Espaço & Geografia

METHODOLOGY FOR INTEGRATION OF THE CLIMATE CRITERIA FOR URBAN PLANNING IN SMALL AND MEDIUM-SIZED CITIES IN THE CENTRAL WEST OF BRAZIL

Metodologia para integração dos critérios climáticos para o planejamento urbano em pequenas e médias cidades do centro-oeste do Brasil

Metodología para la integración de criterios climáticos para la planificación urbana en ciudades pequeñas y medianas del centro-oeste de Brasil

João Carlos Machado Sanches[1], Oscar Daniel Corbella[2], Renata Mansuelo Alves Domingos[3], Emeli Lalesca Aparecida Guarda[4] e Eleonora Sad de Assis[5]

[1] Universidade do Estado de Mato Grosso, Sinop, Brasil. sanches@unemat-net.br.
ORCID: https://orcid.org/0000-0002-1330-6696
[2] Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brasil. oscar.corbella@gmail.com
ORCID: https://orcid.org/0000-0003-3977-5877
[3] Universidade Federal de Santa Catarina, Florianópolis, Brasil. mansuelo.alves@gmail.com
ORCID: http://orcid.org/0000-0002-6428-5223
[4] Universidade Federal de Santa Catarina, Florianópolis, Brasil. emeli.guarda@gmail.com
ORCID: https://orcid.org/0000-0001-7536-4448
[5] Universidade Federal de Minas Gerais, Belo Horizonte, Brasil. eleonorasad@yahoo.com.br
ORCID: https://orcid.org/0000-0001-7702-5669

Recebido: 17/02/2022; Aceito: 14/08/2022; Publicado: 29/11/2022

DOI: https://doi.org/10.26512/2236-56562022e39670

ABSTRACT

The present work starts from the problem of the lack of insertion of issues related to climate within the current context of formulating proposals and guidelines for urban legislation in small and medium-sized cities. It is proposed to study the situation of the city of Sinop, located in the North of Mato Grosso, in Brazilian Legal Amazon. The objective is to develop a methodology for evaluating and formulating proposals and guidelines related to the adequacy of urban spaces to the climate in which they operate. The developed methodology organizes the results obtained mainly in graphs and maps, from mobile transects, conducted in the two seasons of the year, the hot and dry season, and the hot and humid season. Measurements took place at three different times, on four days. The maps of the areas with climate change throughout the year and of classification of urban structures according to their ability to impact the climate are then produced, which generate the city's climate analysis map. This provides subsidies for the preparation of the map of indications for urban planning. The developed methodology showed an efficient and inexpensive way to obtain climatological data, allowing the insertion of climate issues in urban legislation.

Keywords: Climate Mapping; medium-sized cities; mobile transects

RESUMO

O presente trabalho parte do problema da falta de inserção das questões relacionadas ao clima no contexto atual de formulação de propostas e diretrizes para a legislação urbana em cidades de pequeno e médio porte. Propõe-se estudar a situação da cidade de Sinop, localizada no Norte de Mato Grosso, na Amazônia Legal Brasileira. O objetivo é desenvolver uma metodologia de avaliação e formulação de propostas e diretrizes relacionadas à adequação dos espaços urbanos ao clima em que se inserem. A metodologia desenvolvida organiza os resultados obtidos principalmente em gráficos e mapas, a partir de transectos móveis, realizados nas duas estações do ano, a quente e seca, e a quente e úmida. As medições ocorreram em três momentos distintos, em quatro

dias. Em seguida, são produzidos os mapas das áreas com mudanças climáticas ao longo do ano e de classificação das estruturas urbanas de acordo com sua capacidade de impactar o clima, que geram o mapa de análise climática da cidade. Isso fornece subsídios para a elaboração do mapa de indicações para o planejamento urbano. A metodologia desenvolvida mostrou-se uma forma eficiente e econômica de se obter dados climatológicos, permitindo a inserção das questões climáticas na legislação urbana.

Palavras-Chave: Mapeamento do clima; cidades de médio porte; transectos móveis

RESUMEN

El presente trabajo parte del problema de la falta de inclusión de los temas relacionados con el clima en el contexto actual de formulación de propuestas y lineamientos de legislación urbana en ciudades pequeñas y medianas. Se propone estudiar la situación de la ciudad de Sinop, ubicada en el norte de Mato Grosso, en la Amazonía Legal brasileña. El objetivo es desarrollar una metodología para evaluar y formular propuestas y lineamientos relacionados con la adecuación de los espacios urbanos al clima en el que se insertan. La metodología desarrollada organiza los resultados obtenidos principalmente en gráficos y mapas, a partir de transectos móviles, realizados en las dos estaciones del año, cálida y seca, y cálida y húmeda. Las mediciones se realizaron en tres momentos diferentes, en cuatro días. Luego, se elaboran mapas de zonas con cambio climático a lo largo del año y se clasifican las estructuras urbanas según su capacidad de impacto en el clima, que generan el mapa de análisis climático de la ciudad. Proporciona subvenciones para la elaboración del mapa de indicaciones para la planificación urbanística. La metodología desarrollada demostró ser una forma eficiente y económica de obtener datos climatológicos, permitiendo la inclusión de los temas climáticos en la legislación urbanística.

Palabras clave: cartografía climática; ciudades medianas; transectos móviles

1. Introduction

It is notorious that the effects of urban microclimates cause a number of global environmental problems, and many studies have demonstrated the significant effects of urban climate on human thermal comfort and increasing building energy consumption. (JIN et al., 2020)

It is also observed that the urban climate becomes an important feeder of the process of proliferation of the disease, mainly due to the heat-retaining characteristics that cities provide, maintaining the temperatures within the ideal ranges of proliferation of the vector and accelerating its development. (LEMOS et al., 2021)

Despite that, climate issues are of low relevance in the urban planning process in the Brazilian context, even with the wide knowledge of the negative impacts of urban climate formation and the various mechanisms of bioclimatic adaptation of these spaces. It is believed that the reason for this lack of influence is an important question to which answers must be sought between climate scientists, planners and the planning process itself. Urban planners show interest in climate aspects, but the lack of a clear and practical information system makes it difficult to apply.

For Huang-Lachmann and Lovett (2016), the difficulty of application is often justified by the complexity and cost of obtaining climatological data, the different language, or even the very general character of urban climate studies, due to little detail and accuracy of the information offered.

Nevens et al. (2012) state that the environmental conditions of the present city have challenged its scholars regarding the search for immediate solutions to the serious problems highlighted there. Creativity has to produce knowledge and intervention under new initiatives. It is in this sense that openness to new forms of urban approach must ensure new techniques and methods.

Thus, the fact that environmental characteristics can be largely controlled by planning and project activity, at their different scales, through urban legislation,

"stands out, so that, in principle, there is potential to objectively aggregate climatological information to the planning and city management through so-called climate-responsible urban planning" (ASSIS, 2003, p. 145).

Oke (2006) suggests the need to develop common procedures for processing the collected data and for measuring measurement sites to produce reliable and simple solutions for the design and planning needs of communities in different climate zones. This author highlights the urgency in creating such solutions, thus responding to the rapid growth of cities throughout the tropical world.

That role can be played by maps, that can provide clear information from an urban climate perspective to decision-makers (including the public). These maps can support the urban planning or design proposals, in order to mitigate urban warming. (MATSUO & TANAKA, 2019)

Considering these approaches, one of the questions on the issue of production of urban space, concerns urban intervention possibilities in terms of physical and environmental quality. Such interventions can produce adequate conditions of environmental comfort, considering the vital concerns for the quality of cities in their urbanity context, with respect to typologies, morphologies, landscape and the interrelationships between the various urban elements and their users. (ZHOU et al., 2020)

Assis et al. (2007) point out that the use of natural resources is not yet a practice incorporated into the urban planning actions in the country, with a homogeneity of recommendations in the Brazilian construction legislation, while observing in reality the great diversity of climates in the national territory. Thus, what is in the country is a great distance between the considerations of urban bioclimatology in the plans, codes and municipal laws.

From the middle of the last century, another vision has been developed, in the context of sustainable climate-friendly urban construction, regarding the use of environmental resources, particularly regarding energy. (JIN et al., 2020)

However, this new approach is not yet adopted, in fact, in the urban legislation of most Brazilian municipalities. This requires a review of the concepts of urban

planning, which must start from concrete problems of the majority of the population, considering the elaboration of urban legislation as an opportunity to question and debate real improvements to the problems raised.

Given the above, the present research starts from the problem of the lack of insertion of issues related to climate within the current context of formulating proposals and guidelines in urban legislation, a posture that tends to generate environments that are inadequate to urban functions, causing health problems to the population and increasing the energy consumption in cities.

Thus, one of the main current challenges for climate-friendly urban design and planning is to demonstrate the possibilities of developing methods that bring information from urban climate studies closer to city planning and design. It is hypothesized that small and medium-sized cities, such as Sinop, north of Mato Grosso state, located in the Legal Amazon, tend to present considerable particularities in identifying urban climate differences and different relationships between constructed space and the formation of the urban climate.

In view of this, the general objective is to develop a methodology for evaluating and formulating proposals and guidelines related to the adaptation of urban spaces to the climate in which they operate, within the processes of drafting and monitoring urban laws in small and medium-sized cities, in regions with climatic similarity compared to Sinop in the Midwest of Brazil. It seeks to identify the relevant climatic characteristics for the urban planning process in a region of continental equatorial climate with a defined dry season, incorporating aspects related to the observed urban microclimates and their formation, evidencing their deleterious effects on the evaluated community.

2. Proposed Method

The presented method proposes to detail the different uses of the urban soil, as well as the surroundings of the city, highlighting the commercial, residential, industrial areas, in addition to the green areas and with bodies of water. Other information to be mapped concerns the topography, the type of soil cover and how the population density is distributed, from aerial or satellite photos, urban

planning documents and/or even on-site observations. This organization derives a joint analysis of the mapped information, in order to define the characteristic areas within the urban network with regard to the degree of impact on the formation of specific urban microclimates (ZCUs).

Mobile transects seek to map the distribution of climatological variables by the most consolidated urbanized area of occupation. For this purpose, it starts from a positioning of the measuring points with the most uniform distance possible, in addition to being arranged in order to facilitate the journey, passing through more fluid traffic routes and through characteristic areas, representing different patterns of use and occupation.

Were conducted in the two seasons, representative for the region, the hot and dry season, represented here in the months of July and August 2013, and the hot and humid season, represented the months of February and March 2014. Were proposed measurements at three different times, 8:00 am, 2:00 pm and 8:00 pm, representing the periods after sunrise, the hottest period of the day and the period after sunset. These surveys were also conducted on four consecutive business days, seeking, whenever possible, stable weather conditions.

Finally, based on information from transects, fixed stations and the analysis of the characterization of the city, it is possible to establish an analysis of the city's climatic conditions and comparisons with its rural surroundings, showing where climate change is most intense and where the organization of the urban fabric has a greater influence in this sense (Figure 01).

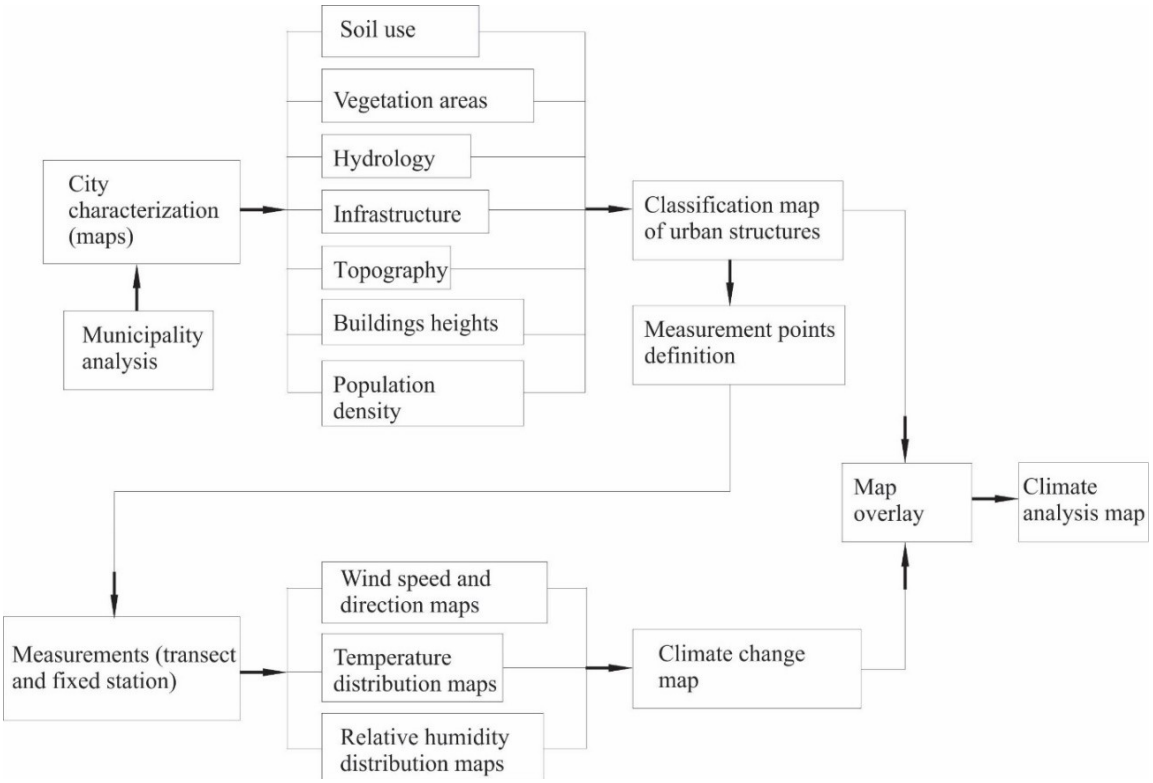


Figure 1. Diagram of the proposed methodology on the scale of small and medium-sized cities.

At the fixed measurement point, installed on the UNEMAT campus, a Vantage Pro2 weather station from the manufacturer Davis Instruments is used. This station consists of two main units, an integrated set of sensors and a console for presenting and recording the data obtained. The communication between these two units takes place through a wireless system that has a maximum range of 300 meters (DAVIS INSTRUMENTS, 2012a).

The sensor set consists of a rain collector, temperature and humidity sensors and anemometer. This set is complete with a solar radiation sensor, purchased separately, and a solar energy collection and data transmission center. The temperature and humidity sensors are mounted inside a radiation protection in order to minimize their impact on the readings of these variables.

For mobile measurements, a compact set from the same manufacturer is used. It is the same console described previously, associated with an integrated set of VantageVue sensors, which contains a rain collector, temperature/humidity sensor, anemometer, and a reed, serving as a windsock. The temperature/humidity sensor is mounted inside a radiation shield to minimize

the impact of solar radiation on the readings (DAVIS INSTRUMENTS, 2012b). This set is coupled to the car by means of a metallic support installed on the roof. The consoles of both weather stations must be synchronized and programmed to obtain data every minute. This becomes important in the mobile data correction stage, to be explained later. This done, the vehicle with the mobile station can go to the starting point (point 1) to start the measurements. For greater reliability, it is important that the measurements always start at the same time, within the stipulated periods (8:00 am, 14:00 pm and 20:00 pm). From there, it proceeds, in sequence, to the stipulated points, at a uniform speed, close to 40 km/h. It is important to stay at each point for at least two minutes. One to stabilize the equipment and another to collect the desired record. For subsequent correction, it is essential to note the exact minute of this collection.

For the correction of moving data from the procedure described above, it is sufficient to observe in which minutes a certain mobile point was recorded and add or decrease the humidity difference value relative or air temperature recorded at the fixed station with respect to the value at the measurement start. For example: in a given mobile transect (mobile station), point 7 was registered at 14:21. The temperature value of the air measured for this point was 32.5°C. At the fixed station, at 14:00 (start of measurements), the recorded air temperature was 31.6°C, and at 14:21 it was 32.1°C, a difference of 0.5 C the most. In this case, then, it is enough to decrease 0.5 ° C to 32.5°C of point 7 of the mobile transect, resulting in 32.0°C of corrected air temperature.

The field data collected at the 16 survey points resulted in a subset of spatial phenomenon values that are representative, which reproduce the spatial distribution and variability both in size, that is, in the number of data points, and in terms of the distribution of the points in the domain to be studied. Any estimate based on sample points is, however, subject to uncertainty, and in this sense, the Geostatistics methodology stands out by providing the uncertainty associated with the estimate.

The Kriging method is used here, which is a geostatistical process of estimating the values of variables distributed in space and/or time, based on adjacent values when considered interdependent by variographic analysis. It can be compared

with traditional methods of estimation by weighted averages or by moving averages, but the fundamental difference is that only kriging presents non-biased estimates and the minimum variance associated with the estimated value. Ordinary Kriging is the most used method, due to the simplicity and results it provides. Ordinary kriging is a local method of estimation and, therefore, estimation at an unsampled point results from the linear combination of the values found in the immediate neighborhood (YAMAMOTO, 2013).

For making the images with the distribution of climatological variables, the SagaGis software is used. It made possible to import files into CAD platform and most of the files generated by spreadsheet software, making it easier to use data from the local government and research in the field. On the other hand, the graphic quality of the final products generated by SagaGis is low. Therefore, it is important to use vector image editing software in order to improve the generated maps, making details clear and facilitating their reading.

3. Results and Discussion

The municipality of Sinop is located in the northern region of the State of Mato Grosso, with an estimated population of 123 thousand inhabitants and MHDI of 0.754, which is considered high. The seat of the municipality is at 11.86°S and 55.5°W, (IBGE, 2010; PNUD, 2013). It has an average altitude of 380 m and a territorial extension of 3,528 km².

The municipality is located in the region known as the Legal Amazon, in the Amazon biome. However, the region is also influenced by the Cerrado biome. Due to these characteristics, the municipality's vegetation is called transition forest. Its hydrographic network belongs to the Teles Pires River basin, belonging to the Amazon Basin (MORENO and HIGA, 2005).

According to the classification proposed by Maitelli (2005), the State of Mato Grosso has two climatic units: I - Continental Equatorial Climate with a Defined Dry Season (3 to 5 months); and II - Continental Tropical Climate Alternately Wet and Dry. These units are further divided into subunits according to characteristics related to temperature, rainfall and altitude. The municipality of Sinop is located in the subunit I-B domains, thus presenting average annual

temperatures between 24.3°C and 26.8°C in addition to total rainfall between 1800mm and 2200mm, with a dry period in the months of April to September.

However, the periods (or seasons) of the year are divided here, defined according to the study by Vieira et al. (2014), carried out based on the analysis of the region's water balance, in a historical series. Thus, the period of drought between May and September and the rainy period between October and April are considered.

This city was planned in an orthogonal way, with roads parallel and perpendicular to the North-South axis. The East-West axis consists of Av. Dos Mognos and its extensions, Av. Alexandre Ferronato to the East and Av. Da Saudade to the West (Figure 02). In the design phase, urban forest reserves were also stipulated, following the water courses present in the region. Thus, the Parque Florestal Reserve in the North, the Ceprotec Reserve in the South and the UNEMAT Reserve in the West were defined.

Figure 2. Map indicating the main roads, reserves and structures in the city of Sinop. Source: adapted from Google Earth (2014).

Sinop is a predominantly flat city, without major differences in altitude, mainly in the polygon formed by its original layout. The exceptions are due to water courses within the Reserves and permanent preservation areas, where the lowest quotas are observed, between 345 and 365 meters. The highest altitudes are recorded on the outskirts and surroundings of the city, with levels between 380 and 385 meters. It is also observed that the prevailing winds, from the East and Northeast, have practically free access to the city, mainly to the Center and South regions.

In general, urban vegetation is scarce and poorly distributed. Expressive areas, with medium and large trees, are mostly concentrated in the Parque Florestal and UNEMAT Reserves. In the surroundings of the city, the most significant vegetation is concentrated in the areas of permanent preservation, along the watercourses. However, these are very narrow and insufficient areas to positively impact local climatic conditions.

The greatest lack of vegetation is located in the Central region, to the south and east of the city. In the Center, the absence of this element is noticeable, mainly in the commercial axis of Av. Dos Mognos and nearby streets. To the south, large deforested areas and allotted, without occupation, and residential areas of low density and few trees form a poor region of vegetation. In the east, there is a large area devoid of vegetation, with exposed soil. It is worth mentioning that it is exactly there that the dominant winds that hit the urban fabric pass through the year. This is especially harmful in the dry season, when this region contributes to the formation of dry, hot and polluted winds.

The demographic density is, in general, very low. Some registration sectors reach densities between 5618.8 to 12275.12 inhabitants/km², but the vast majority of sectors reaches a maximum of 5571.9 inhabitants/km². The highest densities are concentrated in the North of the city and, in peripheral neighborhoods, mainly in the Northwest and South. These are areas occupied in recent years by the population of medium and low income. These are areas subject to congestion, excessive waterproofing of the soil and greater risks of environmental

degradation and pollution. The sectors closest to the Center, even the residential ones, remain with low occupancy.

3.1. Classification map of urban structures

Regarding the different land uses found in Sinop, it is observed that the areas covered by vegetation are concentrated in certain areas of the city, mainly in the reserves created with the original layout. There is a clear lack of parks and recreational areas containing vegetation. One of the few is to the east of the city center (Praça da Bíblia) which was recently urbanized and which maintains a forest with large vegetation.

Industrial establishments are concentrated east of the BR-163 highway, in a sector originally intended for this activity. However, it was noticed that this position was unfavorable, since the winds brought the pollutants generated there to the rest of the city. Thus, smoke, sawdust and dust were released towards residential and commercial areas, especially during the dry season, when, for a long time, the remains of the wood sector's production were burned.

Between 2008 and 2010, this practice was prohibited and the timber sector lost strength, with a stricter inspection of illegal deforestation in the region. Thus, there is a decrease in pollutants from these industries, with dust still a concern. Other industries have moved and new ones have been installed in the southern part of the city, where there is a project to install an industrial and commercial subdivision, currently under construction. Along the urban stretch of BR-163, heavy-duty installations are also concentrated, serving heavy vehicles, agricultural implements, large warehouses and wholesalers.

The area with the highest concentration of shops is on the Av. Dos Mognos axis, in the city center, and in nearby streets. There are the major department stores, home appliances, clothing, and stationery and computer companies. Another important commercial avenue is Vitória Régia, to the Northwest of the Center, which supplies the residential neighborhoods of medium and low standard in its surroundings. Finally, on the margins of the urban stretch of the BR-163, and on Av. Dos Tarumãs, there are vehicle dealers, auto parts, building materials stores, among other large stores.

Regarding residential use, the predominance of single-family single-storey buildings is clear. Verticalization in the city is incipient, but it has gained ground in current developments. What we have, in most cases, are single-storey buildings in the center of the lots, especially in neighborhoods furthest from the Center. In the central region, mixed-use buildings predominate, with shops and services on the ground floor and dwellings on the first floor. This contributes to a reasonable occupation of the city center, even at night.

From the information previously analyzed, it was possible to generate the Classification Map of urban structures, according to their capability to affect the local climate (Figure 03). Based on studies on Urban Climate Zones (WMO, 2008). This map shows how the presence of vegetation, density and land use and occupations, tend to negatively impact the climate. In the case of Sinop, characteristics were identified that configure six of the seven proposed Zones, excluding Zone 1 (Intensely developed areas, with a set of tall buildings nearby, absent in the analyzed urban context) and the addition of a zone representing permanent protection areas and vegetation reserves, where the impact would be minimal.

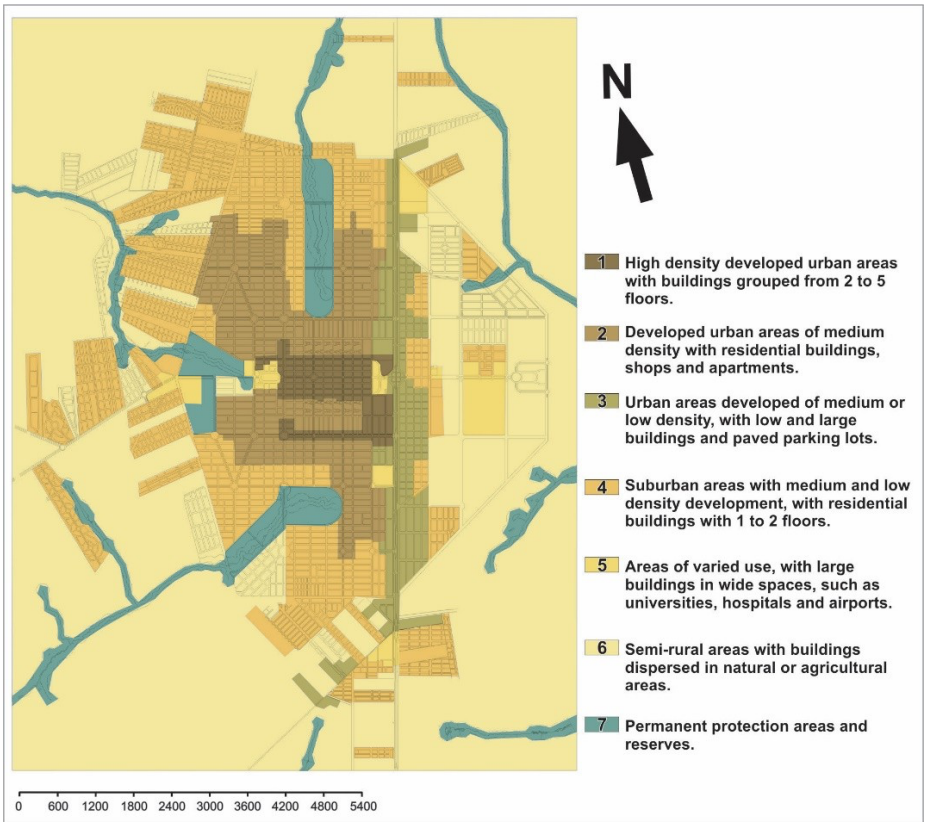


Figure 3. Classification map of urban structures according to their capability to affect the local climate.

In this way, seven climatic zones are proposed, the most impactful being Zone 1, composed of developed urban areas, of high constructive density, with buildings grouped from two to five floors. This zone represents urban spaces occupied predominantly by shops and services, with excessive waterproofing of surfaces, heavy traffic of vehicles and pedestrians and significant human activities. It is located in the commercial center of the city, on the axis of Av. Dos Mognos and adjacent streets, on the stretch of Av. Das Itaúbas near its intersection with Av. Dos Mognos, and on the commercial axis of Av. Dos Tarumãs.

Zone 2 is composed of developed areas of medium density, with single-storey residential buildings, shops and apartments, mainly in mixed use. It presents considerable waterproofing of surfaces, and important traffic of vehicles at certain times. It occupies part of the city center and nearby neighborhoods.

Zone 3 refers to large businesses and services with buildings and warehouses occupying extensive areas. They are also areas that house large maneuvering yards and paved parking lots, such as gas stations, light and heavy vehicle dealerships, agricultural warehouses, industries and wholesalers. It is located on the local roads along the BR-163 axis and nearby streets and avenues.

In Zone 4 there are areas predominantly occupied by residential buildings with one or two floors, located in the center of the lots, with reasonable soil permeability. There are still many empty or underutilized lots, and even unpaved streets. There is little neighborhood trade and little vehicle traffic. It is formed by the neighborhoods furthest from the city center.

Large buildings of varied uses, in wide spaces, configure Zone 5. They are areas with large permeable plots and with the presence of significant vegetation. This Zone is composed of institutional buildings such as the municipal cemetery, the universities present in the city, the football stadium, the cathedral church, among others.

Zone 6 includes areas of urban expansion, characterized by sparse buildings in large areas. These are places often occupied by agricultural activity, especially

the planting of soybeans, corn and cotton, reaching the boundary of developed suburban subdivisions. Another observed use is that of recreation and vegetable production farms.

The last Zone, 7, refers to areas with significant remaining vegetation, within the urban perimeter. They are mainly the Reserves created in the implementation of the original project of the city (R1 to R7), and areas of permanent preservation on the banks of watercourses near the urban network. Some of these areas are under pressure from the intense occupation of the expansion areas outside the original layout of the city, notably in the Northwest part of the city.

3.2. Mobile Transect

The distribution of data collection points is organized based on a joint analysis of previously mapped information. It seeks to define the characteristic areas within the urban network with regard to the degree of impact on the formation of specific urban microclimates. After this analysis, together with spatial distribution criteria, the possibility of route and time, the measurement points to be observed in the mobile transects are defined (Figure 04).

Figure 4. Satellite image of the city of Sinop showing the position of the measurement points and the route proposed by the research. Source: adapted from Google Maps (2014).

3.3. Dry season

From the observation of the maps of distribution of temperature and relative humidity of the air, for the morning period in the dry season, it is possible to verify the formation of a region with higher temperatures in the eastern portion of the city, covering point 9 and approaching the points 8, 10 and 11. It covers points that represent the high-density city center, under the direct influence of BR-163, and the large commercial and service sector on its margins.

In addition, the influence of the wind speed and direction recorded during the measurement period was observed. In this case, on average, a speed of 1.1 m/s and ESE direction were recorded. Thus, the dry and hot air conducts from the eastern outskirts of the city, a region with low occupation and devoid of vegetation, towards the urban fabric.

The city's roughness itself acts as a barrier to the prevailing winds, with the Parque Florestal (Reserves R10, R11 and R12) playing an important role. This area has the function of blocking these winds, in addition to decreasing the temperature and increasing the relative humidity of the air in the West and Northwest regions of the city. Thus, it is possible to observe the formation of a region with lower temperatures and higher values of relative humidity of the air, covering points 14, 15 and 16, under the influence of the UNEMAT Reserve (R7) and west of the Parque Florestal. These are Reserves of significant size and with abundant and large vegetation, with the presence of watercourses.

The maps of the distribution of temperature and relative humidity of the air, for the afternoon period in the dry season, show that the region with higher temperatures and lower values of relative humidity, occurs in the East of the Center. This occurs mainly in the industrial and commercial sector along the BR-163, extending from point 11, to the North, through points 10, 9, 8, 5 and 4, to point 7, to the South.

Again, the influence of the wind speed and direction registered during the measurement period is observed. In the afternoon, on average, a speed of 1.5m /

s and ENE direction were recorded. As in the morning, is conducting the dry air and warm surroundings to the east, toward the fabric of the city.

In this case, it is observed that the Parque Florestal (Reserves R10, R11 and R12) and the UNEMAT Reserve (R7) continue to play an important role. Perform the blocking function of these winds, as well as providing decreasing temperature and increasing relative humidity in areas west and north-west of the city. It is also possible to observe a greater relevance of Reserves R1, R2 and R3 (Reserva do Ceprotec), mainly in the decrease of registered air temperature values.

Thus, the region with lower temperatures and higher relative humidity values is concentrated in the NW portion of the city (points 13, 14, 15, 16), under the influence of the UNEMAT Reserve and west of the Parque Florestal. It extends to the SW (points 1, 2, and 3), under the influence of Reserves R1, R2 and R3.

In the night time of the dry season, the temperature and relative humidity distribution maps show that the region with the highest temperatures and the lowest relative humidity values occurs in the East of the Center, more concentrated in the vicinity of points 9 and 10 , and, mainly, in the industrial sector close to BR-163. It also occurs south of the center, covering the points 3, 5, 6 and 7, in a similar situation found in the previous period, however, discontinuously.

On average, a speed of 0.4 m / s was recorded (much lower than the periods previously analyzed) and ESE direction. In any case, the dry and hot air continues to flow from the surroundings to the East towards the city network. However, the relevance of Reserves R1, R2 and R3 (Ceprotec Reserve) is no longer observed, especially in the increase in the relative humidity values recorded. During this period, the region with the lowest temperatures and the highest relative humidity values is concentrated in the West and Northwest portion of the city, under the influence of the UNEMAT Reserve and the Parque Florestal (points 1, 13, 14, 15 and 16).

Figure 05 below shows the panorama of the distribution of the variables studied in the dry season:

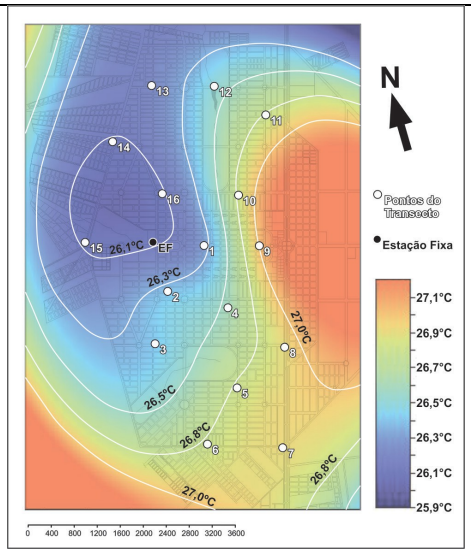
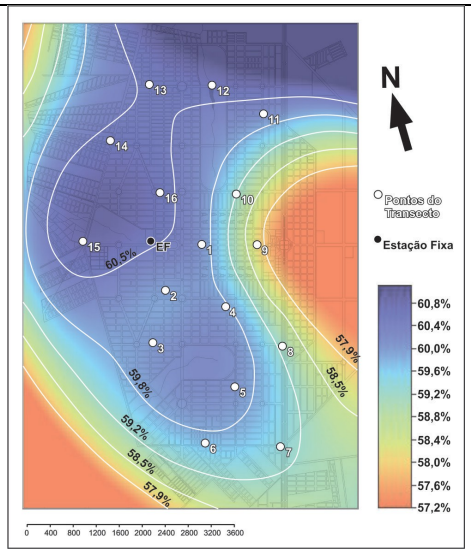
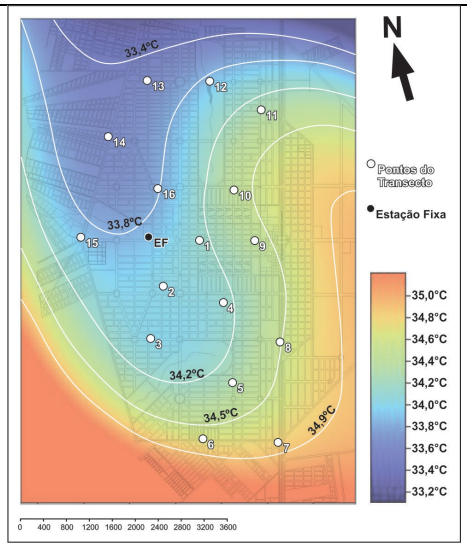
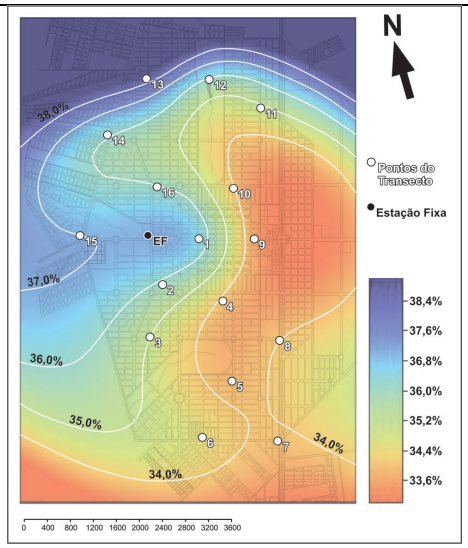
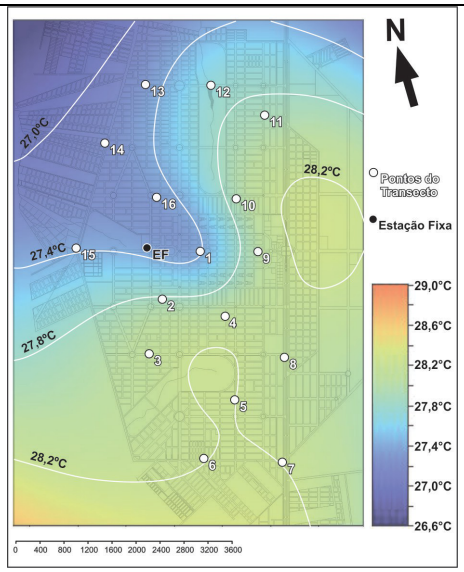
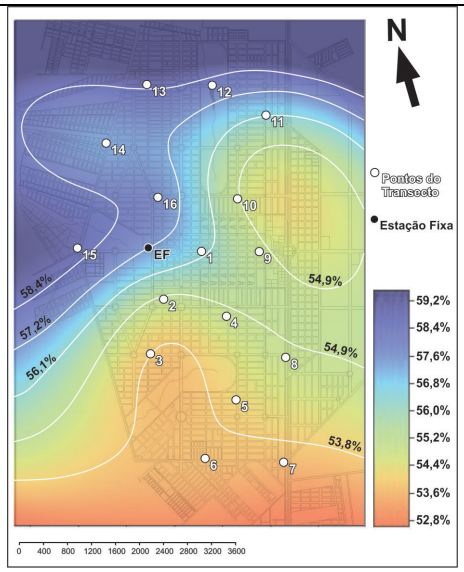
	RAINY SEASON	
	Air temperature	Relative humidity
Morning		
Afternoon		
Night		

Figure 5. Maps of air temperature distribution (a) and distribution of relative air humidity (b) for the city of Sinop in the mean of the measurement days in the dry season.

3.4. Rainy season

From the observation of the maps of temperature distribution and relative humidity of the air, for the morning period in the rainy season, it is possible to verify the formation of a region with higher temperatures and lower relative humidity, in the western portion of the city, extending towards to the South. It covers points 1, 2, 3, 5, 6 and 15, which represent low and medium density residential areas.

Although to a lesser degree, it is observed the influence of the speed and direction of wind recorded in the measurement period. In this case, on average, a speed of 0.8 m/s and NE direction were recorded. Thus, the drier and hotter air formed in the Center takes place, towards the SW region of the city. The regions with lower temperatures and higher values of relative humidity of the air tend, in this case, to group the areas around the city, of low occupation or semi-rural.

The distribution maps of the temperature and relative humidity of the air in the afternoon show that the region with the highest temperatures and the lowest relative humidity values occurs in the city center. This happens mainly in the region that includes points 1 and 2. In the afternoon, on average, a speed of 1.1 m/s and direction SE was recorded. Thus, the urban fabric blocks the dominant winds, more humid and fresh.

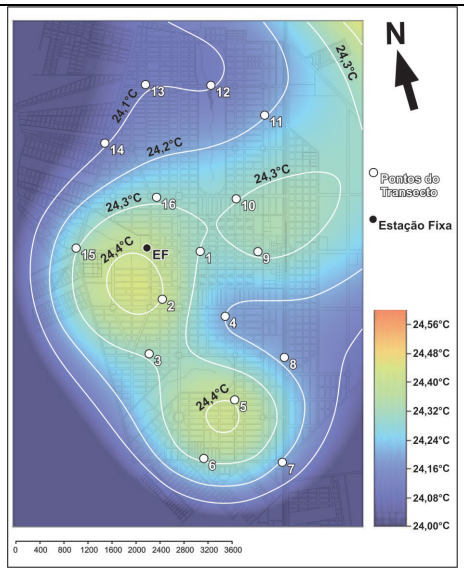
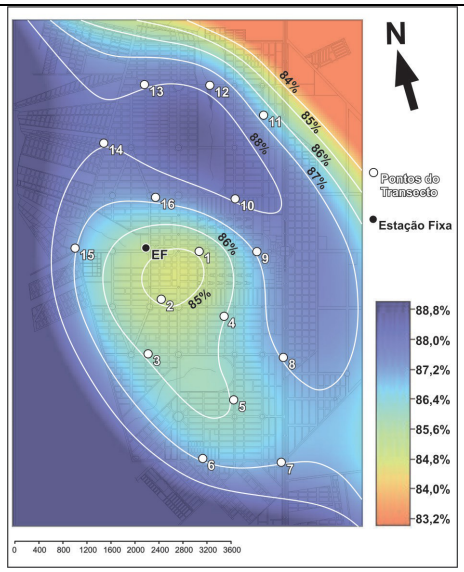
The regions with lower temperatures and higher relative humidity values are concentrated mainly around the city and in its NW portion, under the influence of the UNEMAT Reserve and the Parque Florestal.

At night, the temperature and relative humidity distribution maps show that the region with the highest temperatures and the lowest relative humidity values occurs in the city center, more concentrated near points 1 and 2. It extends south of the center, covering the points 3 and 4 toward the CEPROTEC Reserve.

On average, a speed of 0.8 m/s and NNW direction (opposite to morning and afternoon directions) were recorded. Anyway, the blockade of the winds from

the surroundings towards the city center continues to be observed. During this period, the region with the lowest temperatures and the highest relative humidity values is concentrated in the West and Northwest portion of the city, under the influence of the UNEMAT Reserve and the Parque Florestal (points 12, 13, 14, 15 and 16), and under the influence of moist and cool winds from the surrounding area.

Figure 06 below shows the behavior of the variables in the three evaluated periods:

	RAINY SEASON	
	Air temperature	Relative humidity
Morning		

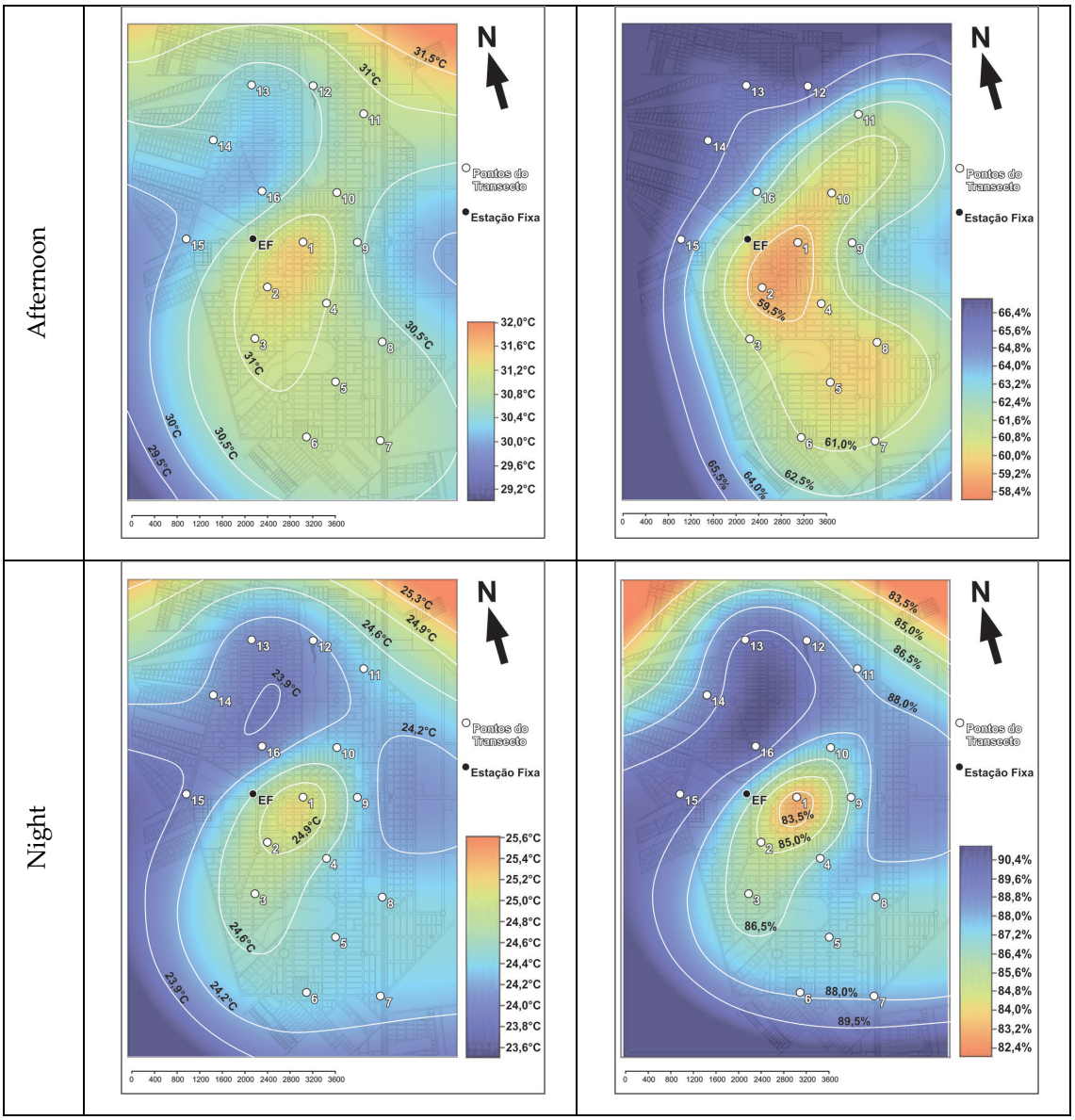


Figure 6. Air temperature distribution maps (a) and relative air humidity distribution (b) for the city of Sinop on the average of the measurement days during the rainy season.

3.5. Map of areas with climate change

From the temperature and relative humidity distribution maps, prepared with the average values of these variables, it is possible to highlight areas with relevant climatic changes in the urban environment. Thus, in each season of the year (dry and rainy), six relevant regions stand out. There are three regions referring to the highest recorded air temperature values (morning, afternoon and night), and three regions referring to the lowest relative humidity values found (also in the three periods).

The overlap of these six regions generates a new grouping, where regions are separated with one or two, three or four and five or six overlays. Three new regions are formed, representing the relevant climatic changes in relation to the temperature and relative humidity of the air, in each of the seasons. That is, six regions are formed, considering the two stations surveyed. Using the same criteria mentioned above, the regions of the two seasons are overlapped. This generates three new regions, now representing the degrees of climate change in the city throughout the year (Figure 07).

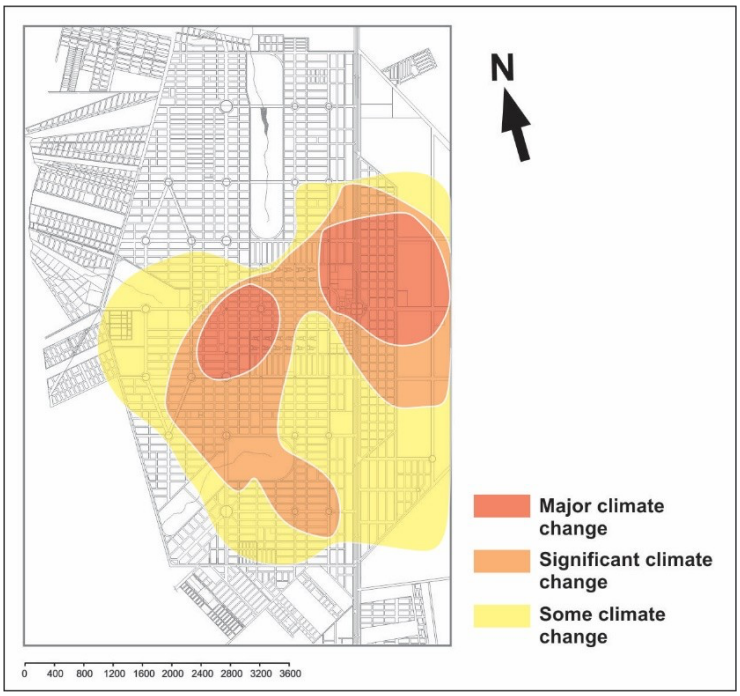


Figure 7. Map of areas with climate change throughout the year in the city of Sinop.

The most affected regions are concentrated in the Center-South portion of the city, considering its original layout. It comprises the eastern part of the city's commercial center, and, mainly, a portion of the large industrial and commercial sector, on the east bank of the BR-163. It also comprises a portion of the area without occupation and without vegetation to the east of the BR-163, which heats up quickly in the early hours of the day and receives directly the dry and hot winds from the surroundings.

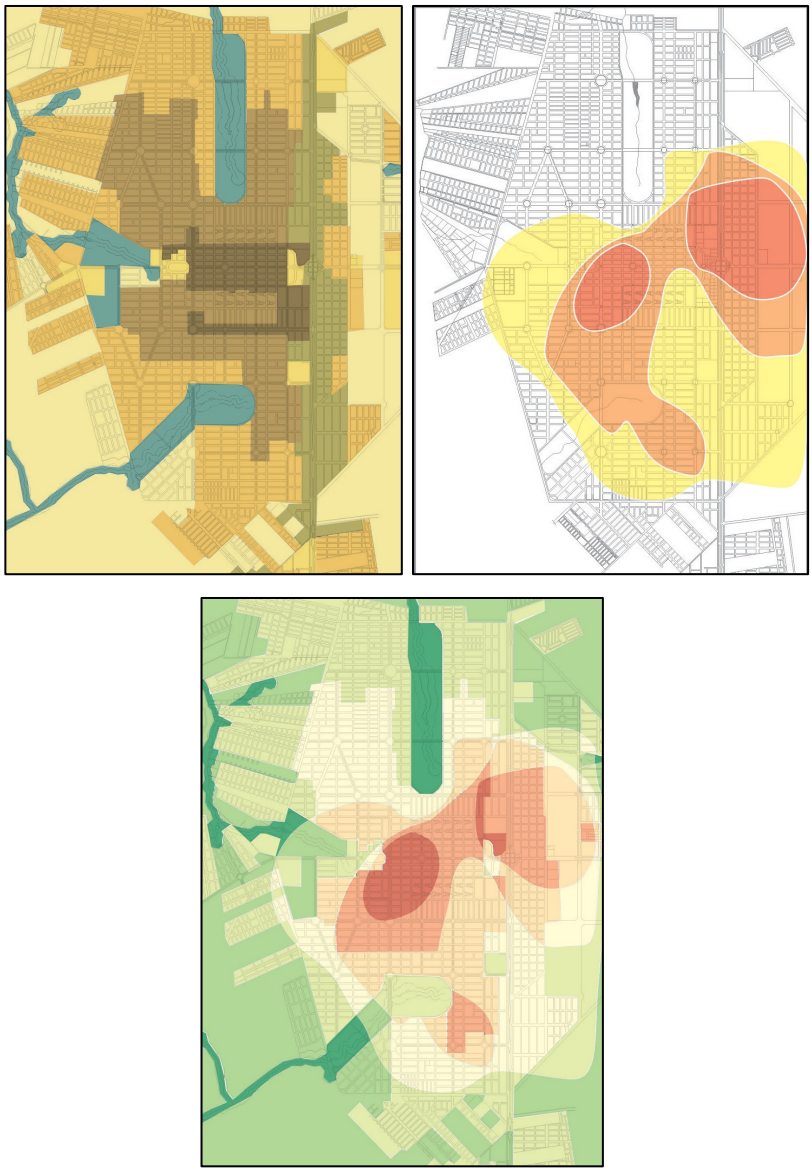
Another compromised region is to the West of the commercial center of the city (formed mainly by Av. Dos Mognos), and part of the commercial region near Av. Das Itaúbas, which cuts the city in the North-South direction. The role of the urban center in increasing the temperature and decreasing the relative humidity

of the air is more evident. Likewise, the influence of the prevailing winds remains clear, driving such climate changes, from the central region, to the city's SW.

There is also a tendency to unite the areas described, exactly on the city center, which has Av. Dos Mognos as its main route. It also shows the tendency of expansion of these climatically impaired regions towards the SW of the city, mainly due to the effects of the prevailing winds in that region.

3.6. Climate analysis map

Based on the overlapping of maps of areas with climate change, and the classification of urban structures with a tendency to impact the climate, there is the map of analysis of climate change in the city (Figure 08). The six areas of the map (a) and the three areas of the map (b) are superimposed, except for the areas of vegetal reserve and grouping the others, two by two. Thus, six new regions are generated, maintaining plant reserves, totaling seven regions, which are classified according to the degree of climate change in each of them (c).



(a) (b) (c)

Figure 8. Overlapping Maps of areas with climate change throughout the year (a) and classification of urban structures according to their ability to impact the climate (b), generating the Map of climate analysis in the city of Sinop (c) .

The seven ratings indicated on the map of Sinop climate analysis (Figure 09) are arranged according to the areas that have larger changes in relation to the climate, to the areas that contribute most to the control and mitigation of the local climate rigors.

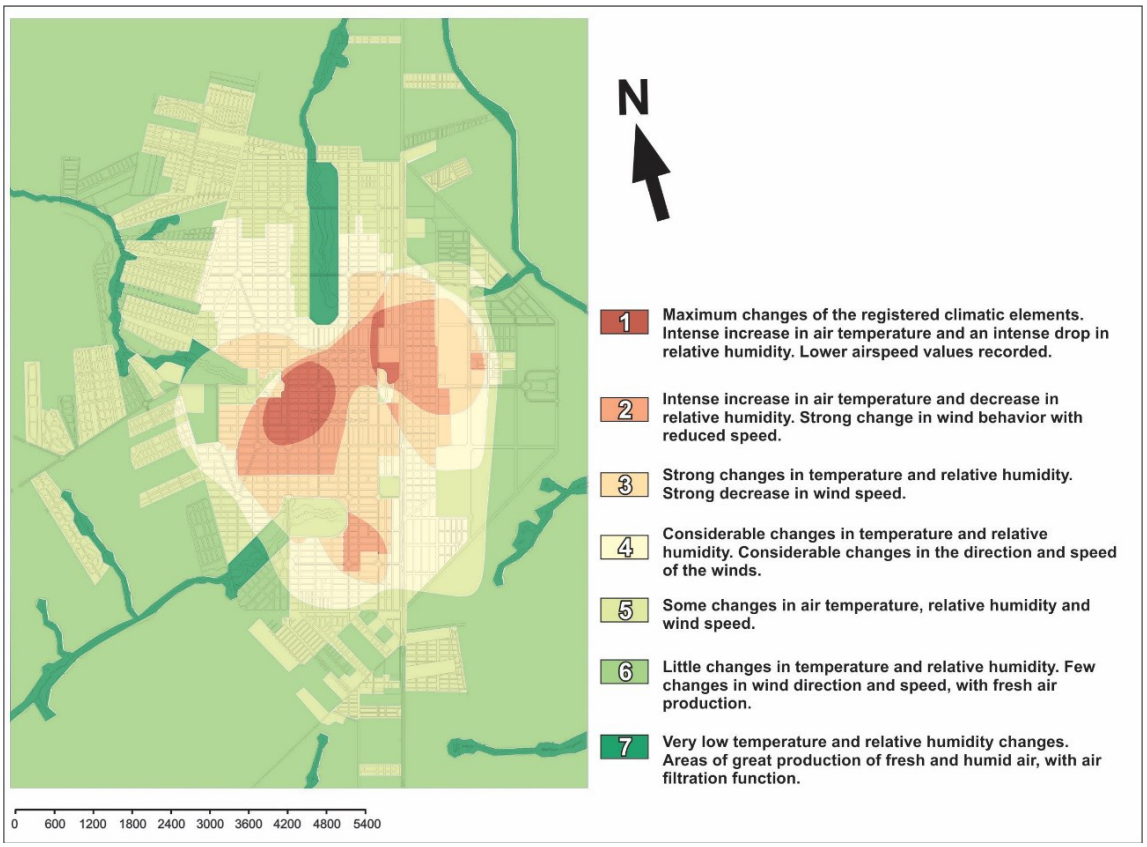


Figure 9. Map of climate analysis in the city of Sinop.

In zone 1, there are the areas where climatic changes are maximum, with an intense increase in temperature values and a decrease in the relative humidity values of the air, in addition to registering the lowest air velocity values. It is mainly concentrated in the western part of the citycenter, on the axis of Av. Dos Mognos, and extends to the south, following the commercial axis of Av. Das Itaúbas. It is also found in a small parcel to the east of the city center, close to the BR-163, extending to the north, following Av. Dos Jacarandás and nearby streets.

Zone 2 records an intense change in the climate variables surveyed, with higher temperatures and a decrease in the relative humidity and air velocity values. It is located around zone 1, covering parts of the regions of Av. Dos Tarumãs, Av. Dos Mognos and Rodovia BR-163. It extends to the East, for a considerable part of the industrial and heavy services sector, and is present in a small part of the southern region of the city, close to the Ceprotec Reserve.

Likewise, zone 3 is still experiencing severe climate change. It is located around zone 2, extending mainly towards the south. It comprises a significant part of the

neighborhoods to the south of the city center and areas to the east of the BR-163 highway, including unoccupied areas with exposed soil.

In zone 4, climate change is considerable, with a significant decrease in air speed and change in wind direction. It is around Zone 3, extending in the North and South directions of the urban network. Some changes in the surveyed climatic elements are still recorded in zone 5. This zone includes the peripheral neighborhoods of the city, and areas with low occupation and little developed. Wind speed and direction are little affected.

In zone 6, however, there are few climate changes registered. There is a certain production of fresh and humid air around urbanized areas, especially in the rainy season. This zone is basically formed by semi-rural areas and unoccupied subdivisions or under implementation.

Finally, zone 7 represents areas where climatic conditions are very close to natural ones. It includes a good part of the Vegetation Reserves and the permanent preservation areas along the watercourses. They are fundamental areas in the regulation of the local climate and important in the production of fresh and humid winds throughout the year. They also contribute in filtering air pollutants.

3.7. Map of indications for urban planning

From the analyzes recorded on the city's climate analysis map, and from the information generated in relation to the climate and land use and occupation, both in the city and in the municipality, we have the Map of indications for urban planning (Figure 10).

Figure 10. Map of indications for urban planning for the city of Sinop.

This map shows six zones, divided into built areas with a climate-related function and open areas with climatic activities, always classified according to the degree of relevance to the local climate.

Thus, Zone 1 refers to areas built with high climatic function. They are the most compacted, densified and developed areas of the city, with the vast majority of waterproofed surfaces. They are also major focuses of human activities, use of equipment (especially for air conditioning), and heavy traffic of motor vehicles throughout the day and most of the night.

The need for interventions in these areas is evident, in order to mitigate the observed climate changes. The increase in permeable areas with a significant presence of vegetation, the significant increase in road afforestation, measures to contain density and verticalization should be promoted. Another important measure is the restriction of access for motor vehicles, mainly on the commercial axis of Av. Dos Mognos, where an exclusive route for pedestrians and cyclists is proving quite viable.

Zone 2 corresponds to areas with significant climatic function. They are developed and densified regions, mainly in the city center and surroundings. It also has a large part of the waterproofed surfaces and heavy vehicle traffic, especially on the avenues.

Measures to control the intensification of land use and occupation are also necessary, as well as measures to contain vehicle traffic. There is also a need to increase green areas and road afforestation, notably on the local BR-163 roads, close to the city center.

On the other hand, a moderate intensification of the use and occupation of urban land is already possible in Zone 3. It encompasses areas that register some changes in the studied climatological variables. It is found in neighborhoods close to the city center and, in the east, in unoccupied areas close to the UFMT Campus.

Maintenance measures and increment of vegetated and permeable areas are necessary in this zone, notably in its eastern portion, a region of passage and formation of winds that reach the urban center, in both seasons.

In Zone 4, there are the neighborhoods furthest from the Center, with low density, and / or in regions favored from the climatic point of view, either due to the proximity of the vegetation reserves, or due to the prevailing winds regime. In any case, they are underdeveloped areas with lots of vacant or underutilized land.

Therefore, the intensification of use and occupation of this area should be encouraged, in order to take advantage of sectors of the city already served by relatively adequate urban infrastructure. In many cases, they are areas with easy access to the Center and the main points of attraction of the city.

Zone 5 already deals with open, unoccupied areas, and in this case, predominantly composed of undergrowth or exposed soil (depending on the season). These are areas bordering the urban network or preservation areas, currently treated as areas of urban expansion.

However, it is noted the importance of densifying, as a priority, the regions formed by zones 3 and 4, already consolidated, leaving zone 5 as a land reserve, but, above all, destined to the creation of green areas and leisure and sport activities, such as squares and parks. It should also be occupied with sparse buildings, leaving the largest portion of the soil permeable, with the presence of vegetation. This area also contributes as areas of production of fresh and humid wind and as corridors of wind, capable of carrying air to the most central regions.

Finally, zone 6 represents areas with a significant concentration of vegetation (reserves and permanent protection areas), in addition to adjacent areas, forming a green belt around the city. Obviously, this area also has the function of limiting urban expansion beyond the regions currently occupied, favoring the consolidation of areas already consolidated.

Another function of the delimitation of this area is to guarantee the preserved areas of vegetation and the reforestation of areas between the current reserves. In this way, it is possible to guarantee the presence of vegetation for the production and filtering of winds near the urban network, especially in the orientations of greater occurrence of regional winds.

4. Considerações Finais

The methodology developed in this work showed an efficient, inexpensive and practical way of obtaining climatological data. From the acquisition of only two sets of sensors, arranged in a fixed station and a mobile, it was possible to monitor the city with the aid of only one car.

The fixed station made it possible, in addition to correcting the data obtained, to compare its climatological data with the official rural station, available in most Brazilian municipalities. For small and medium-sized cities with a slightly rugged topography, this configuration was sufficient to highlight climate change in the urban space.

The choice of data collection at the height of the dry and rainy periods represents the regional climatic differences quite faithfully and is sufficient for the type of analysis intended. In any case, the conduction of transects should not be ruled

out also in the transition periods between the main seasons, especially in regions where there is no clear definition of the dry and rainy seasons, or which present colder periods throughout the year.

In Sinop, the distribution of 16 mobile measurement points across the city proved to be sufficient to represent the climatic differences of its different regions. With this type of data collection, it is possible to observe, in addition to the spatial distribution of the surveyed variables, a coherent profile showing the climatic differences between rural and urban environments (in any desired direction). It is also possible to represent, satisfactorily, the climatic differences of smaller portions of the city (such as the city centre, for example).

In this methodology, the data obtained were arranged in the form of maps of temperature and relative humidity, using the kriging method from Saga GIS software. This process enabled the spatialization of information quickly, with a good degree of reliability. It is a more accessible and direct language, which allows the visualization of climate changes encountered in a very intuitive way, using symbols and colors. Thus, the causes and effects of the formation of urban climates, as well as the possible mitigating measures are also more evident, allowing a greater number of people to participate and contribute to the process of drafting laws that take into account the climatic aspects.

The method was also shown to be consistent in evaluating and proposing measures for a challenging climate context. It is a region with seven rainy months and five dry months, always hot. It is known that bioclimatic strategies and even the conformation of the urban network for these two types of climate are often contradictory. When initially considering separate assessments for the two periods of the year, it is possible to identify the least desirable areas and arrangements from the climatic point of view in each season, having similar weights in the design of an overview for the whole year.

The developed methodology was described in order to allow its application in other cities and in climatic regions similar to Sinop-MT. However, it is necessary to deepen studies for its validation in regions where there are cold periods or very rugged topography, in order to establish new evaluation parameters and

the insertion of new information in the production of the proposed thematic maps. Other studies that may contribute to the results presented here, concern the continuity of monitoring the climatic conditions over time, as well the wind conditions in the cities.

Thus, it will be possible to observe how climate change evolves, as well as the effectiveness of the measures adopted in urban planning, with regard to mitigating the impacts initially recorded. It is also worth noting different methods of recording and monitoring these developments, showing how technologies of geographic information systems can contribute to the effective participation of agents involved in city planning.

6. Referências Bibliográficas

1. ASSIS, E. S. Aplicações da climatologia urbana no planejamento da cidade: revisão dos estudos brasileiros. RUA. **Revista de Arquitetura e Urbanismo**, v. 9, p. 20-25, 2007.

2. DAVIS INSTRUMENTS. **Vantage Pro2 Console Manual**. Davis Instruments Corp., 2012a. Disponível em: http://www.davisnet.com/product_documents/weather/manuals/07395-234_IM_06312.pdf

3. _____. **Vantage Vue Integrated Sensor Suite Installation Manual**. Davis Instruments Corp., 2012b. Disponível em: http://www.davisnet.com/product_documents/weather/manuals/07395-262_IM_06357.pdf

4. IBGE. Instituto Brasileiro de Geografia e Estatística. **Síntese de indicadores sociais - 2005**. Disponível em: http://www.ibge.gov.br/home/estatistica/populacao/condicaodevida/indicadoresminimos/sinteseindicsociais2005/indic_sociais2005.pdf. 2005.

5. _____. **Censo de 2010**. Disponível em: http://www.censo2010.ibge.gov.br/resultados. Acessado em: 12/04/2014.

6. JIN, L., PAN, X., LIU, L., LIU, L., LIU, J., & GAO, Y. Block-based local climate zone approach to urban climate maps using the UDC model. **Building and Environment**, 186. 2020. https://doi.org/10.1016/j.buildenv.2020.107334

7. MAITELLI, G. T. **Interações atmosfera-superfície: o clima**. In: Geografia de Mato Grosso: território, sociedade, ambiente. MORENO, G.; HIGA, T. C. S. (orgs.). Entrelinhas. Cuiabá, 2005.

8. MATSUO, K., & TANAKA, T. Analysis of spatial and temporal distribution patterns of temperatures in urban and rural areas: Making urban environmental climate maps for supporting urban environmental planning and management in Hiroshima. **Sustainable Cities and Society**, 47. 2019. https://doi.org/10.1016/j.scs.2019.01.004

9. MORENO, G.; HIGA, T. C. S. **Geografia de Mato Grosso: território, sociedade, ambiente**. Entrelinhas. Cuiabá, 2005.

10. NEVENS, F.; FRANTZESKAKI, N.; GORISSEN, L.; LOORBACK, D. Urban Transition Labs: co-creating transformative action for sustainable cities. **Journal of Cleaner Production**. V.50, p. 111-122. doi.org/10.1016/j.jclepro.2012.12.001

11. OKE, T. R. Towards better scientific communication in urban climate. **Theor. Appl. Climatol**. 84, 179–190, 2006.

12. PNUD. **Relatório do Desenvolvimento Humano 2013**. Disponível em: http://www.pnud.org.br/arquivos/rdh-2013-resumo.pdf. Acessado em: 22/02/2015.

13. SHI, Y.; LAU, K. K.; REN, C.; NG, E. Evaluating the local climate zone classification in high-density heterogeneous urban environment using mobile measurement. **Urban Climate**. V.25, p. 167-186. doi.org/10.1016/j.uclim.2018.07.001

14. VIEIRA, N. L.; QUEIROZ, T. M.; FAGUNDES, M. C.; SANCHES, J. C. M. POTENCIAL DA UTILIZAÇÃO DO EXCESSO HÍDRICO PARA IRRIGAÇÃO DE TETOS ECOLÓGICOS EM DUAS ZONAS BIOCLIMÁTICAS NO ESTADO DE MATO GROSSO. **Bioscience Journal** (Online) v. 30, p. 1389-1394

15. WMO. WORLD METEOROLOGICAL ORGANIZATION. **Guide to Meteorological Instruments and Methods of Observation**.WMO, Report No. 8. 7th Edition, 2008.

16. ZHOU, X., OKAZE, T., REN, C., CAI, M., ISHIDA, Y., WATANABE, H., & MOCHIDA, A. Evaluation of urban heat islands using local climate zones and the influence of sea-land breeze. **Sustainable Cities and Society**, 55. 2020. https://doi.org/10.1016/j.scs.2020.102060