# Characterization of an urban area in the legal Amazon using Local Climate Zones (LCZ)

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**Abstract**

The growth of agricultural production and the internalization of the industrial sector has led to a significant increase in the populations of small and medium-sized towns in the Midwest region of Brazil. This movement increases the demand for a built environment and promotes the anthropization of the landscape in these cities, altering the ecosystem in general, but especially the local microclimate. This study therefore aims to map and classify the urban perimeter of the municipality of Nova Mutum, located in the north of the state of Mato Grosso, using the Local Climate Zones (LCZ) methodology. To this end, the area studied was divided into 500x500 meter quadrants, which, using satellite images made available, by Google Earth Pro, were analyzed individually, taking into account elements such as densification, land cover and verticalization. Once the existing zones in the study area had been identified, a Climate Zones map was generated, which was analyzed and cross-referenced with data from the municipal urban legislation. As a result, the municipality has an urban perimeter considerably larger than the area occupied by the urban network, so that a large part of the perimeter is occupied by agricultural production, classified as LCZ D, with herbaceous vegetation. In addition, the municipality already has areas of verticalization and medium-sized densification, mainly in the central zones, which requires attention from the public authorities and local urban planning due to the generation of urban heat islands.

**Keywords:** Central-western Brazil; Urban planning; Urban heat islands;

## 1. INTRODUCTION

Since the industrial revolution, there has been a constant increase in the urban population all over the planet. At the moment, urban dwellers account for around 56% of the global population, and this figure is expected to reach 68% of the world's population living, consuming and traveling in urban areas by mid-2050 (UN BRAZIL, 2022; UN-HABITAT, 2022).

In this sense, as Silva (2011) explains, with the growth of the agricultural sector and the internalization of industrial production in Brazil, the gradual movement of the population from rural to urban areas is largely taking place in inland regions, inflating small and medium-sized cities. In this process, the Central-West region plays a leading role due to the industrialization of agricultural production, especially in Mato Grosso. Cities such as Sinop-MT, Lucas do Rio Verde-MT and Nova Mutum-MT saw population growth of around 80% between 2010 and 2022 (IBGE, 2010; IBGE, 2022), a demographic change that increases the demand for the environment and built space in these cities, raising the level of anthropization of the landscape, which is modified to meet the most diverse needs, whether social or economic, directly impacting on the ecosystem (Nunes, Palmisano and Godoy, 2023) with an influence on climate change in these cities.

In urban environments, these climate changes end up manifesting themselves through an increase in extreme phenomena, such as heat waves, long periods of drought, extreme rainfall, floods, etc. It should be noted that in Brazil, these climate changes are aggravated by social problems and inequalities, due to the lack of basic infrastructure such as urban drainage, drinking water supply or even access to health services (Barbi and Rei, 2021; Paula, 2021).

In this way, meeting the need for space and a built environment in cities drives the deterioration of vegetated areas and soil sealing, characteristics which, as Ferreira, Ferretto and Duarte (2023) explain, influence the urban climate of a given region. According to Stewart and Oke (2012), these characteristics, along with other data such as density, verticalization, building typology and the type of vegetation in the landscape, can be used to classify a given region in terms of its particularities, presenting the physical and radiative properties of different urban structures

## 2. OBJECTIVE

Climate-sensitive urban planning has the potential to mitigate and circumvent the problems arising from extreme weather events and the formation of urban heat islands (Stewart and Oke, 2012). To this end, this research aimed to map and characterize the entire urban perimeter of the municipality of Nova Mutum using the Local Climate Zones methodology presented by Stewart and Oke (2012).

## 3. STUDY AREA

According to Kohlhepp and Silva (2022) and Almeida (2021), the state of Mato Grosso underwent colonization processes, encouraged by the federal government, in the middle of Brazil's dictatorial period (between 1964 and 1985). With the slogan "Integrate so as not to surrender" (Souza, 2020, p. 140), created by the government of General Médici, the policy of occupation and integration of the areas of the legal Amazon was structured, which included processes of colonization of such regions and infrastructure projects and works, such as the Transamazônica and Santarém-Cuiabá highways, currently the BR-163 (figure 01).

Figure 01: Map of Nova Mutum's situation in relation to biomes
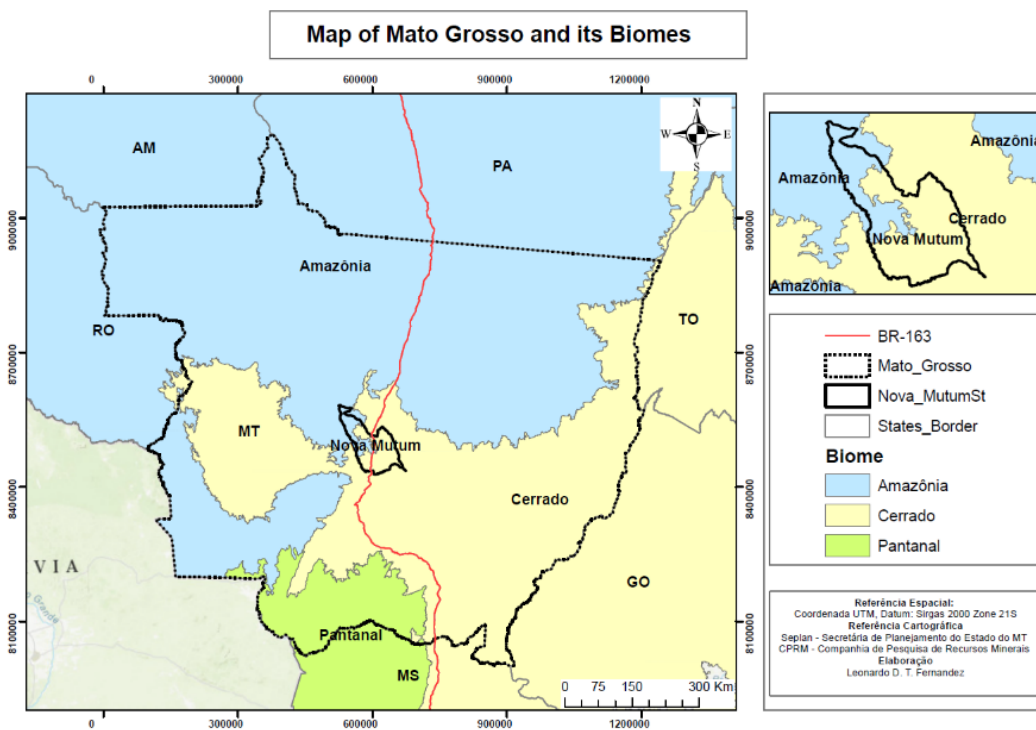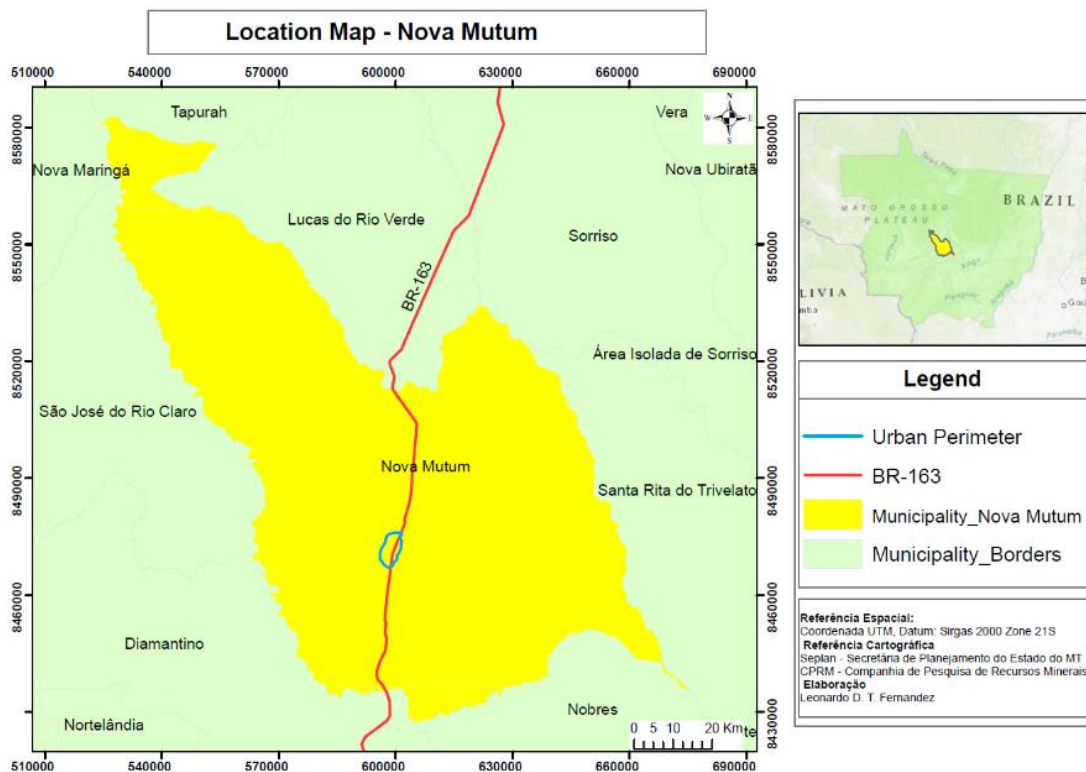


Source: Fernandez (2023)

The occupation process took place in several phases and was largely made up of people from the southern region of Brazil, which was already largely occupied and had inflated land prices, which acted as an incentive, at the first moment of the local occupation, for the migration of these people to the northern region of Mato Grosso, where the vacant lands, allotted by the government itself or even by private colonizers, were affordable (Kohlhepp and Silva, 2022). From the outset, the colonization process aimed to occupy and use the land for agricultural

production, which began with the production of latex, through the extraction of rubber, coffee and cocoa production (Prefeitura Municipal de Nova Mutum, 2020).

In the second phase of Mato Grosso's colonization process, around 1980, as seen in Almeida (2021), settlers arriving in the region found more valuable land. With the opening of the Santarém-Cuiabá highway (BR-163) in 1976 and the creation of the Brazilian Agricultural Research Corporation (Embrapa) in 1973, the production of commodities such as soybeans and corn, driven by the possibility of competing with the United States in these markets, became a viable business, further accelerating the process of colonization in the region (Almeida, 2021; Kohlhepp e Silva, 2022).

Nova Mutum, the spatial focus of this research, emerged through a process of private colonization, during what Almeida (2021) describes as the second wave of colonization in the mid-north of Mato Grosso between 1970 and 1980. The municipality arose on the banks of the BR-163 highway (figure 02), when a group of investors from São Paulo, led by businessman José Aparecido Ribeiro, acquired a total of 169,000 hectares of land, culminating in the Mutum Colonization Project. The rural plots were sold to settlers arriving from the south, who received urban plots in what is now the central area of the municipality of Nova Mutum as a bonus for their purchase (Prefeitura Municipal de Nova Mutum, 2020). In the early days of local colonization, the main activities were planting rice and farming; however, with private and state incentives, local producers began experimenting with grain production such as soybeans and corn, which proved to be more economically beneficial (Almeida, 2021; Kohlhepp e Silva, 2022; Prefeitura Municipal de Nova Mutum, 2020).

Figure 02: Situation map of the study area



Source: Fernandez (2023)

Currently, Nova Mutum stands out as one of the most important municipalities in state and national agricultural production, according to data from the Socioeconomic Profile of Nova Mutum (2021) the municipality was, in 2019, second in the national ranking of soybean producers and the fifth largest corn producer at national level, and is also important in state livestock production, where Nova Mutum is the largest producer of chickens and the second largest pig breeder at state level (Sebrae, 2021). This economic data has acted as propaganda for the municipality over the years (Prefeitura Municipal de Nova Mutum, 2020), making Nova Mutum, in 2020, the city with the 4th largest population growth in the state of Mato Grosso (figure 02), currently having a total of 58,832 inhabitants, according to IBGE data (2022). Nova Mutum has a land area of 954,457 hectares (9,544.57 km²) and even with the importance of local agricultural production, it is characterized as a municipality with a mostly urban population, so that in 2010, 82% of the population already lived in the urban perimeter (Sebrae, 2021), which currently has about 13,675 hectares, or 136,750 km².

The site of this study therefore comprises the urban perimeter of the municipality of Nova Mutum, which, updated in 2015, has a considerably larger area than the municipality's current urban network. These areas, within the urban perimeter, which are not yet urbanized, are destined for agricultural use, for the production of soybean and corn monocultures and, as can be seen on the zoning map (figure 03), a substantial part of these plots are treated as Residential Zone 3, a zone in which the local land use and occupation legislation (Nova Mutum, 2023) allows verticalization of up to 5 floors and an occupancy rate of up to 80%.

Figure 03: Zoning and urban perimeter of Nova Mutum
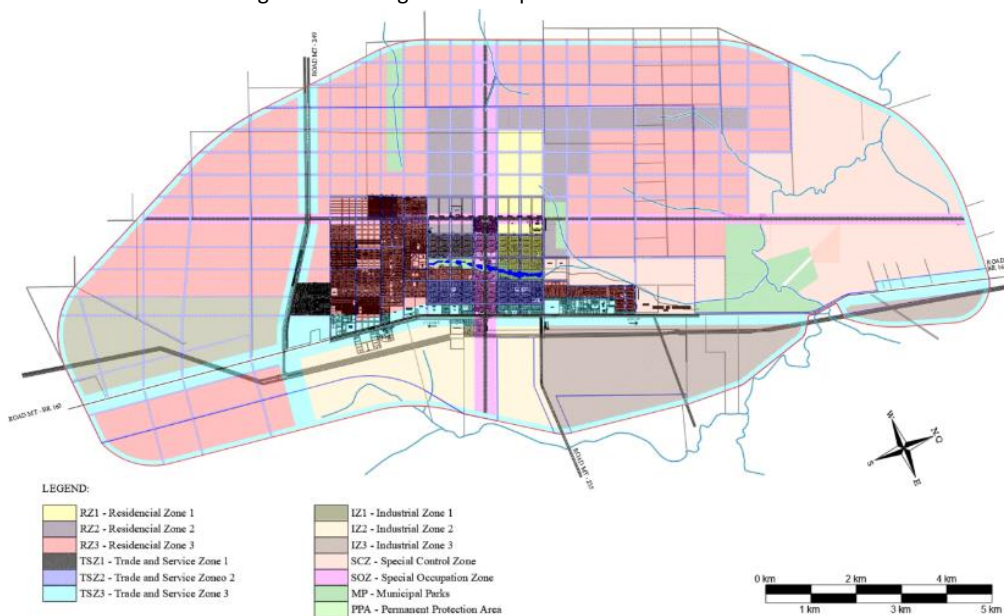


Fonte: Nova Mutum City Hall, adapted by the authors, 2015

The municipality is located in the northern macro-region of the state of Mato Grosso as part of the Alto Teles Pires micro-region, situated in the Amazon basin. Considering its location, its predominant climatic zones, according to surveys by Aparecido (2020), are the Tropical zone (Aw), according to the Koeppen and Geiger method (1928) and the Equatorial zone

(EQ-Moi and EQ-UMi) according to the Camargo method (1991). However, as Aparecido (2020) explains, the Camargo (1991) methodology has a favorable approach to studies with smaller spatial sections, and is therefore more suitable for the study presented in this article.

With two well-defined seasons, the dry season (between May and September), when the relative humidity is 35%, and the rainy season (between October and April), when the relative humidity is 80%, Nova Mutum has an average annual temperature of 24°C, with an average annual maximum of 33°C and an average annual minimum of 21°C, and an average annual rainfall of 2,200mm (Sebrae, 2021; Aparecido, 2020).
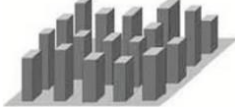
## 4. METHODOLOGY

This study is based on the local climate zone classification method presented by Stewart and Oke (2012), which was used to map and classify the urban perimeter of the municipality of Nova Mutum-MT.

According to Ferreira, Ferretto and Duarte (2023), the method for classifying local climate zones was developed as a doctoral thesis by researcher Ian Douglas Stewart, under the guidance of Professor Timothy Oke. The method consists of a system for classifying local climate zones (LCZs) for heat island studies, allowing studies to be standardized in different locations, as opposed to traditional heat island studies, which consist of comparing urban and rural temperatures.

The Local Climate Zones (LCZ) classification has 17 standard classifications which are divided into two groups: built-up areas and non-built-up areas. Within each group, LCZs are differentiated by land cover, building type, densification, verticalization and vegetation structure present in the location to be classified (tables 01 and 02). These classifications can also be merged, creating LCZ subclasses in order to give the classification more precision (Ferreira, Ferretto and Duarte, 2023; Paula, 2021).

Table 01: Types of built-up climate zones

| LCZ group by type of buildings | | |
| --- | --- | --- |
| LCZ | Representation | Description |
| **LCZ 1** <br><br> **Compact high-rise** | | Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials. |
| **LCZ 2** <br><br> **Compact midrise** | | Dense mix of midrise buildings (3–9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials. |
| **LCZ 3** <br><br> **Compact low-rise** | | Dense mix of low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials. |
| **LCZ 4** <br><br> **Open high-rise** | | Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials. |
| **LCZ 5** <br><br> **Open midrise** | | Open arrangement of midrise buildings (3–9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials. |
| **LCZ 6** <br><br> **Open low-rise** | | Open arrangement of low-rise buildings (1–3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials. |
| **LCZ 7** <br><br> **Lightweight low-rise** | | Dense mix of single-story buildings. Few or no trees. Land cover mostly hard-packed. Lightweight construction materials (e.g., wood, thatch, corrugated metal). |
| **LCZ 8** <br><br> **Large low-rise** | | Open arrangement of large low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Steel, concrete, metal, and stone construction materials. |
| **LCZ 9** <br><br> **Sparsely built** | | Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees). |
| **LCZ 10** <br><br> **Heavy industry** | | Low-rise and midrise industrial structures (towers, tanks, stacks). Few or no trees. Land cover mostly paved or hard-packed. Metal, steel, and concrete construction materials. |

Source: Adapted from Stewart and Oke (2012)

Table 02: Types of built-up climate zones

| LCZ group by type of buildings | | |
|---|---|---|
| **LCZ** | **Representation** | **Description** |
| **LCZ A**<br><br>**Dense trees** | | Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park. |
| **LCZ B**<br><br>**Scattered trees** | | Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park. |
| **LCZ C**<br><br>**Bush, scrub** | | Open arrangement of bushes, shrubs, and short, woody trees. Land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture. |
| **LCZ D**<br><br>**Low plants** | | Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park. |
| **LCZ E**<br><br>**Bare rock or paved** | | Featureless landscape of rock or paved cover. Few or no trees or plants. Zone function is natural desert (rock) or urban transportation. |
| **LCZ F**<br><br>**Bare soil or sand** | | Featureless landscape of soil or sand cover. Few or no trees or plants. Zone function is natural desert or agriculture. |
| **LCZ G**<br><br>**Water** | | Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons. |

Source: Adapted from Stewart and Oke (2012)

The LCZ methodology makes it easy to compare data from the site surveyed, as each local climate zone is unique due to the elements that make it up and which will be used as the basis for its classification. Thus, the authors state that each LCZ should have a minimum diameter of 400 to 1,000m so that the air portion of its surface layer remains entirely within it and does not overlap with adjacent LCZs with different structures or ground covers.

In this sense, Stewart & Oke (2012) have reservations about the use of subclasses, either because it is difficult to recognize the thermal behavior in advance due to the lack of pre-defined physical properties in the system, or because the thermal differences between successive LCZs in the standard set do not exceed 1-2°C, that is, the thermal field of the LCZs is spatially continuous, leading the air condition of one class to gradually merge with that existing at the limits of the surrounding LCZs.

The mapping is based on a Google Earth Pro satellite image (2023, Maxar Technologies). To carry out the classification, the map was divided into 500x500 meter quadrants (figure 4), so that each quadrant can be analyzed individually.

Figura 04: Urban perimeter of Nova Mutum-MT in 500x500m quadrants
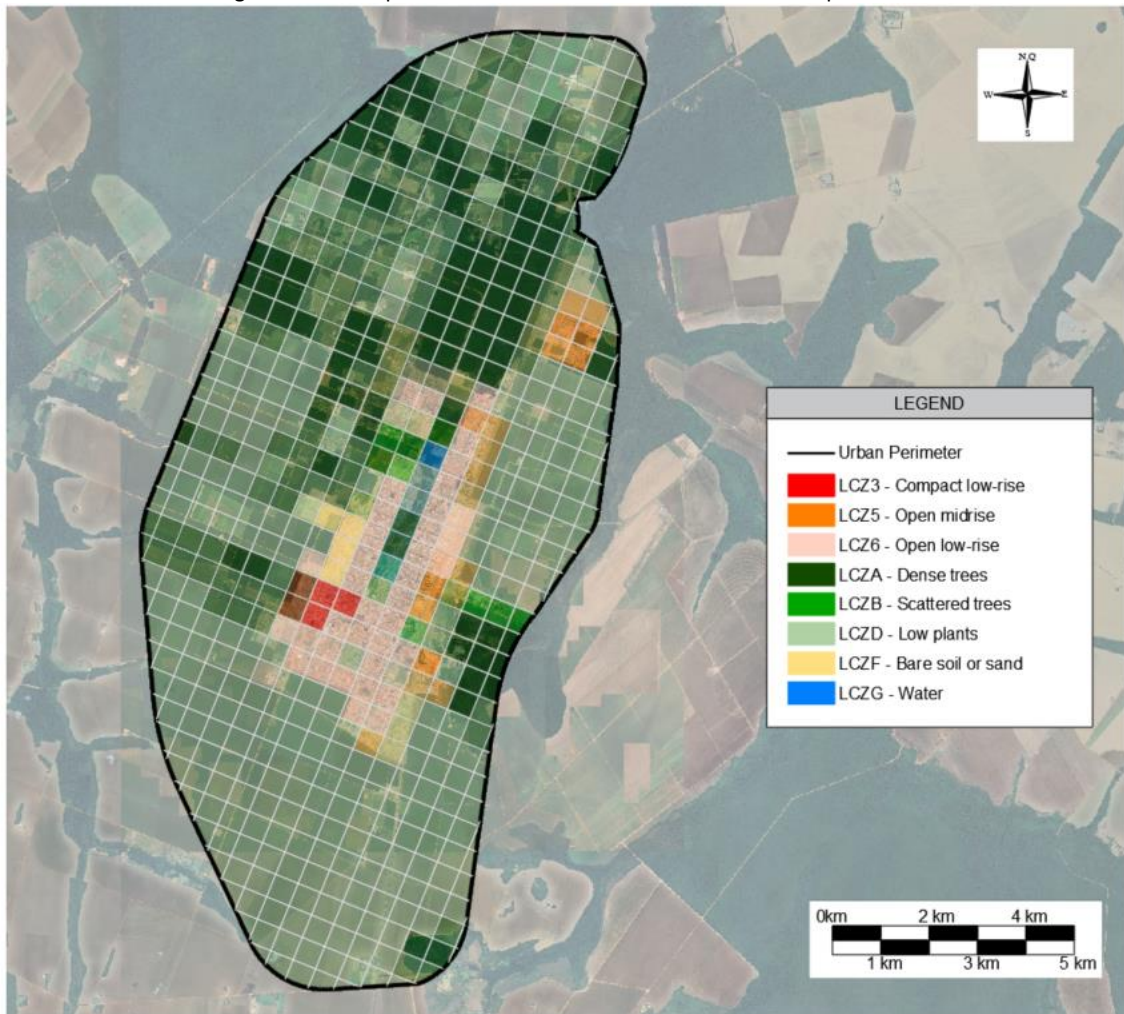


Source: Map drawn up by the authors from Google Earth images, Maxar Technologies (2023)

The map was produced according to the following flowchart (figure 5). Based on this map, a photographic survey was carried out to help analyze building typologies and ground cover.

Figure 05: Flowchart for producing the analysis map
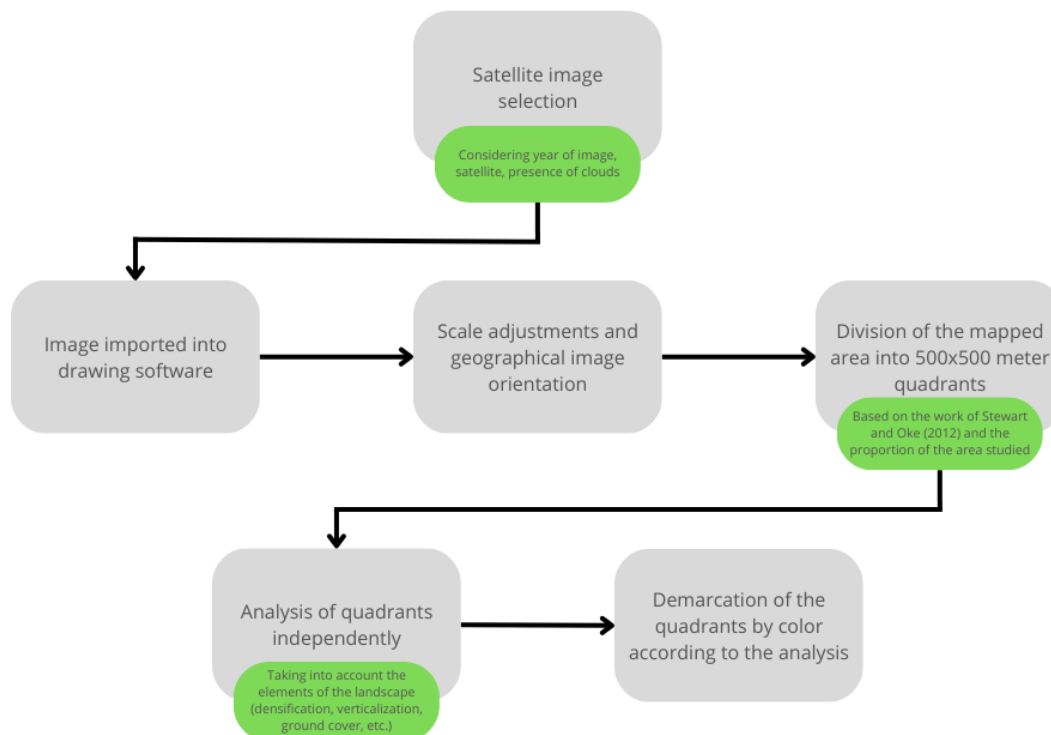


Source: Authors

In order to classify the local climate zones in the municipality of Nova Mutum - MT, the parameters described by Stewart and Oke (2012) were followed, as shown in Tables 01 and 02, thus using images made available by Google Earth of the urban perimeter of Nova Mutum, in July 2023, the choice of image was due to the best visualization parameters for characterizing the areas.

The satellite image provided by Google Earth was transferred to AutoCAD software, then the urban perimeter was demarcated using the zoning maps of Nova Mutum - MT, according to the material provided by the city hall. The layout of the grid was based on two of the municipality's main roads, Avenida das Araras and Avenida Mutum.

## 5. RESULTS

Applying the methodology described, the map shown in figure 6 can be obtained, representing the morphology in the year 2023 according to the LCZs identified. The classes obtained were: LCZ3 - Low Compact; LCZ5 - Medium Open; LCZ6 - Low Open; LCZA - Dense Tree Vegetation; LCZB - Sparse Tree Vegetation; LCZD - Herbaceous Vegetation; LCZF - Exposed Soil; LCZG - Water.

Figure 06: Graphic representation of the urban perimeter of Nova Mutum-MT according to the colors of each LCZ typology
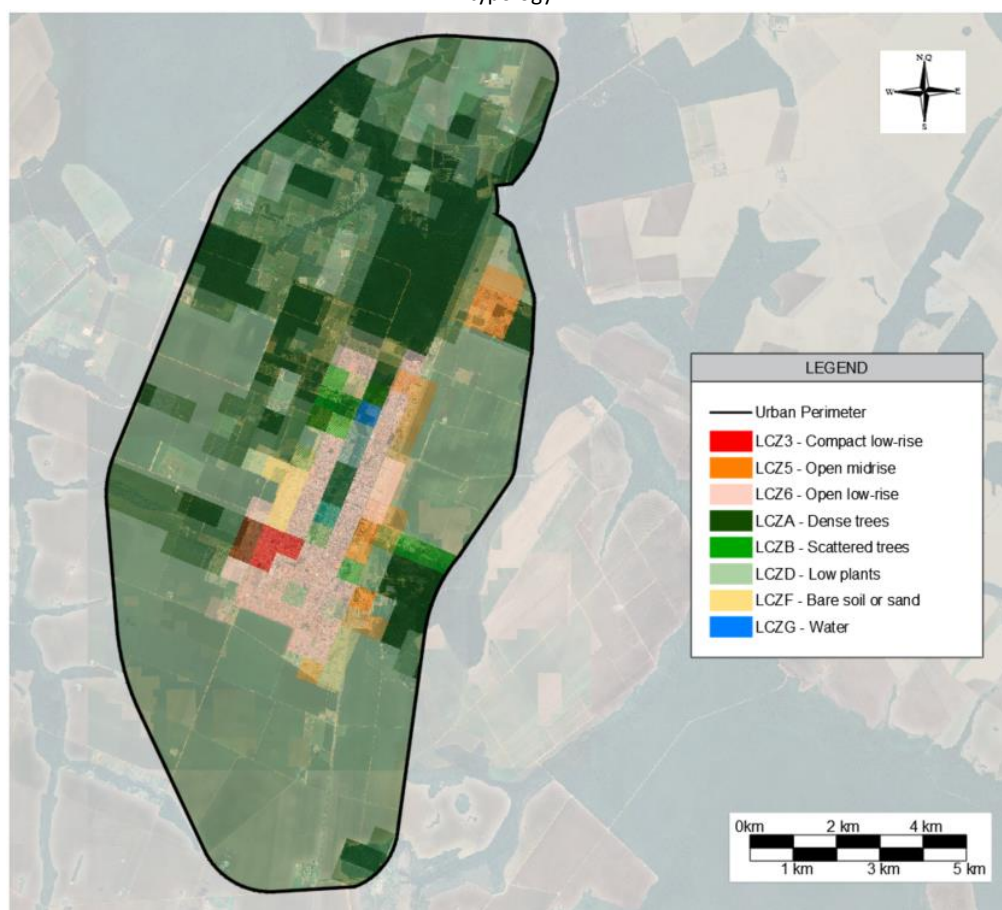


Source: Map drawn up by the authors from Google Earth images, Maxar Technologies (2023)

From the map analysis, 0.55% can be considered as LCZ3, which has a building arrangement of densely built areas and little vegetation; 0.91% as LCZ5, with medium height buildings in an open arrangement in a natural environment; 6.03% as LCZ6, with low buildings, up to 3 stories, in an open arrangement with an abundance of permeable cover; 15.97% as LCZA, with areas densely covered by tree vegetation and predominantly permeable ground cover; 0.50% as LCZB, with areas covered by sparse deciduous and/or evergreen vegetation and predominantly permeable ground cover; 48.07% as LCZD, with areas of herbaceous vegetation, predominantly the area of future expansion of the urban perimeter which is currently used as an agricultural area.

In addition, it is possible to find a series of areas that can be classified as mixed LCZ where, 0.37% as LCZ3A; 0.18% as LCZ56; 0.37% as LCZ5AG; 0.91% as LCZ5D; 0.18% as LCZ65; 0.37% as LCZ6A; 0.18% as LCZ6AD; 0.18% as LCZ6B; 0.18% as LCZ6BF; 0.18% as LCZ6D; 0.18% as LCZ6DF; 0.18% as LCZ6DG; 0.55% as LCZ6F; 0.18% as LCZAB; 4.85% as LCZAD; 0.18% as LCZAG; 0.18% as LCZAGF; 0.18% as LCZB6; 0.18% as LCZBA; 0.914% as LCZD5; 0.18% as LCZD5B; 0.55% as LCZD6; 18.55% as LCZDA; 0.18% as LCZDB; 0.18% as LCZDF; 0.37% as LCZF5; 0.18% as LCZF5D; 0.37% as LCZF6; 0.18% as LCZF6B; 0.914% as LCZFA; 0.18% as LCZFAB; 0.18% as LCZFD.

Table 03 shows some images exemplifying the predominant types of construction and roofing:
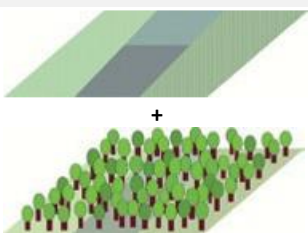
Table 03: Classification of Typologies of Built-up Climate Zones
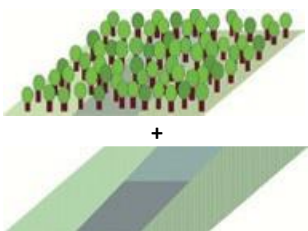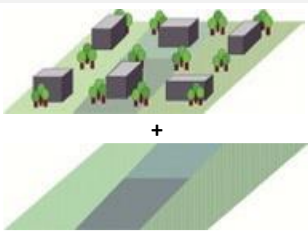
| LCZ 3 |
|---|



| LCZ 5 |
|---|



| LCZ 6 |
|---|



| LCZ A |
|---|



| LCZ B |
|---|

**LCZ D**



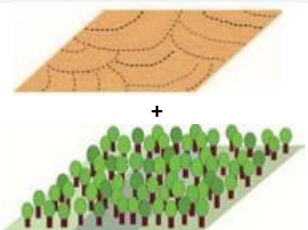**LCZ $D_A$**



**LCZ $A_D$**



**LCZ $5_D$ /$D_5$**



**LCZ $F_A$**

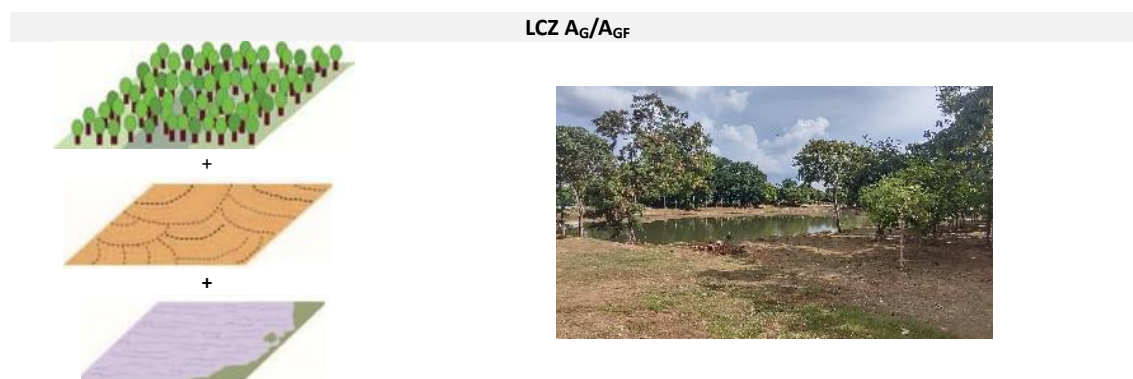**LCZ A_G/A_GF**



Source: Images - Adapted from Stewart and Oke (2012); Photos - Authors 2023

Given that most of the urban perimeter is still made up of agricultural areas, the areas classified as herbaceous vegetation make up most of the urban perimeter. However, if only the urbanized area of the municipality is considered, it can be seen that the LCZ6 areas are the largest in number, starting from the west bank of the BR-163 highway. However, the municipality already has a forecast of zones for expansion of the urban perimeter, where agricultural activity is currently predominant, and can thus generate a forecast of how the municipality will be shaped once it reaches its full expansion.

In addition, areas of densification in LCZ3 are already conspicuous in the municipality, especially in the central areas, due to the process of local colonization, as well as occasional verticalization, which could harm the local microclimate due to the formation of heat islands.

## 6. CONCLUSION

The results obtained from the analysis of LCZs show some factors that may influence the formation of urban heat islands in the future, such as the presence of regions that are already highly urbanized, despite the presence of preserved vegetation at the time of the analysis. Regions that are currently sparsely urbanized are being rapidly occupied, often ignoring the importance of preserving vegetation and permeability. Another concern is the use of areas far from the center that are expected to be occupied by residential occupants, since these areas are often used for the construction of social housing developments, projects in which the authorities and technicians are often unconcerned about permeability and vegetation.

During the study, some areas were difficult to analyze due to the heterogeneity of the materials presented in certain quadrants, making analysis difficult.

It was not possible to verify thermal analyses due to a lack of equipment and data to ascertain whether the area analyzed already has heat islands, which require action by public management at the present time. However, observing the formation of the urban layout and how it has been expanding, future administrations should pay attention to preserving permeable and vegetated areas, especially in areas where verticalization and densification are already significant, as well as in future areas of

expansion in order to prevent the formation of extreme heat islands, especially in the face of the current climate change scenario.

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