GIS and software for manipulating satellite images and vector data proved to be extremely important for the characterization of continuous and non-continuous urban areas, bringing satisfactory results in the area covered.

Land use data, according to Somantri and Nandi (2018), are indispensable to solving problems on the earth's surface, such as the phenomenon of natural disasters, poverty, regional planning, exploitation of natural resources and public policies. From this perspective, they should be analyzed as consideration for problem-solving recommendations.

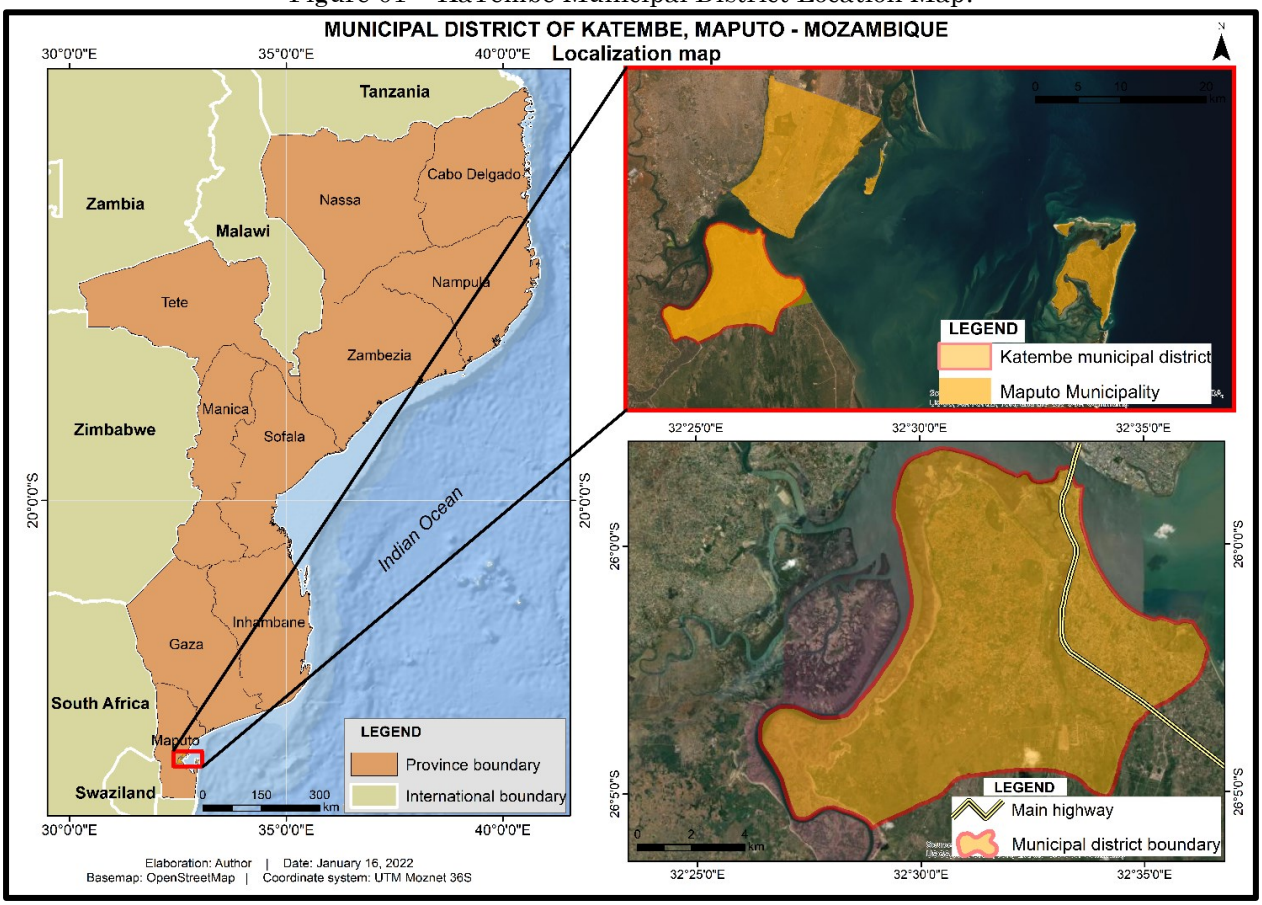
It is also worth noting that obtaining high-resolution images is still an expensive option in the satellite imagery market. However, other options can be explored in order to classify land use and/or occupation, as is the case with the free images provided on the Google Earth platform.

Given the size of the study area (relatively small), it was considered viable to use the Google Earth platform as a direct source of data for mapping land occupation through a visual and manual interpretation and vectorization of these images. However, it is important to mention the difficulty that this methodology represents when working in larger areas (vectorization would take a long time). Despite the use of this methodology, Jacobson *et al*. (2015) consider that the method can achieve a relatively satisfactory classification of satellite images, which may provide some opportunities for detailed mapping of land occupation.

STUDY AREA

The municipal district of KaTembe belongs to the Municipality of Maputo, located in the province of Maputo in southern Mozambique and is located between 25º58' and 26º5' south, and 32º26' and 32º36' east. Its borders are limited to the north by Maputo Bay, which separates it from the central area of Maputo city to the west by the Tembe River, to the east by Maputo Bay and south by the district of Matutuíne (figure 01). The district is administratively constituted by 5 districts, namely, Chali, Chamissava, Guachene, Incassane and Inguide. It is an area in process between rural and urban, with potential for urbanization.

Figure 01 – KaTembe Municipal District Location Map.



Source: The author (2022).

The land occupation process in the municipal district of KaTembe was largely carried out informally, although on the coastline there are configurations of some consolidated and orderly occupation. According to Mendonça and Monteiro (2017) the areas of disorderly occupation located at the rear of the ordered mesh, on the coastline, configure flood risk areas where the population with fewer resources, less population density and with greater dispersion of housing resides.

The region was originally inhabited by peoples of Bantu, Ronga origin and further south also by Zulu and Swazi. KaTembe was initially created as an Administrative Post in 1915 as part of the civil circumscription of Maputo, within the framework of the organic structure of the Portuguese colonial administration, being always connected to the city of Lourenço Marques (present-day Maputo city, capital of Mozambique), and its seat village could be considered an extension of Lourenço Marques. It was designated a municipal district within the framework of the autarchy underway in the country. However, the biggest difficulty that the people of KaTembe have always experienced was its connection with the central part of the Maputo city due to the bay that separates the municipal district from the rest of the city despite its geographical proximity (about 600 meters). This crossing was carried out by traditional boats, commonly known as canoes, in a first phase, and rowing and sailing boats were temporarily used, and later with motorboats such as "ferryboats" (figure 02) were the main means of transport crossing before the construction of the bridge. The capacity of the "ferryboat" was 200 passengers and 12 seats for light cars per trip. (TEMBE 2017).

Figure 02 – "Ferryboat" used in the Maputo-KaTembe crossing.

Source: WIKIMEDIA COMMONS (2013).

With the construction of the bridge (figure 03) and its inauguration on November 10, 2018, the scenario changed, creating several possibilities for the development of the municipal district of KaTembe. One of the main constraints for the district was the accessibility that for a long time served as a weakness for its development that did not follow the same way as the city of Maputo. The

start-up of the bridge, according to Uamusse (2021), significantly affected the operation of maritime passenger transport in Maputo Bay. According to the author, the company that manages the "Ferryboat" recorded a drop from 2,705 passengers daily to just 192, a situation that precipitated the interruption of the circulation of vessels.

Figure 03 - Maputo-KaTembe crossing bridge.

Source: WIKIMEDIA COMMONS (2018).

Accessibility represents a key element for the development of any region. According to Villaça (1996):

> Accessibility is the most important use-value for urban land, although each and every land has it to a greater or lesser extent" […] and "transport routes have an enormous influence not only on the internal arrangement of cities, but also on the differentials of urban expansion" […], in this way, "the intra-urban transport system, when it presents the possibility of offering urban passenger transport, attracts urban occupation inaccessible or potentially accessible points, since it changes the use-value of the land, generating an offer of new locations occupied by part of the population and activities generated from the expanding central city. (VILLAÇA, 1996, p. 74).

The decentralization of the city of Maputo is a reality. It is noted the emergence of new centralities represented by "fuel stations, surrounded by convenience stores, service and commercial establishments" (CHICOMBO, 2020). These points influence the process of expansion of the urban area. Land occupation is intensifying in the peripheries, influenced by the emergence of such urban sub-centralities in Maputo city. Decentralization "is associated with the growth of the city, both in demographic and spatial terms" (CORRÊA, 1995). However, the expansion of the central part of the city was conditioned to a 90º angle because of its location. In this logic, fundamental processes are recurrent in this context, such as the intensification of urbanization in the urban area with occupation of risk areas, processes of urban conurbation with the Municipality of Matola to the west and the district of Marracuene to the north. Once the Maputo-KaTembe bridge comes into operation, there is a possibility of expanding the city by 180º.

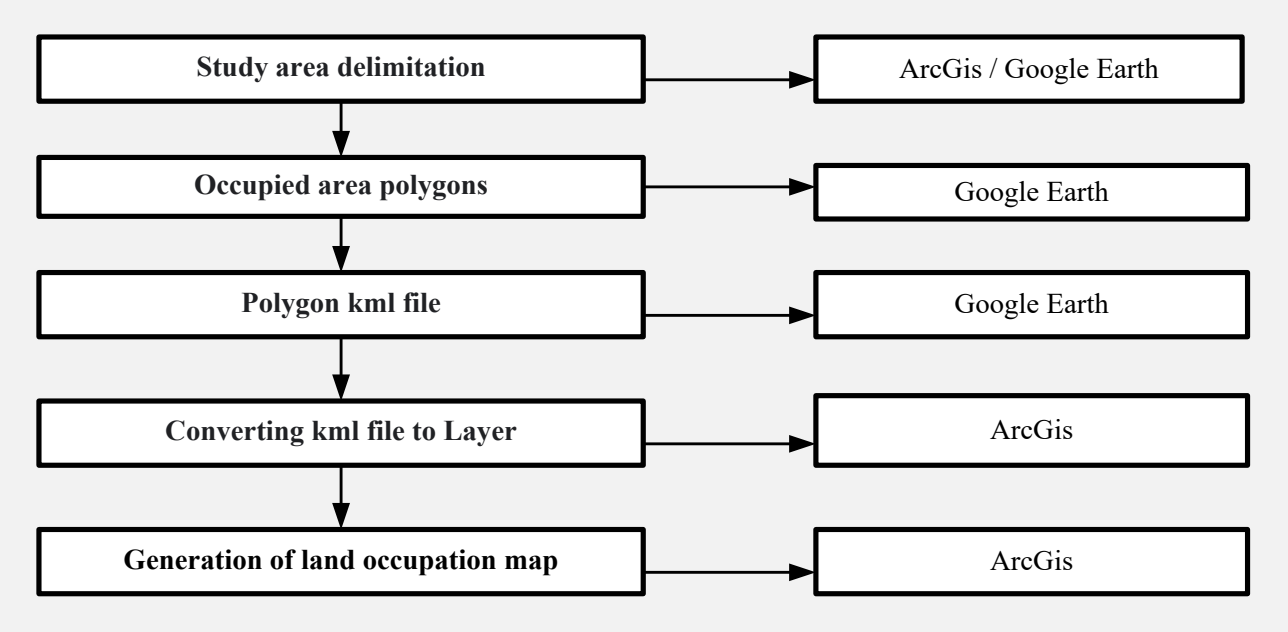
This possibility puts KaTembe subject to increasing pressure for urban development. Coutinho (2018) explains that this development is due to the growth of the population of the city of Maputo. Expanding Maputo to the north is no longer an adequate option with urban areas already very restricted, and the chaos of unplanned urbanization is a reality.

This is why, we are allowed to reflect on the dynamics of land occupation in the municipal district of KaTembe, through this study that proposes to analyze this dynamics, assuming that the bridge came to solve the problem of accessibility, making the district easily accessible, as the ways of crossing diversified, becoming faster and less expensive. In this case, the new road access, according to Mendonça and Monteiro (2018), makes it possible to establish at KaTembe, in addition to a housing nucleus, a business, logistics, commerce, industry center and also a tourism hub.

METHODS

The maps of land use in the municipal district of Katembe were elaborated through the visual interpretation of images in Google Earth and the creation of polygons representing occupied areas. The interpretation involved analyzing the content of the images and perceiving the objects according to their attributes and meanings. Figure 04 illustrates the flowchart of activities of the methodology used in the present study.

Figure 04 - The main methodological steps.



Source: The author (2022).

The ArcGis program and Google Earth client version were used to carry out the process of preparing the map in version 10.4.1. The delimitation of the study area consisted of the conversion of the Shapefile with the limits of the study area to the Keyhole Markup Language (KML) format, in order to allow the delimitation of the image visualized in Google Earth and subsequent digitization. When creating the polygons representing occupied land (figure 05), all occupied plots were considered, without using any sample. Each location was examined using the Google Earth navigation tool, depending on the actual interpretation of its meaning, that is, the presence of built infrastructure. The examination of each location was precise, taking into account the possibility of enlarging the actual image offered by the tool used.

Figure 05 – Vectorization of the image in Google Earth.

Source: The author (2022).

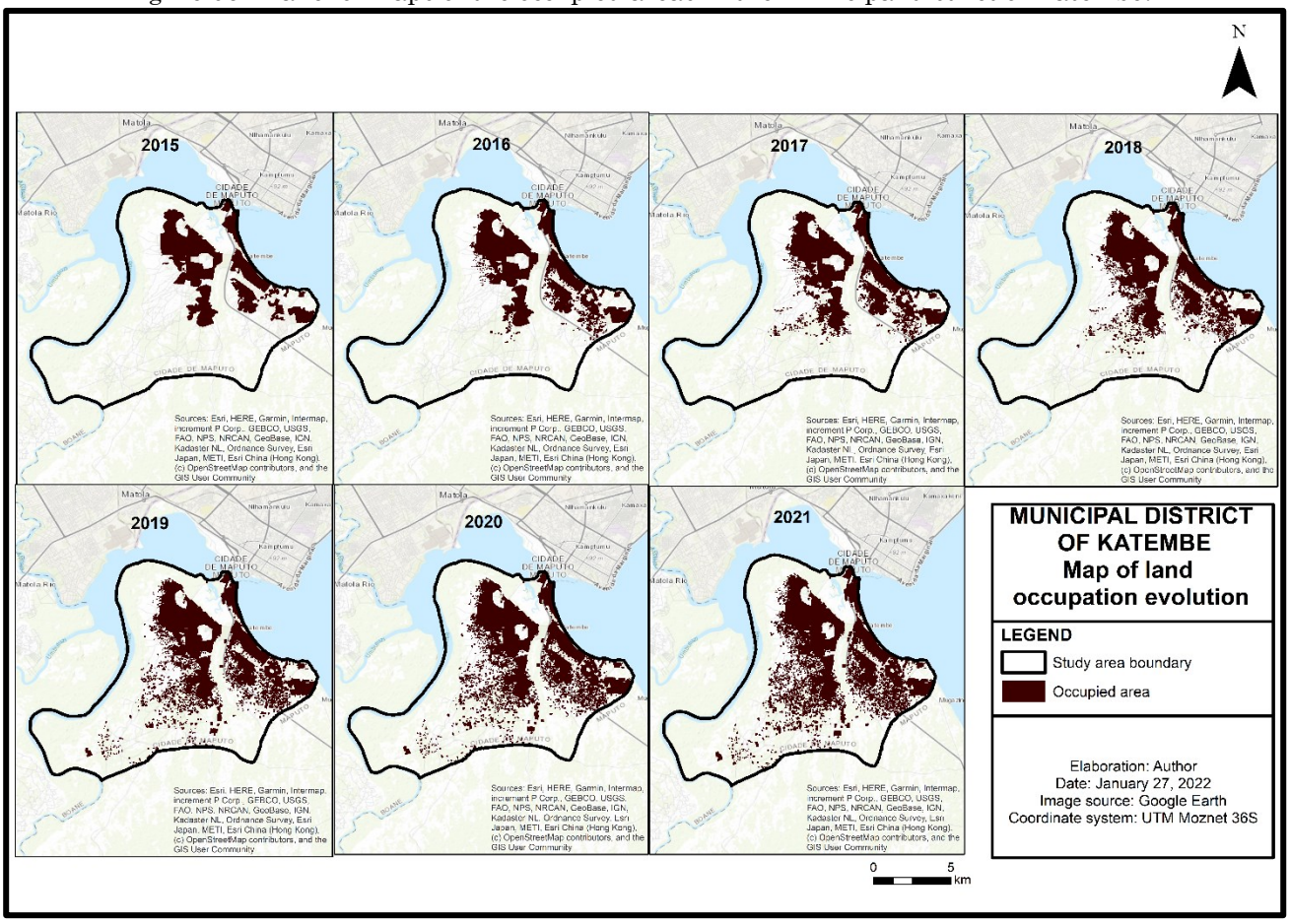
The choice of the images followed the period under analysis (2015 – 2021), considering three years before the bridge came into operation, from the year of the inauguration and three years later. A date was sought after the bridge's inauguration, and from there, a three-year retreat was made, and a three-year advance was made, seeking to maintain an almost equal time interval between the analyzed images, so the month of December was chosen, which presented available images in the image history file for the seven years analyzed.

Then, a kml file was created containing the polygons representing occupied areas in the municipal district. The file was later converted to Layer in ArcGis, which allowed the elaboration of the land occupation map in the study area.

RESULTS AND DISCUSSION

The intensification of land occupation in the KaTembe district from 2018, is shown through the map of land occupation patterns and its temporal dynamics (figure 06), which leads us to conclude that the bridge created a new dynamic in the occupation of the land, that is, with the operation of the bridge, the district has been registering new dynamics in the processes of extension of occupied areas (through the conversion of areas of rural use into areas of urban use) and the intensification of occupation of empty areas within the parceled area.

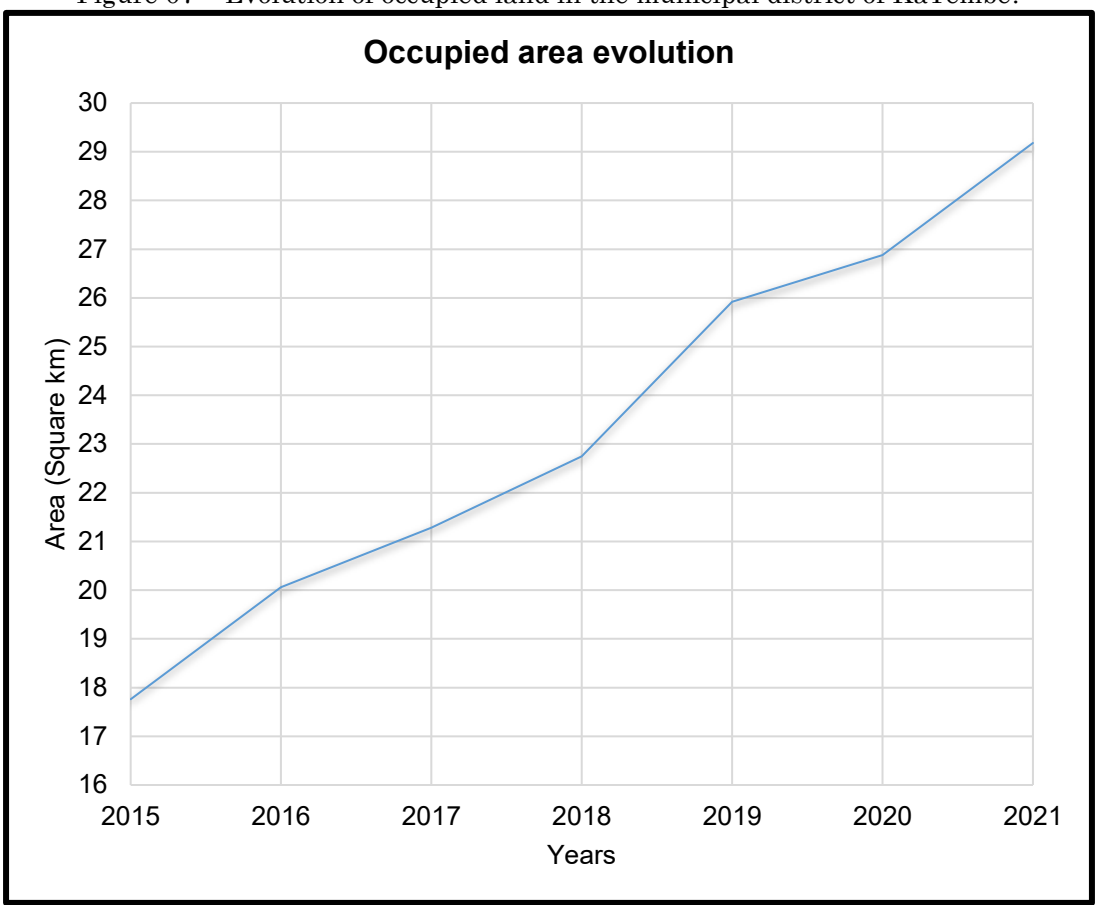
Figure 06 - Panel of maps of the occupied areas in the municipal district of Katembe.



Source: The author (2022).

In the year (2015), which was the first year analyzed, the occupied land corresponded to 17.76 square kilometers, representing about 15% of the entire area of the municipal district (figure 6). Data presented in Figure 07, shows that over the past three years (2015, 2016, 2017) before the implementation of the crossing bridge, the occupied land area recorded an average growth of 1.58 square kilometers per year.

Figure 07 – Evolution of occupied land in the municipal district of KaTembe.



Source: The author (2022).

By observing figure 07, we can infer the occurrence of a pulse in the growth of the occupied land. It emerges from this observation the role that the operation of the bridge has been playing in the dynamics of land occupation, characterized by the significant increase in occupied areas encouraged by the bridge. During the three years analyzed after the bridge came into operation (2019, 2020 and 2021), the increase in the occupied area became 2.14 square kilometers on average per year.

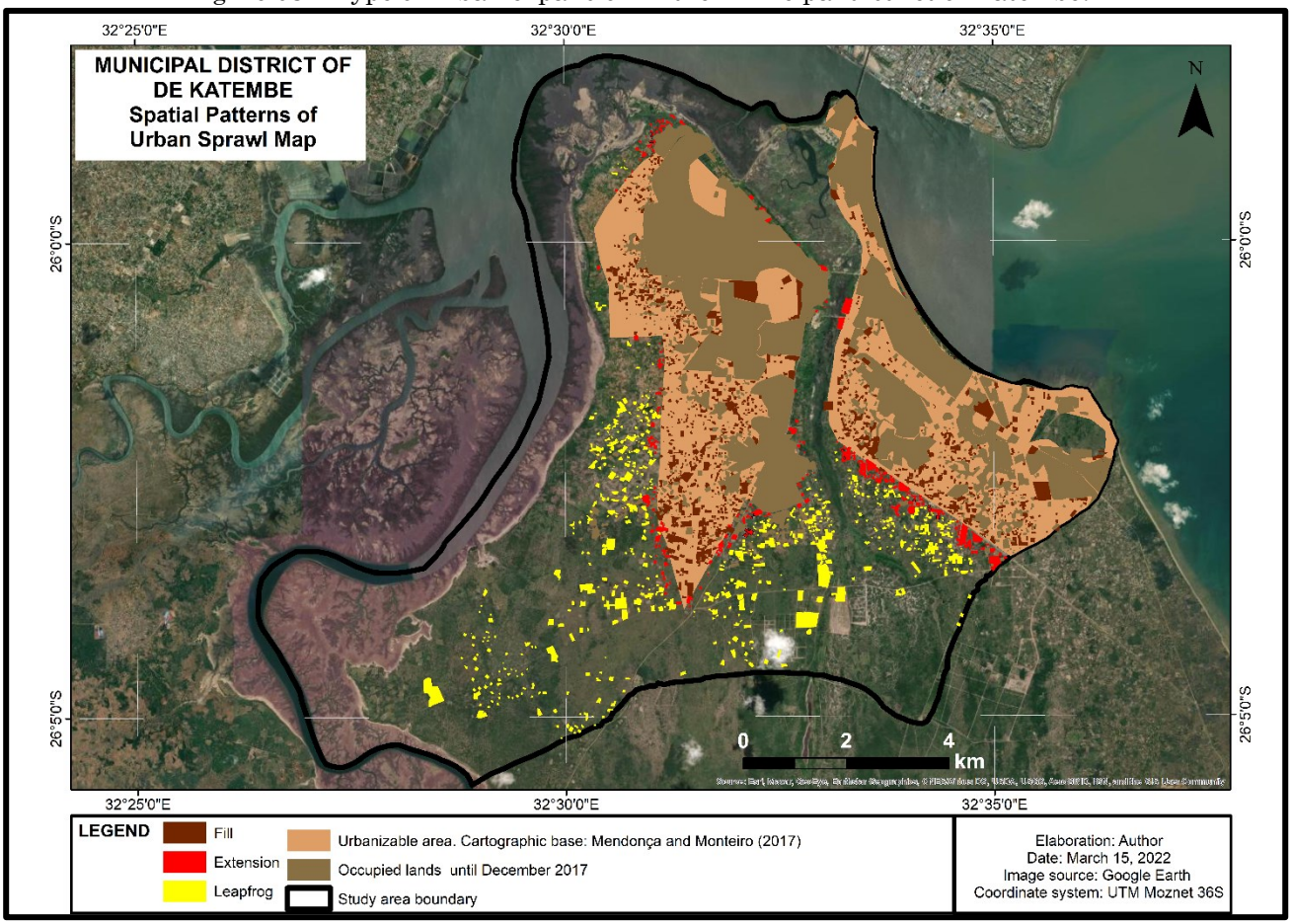
The visit carried out in the field showed that the disorderly and unplanned occupation of land is a reality in the district. At this point, the conclusion made by Mendonça and Monteiro (2017) deserves to be highlighted, when they state that:

> The existing roads at KaTembe do not have well-defined geometries, either in plan layout, in longitudinal profile or in cross-section. There are no pavement structures, so the platform was built directly on the ground. There is no rainwater drainage or sidewalks and, as such, pedestrians and vehicles occupy the road and create risk situations in terms of its integrity and safety. (MENDONÇA; MONTEIRO, 2017, p. 4).

The expansion of urbanized areas results from socio-economic and cultural factors. However, in the case of the municipal district of Katembe, specific consideration must be given to the impetus that the bridge brings to the land occupation process. This fact is important considering the reduction of transport costs produced by this infrastructure.

Considering the slow state that characterized the expansion of land occupation in the municipal district, presenting several unoccupied spaces along the area delineated as urbanized, the operationalization of the bridge created another dynamic. As can be seen in the map (Figure 08), the expansion of urbanization intensified in the period after the bridge came into operation, where three forms of expansion were recorded, namely, filling, extension and leaps (Leapfrog).

Figure 08 – Type of urban expansion in the municipal district of Katembe.



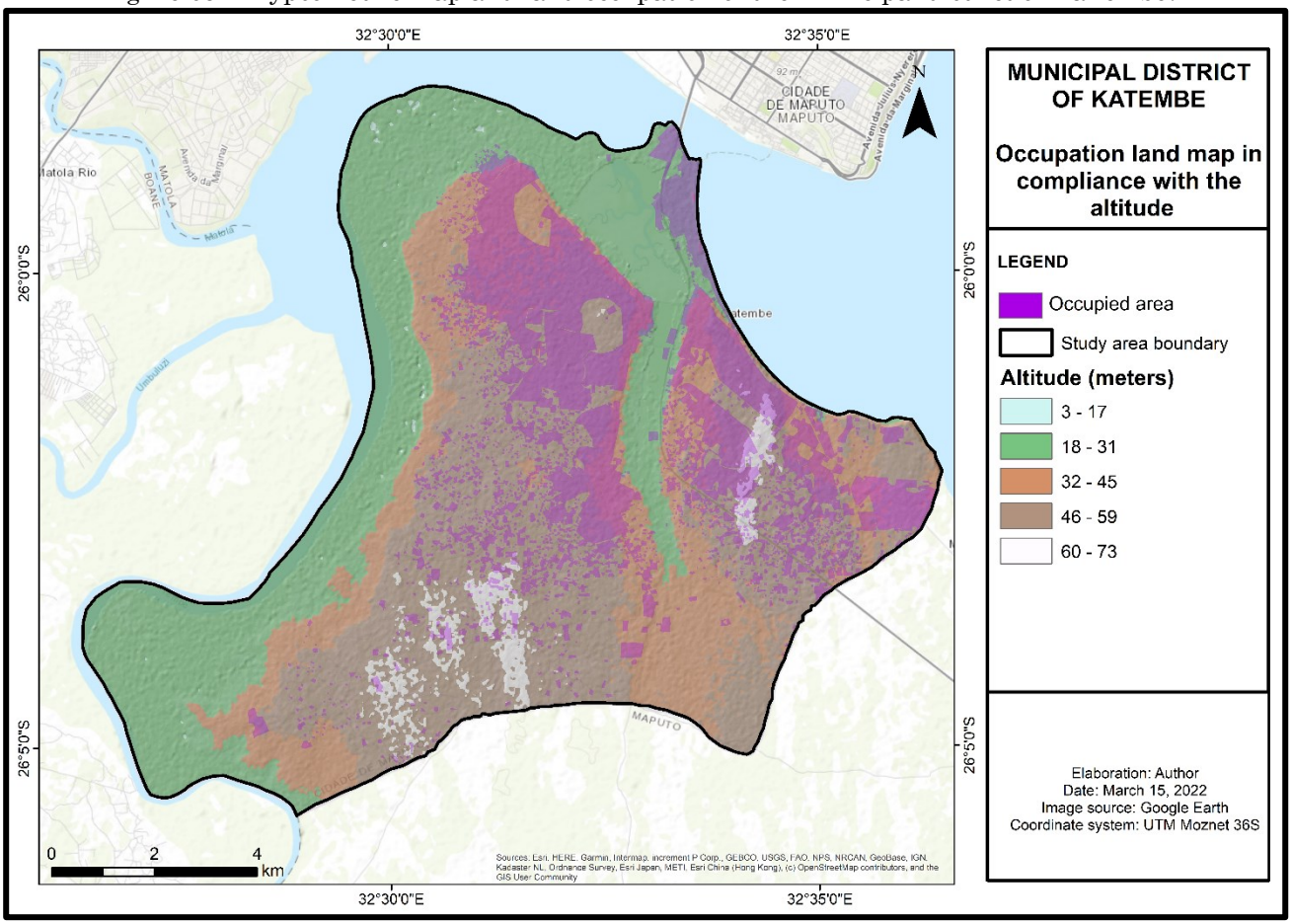
Source: The author (2022).

According to the data processed on the map, the expansion by filling the area was the most representative, after the construction of the bridge until 2021. New occupations were taking place in empty spaces in the perimeter of the urbanized area. As a result, there was an increase in the contiguity of the built-up area. Leapfrog expansion was the second most representative. This form of expansion consisted of new occupations that do not intersect the perimeter of the urbanized area and there is no contiguity with the previous occupation, contributing to the fragmentation of the urban footprint. This is an expansion that is also seen in general in Latin American megacities that, according to Camargo *et al*. (2020) differs from what is identified in Anglo-Saxon countries. Studies drawn by Akhter and Noon (2016) based on data from recent years of advancing development in Pakistan concern the institutional ineffectiveness to control such a form of urban sprawl, regardless of the existence of resources and management tools, as "it is costly for public management, forcing services related to urbanities, such as asphalt and basic sanitation, to be washed to increasingly distant areas" (BURCHELL; SHAD, 1998 apud CAMARGO *et al.* 2020).

There was also an extensive expansion, which was characterized by new constructions intersecting the urbanized area, extending beyond the previous occupations. In some cases, in this form of expansion, it is recorded the occupation of areas at risk of flooding which, according to the plan that delimited the urbanized areas, were not recommended for occupation.

However, even though the occupation is disordered, it is still limited to the area with the highest altitudes (figure 09), showing some concern on the part of the population to avoid low-lying areas, although there is the emergence of some occasional occupations in areas prone to flooding.

Figure 09 – Hypsometric map and land occupation of the municipal district of KaTembe.



Source: The author (2022).

Although the growth of the occupied area does not follow a geometric pattern, specifically in the new areas being occupied, the geomorphology is seen as the key element that is directing the occupation of the land. According to Daoudi and Niang (2021), it is, very often, the first base for choosing the place of occupation. It constitutes a condition in the direction that the occupation of the land is taking. However, the authors point out that the interaction between rapid urban expansion and geomorphological processes can result in increased exposure to natural hazards. For example, Fitzpatrik *et al*. (2005) consider that in urban development, the impermeable surface area (roads, sidewalks, parking areas, roofs) increases, which decreases infiltration and increases the rate and volume of surface runoff.

In spite of this, it is important that the land occupation is based on environmental impact studies in order to avoid future problems to the environment. The different actors in the land occupation process must be aware of the possible problems of disorderly land occupation, at a time when:

> Interventions in the peri-urban space involves a wider range of actors, in the form of different types of partnerships, with different interests and rationalities, benefiting a target population that is also diversifying, with the arrival of foreigners and the emergence of a fringe population with greater purchasing power. Although plots continue to be demarcated and made available, with or without basic infrastructure and/or housing, the current dynamics of the real estate market and the construction of new infrastructures, promoted by the recent economic growth, are insufficient or incapable of responding to the interests and needs of the majority of the population, which continues to resort to self-production. (JORGE; MELO, 2014, p. 61).

However, it is important that these areas are occupied in the context of planning. The lack of planning is a social problem characterized by the lack of pre-existing infrastructure necessary for adequate living conditions, aggravated by the disordered spatial distribution of housing, including low areas prone to flooding. (COUTINHO, 2018).

It is in this sense that the current pressure exerted on the KaTembe district must be anticipated with occupation plans in order to prevent future problems both in urban mobility and in the environment. The planning must allow the district to present a structure that includes the location and composition of urban infrastructures such as residential, commercial, tourist areas, leisure and recreational areas, reserves, environmental protection areas, drainage systems and road systems.

However, it is necessary to consider that Mozambique has a governance structure that allows for territorial planning and management. The national system of territorial planning and management in Mozambique has ramifications at the provincial, district and municipal levels, and its execution is guaranteed by various actors such as provincial governors, the Minister of Agriculture and Rural Development, the Council of Ministers and the Mayors.

As for the legal instruments of planning and management, and in the case of the municipality of Maputo, one can refer to the urban structure plan of the municipality of Maputo-2008, which defined among its priorities i) reorganizing informal neighborhoods; ii) recovering land for all exchange activities, services and public equipment; iii) densify the occupation of the urban fabric to avoid the continuation of the unregulated occupation of urban land; iv) reserve areas to restore balance and ensure the maintenance and improvement of environmental quality; and v) promote the diversification of urban activities and functions, avoiding suburbanization and the spatial and environmental segregation of the most disadvantaged social strata. These instruments, when properly implemented, can reduce the problem of land occupation mentioned above.

It should be noted that in Mozambique, the land is owned by the state. It cannot be sold, mortgaged, pledged or disposed of according to article 3 of the Land Law of 1997. The use and occupation of land are carried out by granting titles of Right of Use and Benefit of Land (DUAT). Such use may be carried out in the form of i) Occupation according to customary norms and practices; ii) occupation in good faith; and iii) Formal authorization. However, Andersen *et al*. (2015), based on four decades of empirical research work in Maputo, explained that land use planning based on state control has limited practical impact. Urban land is physically structured and planned by urban dwellers. According to the authors, in places where "ordered" land-use practices are not implemented (either by state or non-state actors), collective forms of socio-cultural organization still guide and reorient land-use practices in many "unplanned" areas, and this remains the dominant form of land development.

However, it is important to insist on the fact that the occupation of land in the municipal district of KaTembe takes into account the environmental impacts caused mainly by the instability of the cliffs and dunes through the removal of coastal vegetation for the construction of infrastructure.

FINAL CONSIDERATIONS

Factors such as the departure of the rural population, the search for better living conditions in the city and population growth, results in pressure on land use in urban areas, demanding the occupation of new areas. However, it is important that governments, communities and individuals have information about the forms of land occupation over time, that is, they must be aware of the characteristics of land occupation in the past, present and future. It is necessary, however, that there is a constant monitoring of land occupation in order to guarantee its sustainable use.

Remote sensing emerges as an important tool for monitoring land use and occupation, in which satellite images are used to produce the respective maps.

The present study sought, from good resolution images available on the Google Earth platform, to show how an infrastructure (bridge) changed the dynamics of land occupation in the municipal district of Katembe, in Mozambique. The use of Google Earth proved to be effective in the production of maps considering its performance by providing high-resolution images of the past and free access with the possibility of seeing even the building level, road and other targets on the

surface of the earth with greater detail, which facilitated the process of recognizing occupied areas.

Information obtained from the cartography allowed us to point to the change in the dynamics of land occupation in the municipal district of Katembe with the entry into operation of the Maputo-Katembe crossing bridge. The new dynamic was characterized by the intensification of occupation. It is clear that the bridge made the district more accessible, and from there, a new dynamic of occupation by the populations that once did not consider the municipal district as an option to inhabit was unleashed. From this perspective, it is expected to see the expansion of the city of Maputo increasingly to the south.

Another analysis consisted of showing the forms of expansion registered in the municipal district of Katembe, so it was found that the dominant form of expansion is the filling, that is, the occupation took place in empty spaces of the urbanized area. Secondly, the expansion is running in the form of leaps (Leapfrog) and thirdly in the form of an extension at the edge of the urbanized area.

With the bridge, the movement of people and goods became easy. Land transport starts to be used, a fast and cheap transport, which could accelerate the development of the municipal district. This reality will cause a rapid growth of the population and, consequently, an increase in traffic, deserving special attention in the improvement of the access and transport system by the public authorities.

In the bibliographic research, it was possible to verify the existence of plans and projects, which place KaTembe as a possibility for the emergence of a new urban centrality in the region. However, its implementation must anticipate the ongoing process of disorderly occupation. Otherwise, the construction of urban infrastructures foreseen in these plans and projects will be very expensive as it will imply demolition and appropriation of areas already inhabited, which will cause tensions with the residents of these areas.

Therefore, it is expected that the present study brings contribution to the process of land occupation through the visual interpretation of images in Google Earth and the subsequent creation of polygons representing occupied lands, a method that has as a limitation the consumption of a lot of time when dealing with large areas to be analyzed.

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AUTHORS' CONTRIBUTION

Tomé Francisco Chicombo: conceived the study, collected, analyzed the data and wrote the text.