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The Importance of Urban Greenery in the Construction of a Smart Landscape to Reduce Negative Environmental and Climate Impacts

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Abstract

The intense urbanization of the Municipality of São Paulo, SP, Brazil, highlights the high soil sealing, the reduction of open spaces, hinders stormwater runoff, and intensifies the process of Urban Heat Island. The objective of the work is to evaluate the importance of Urban Greenery analysis in order to contribute to a balanced system of permeable surfaces and urban afforestation, collaborating to a sustainable drainage system and cooling of the Urban Heat Island. Thus, the use of geo-technologies was used to obtain the maps of land use and occupation, Vegetation Index, and Land Surface Temperature and also statistics on the data and thus analyze the landscape in search of Nature-based Solutions. The analysis and implementation of Green Infrastructure in this research focuses on medium and large-sized street afforestation, and this must present harmony with all the city's infrastructure, collaborating with the environmental systems. The work can contribute to rethinking the green areas, with emphasis on Planting trees in cities to improve air quality, and reduce heat island effects, in order to build a smart landscape that aims to mitigate negative environmental and climate impacts, for the entire Municipality of São Paulo and thus meet the Nature-based Solutions.

Keywords

Environmental planning; Geotechnologies; Nature-based Solutions; Green Infrastructure; Quality of Life

1. Introduction

In the urban sprawl, since the 19th century, with a focus on Brazil, the theme of urban landscape planning linked to environmental issues has been growing, in order to think about nature and culture in an integrated way. In order to seek solutions to plan and intervene in the city based on nature, with the landscape as a basis. (Sant'Anna, 2020).

In this way, it is important to study the land use, temperature, and vegetation index of a landscape, in order to know the potential and flows that the area has, and to make some solutions that balance nature and the constructions in the city.

The process of territorial expansion is accelerated, causing several environmental impacts, among them: the potentialization of floods, pollution of soils, rivers, landslides due to disorderly occupation and deforestation and

atmospheric pollution resulting from the high circulation of vehicles and the release of gases from industries (Porangaba; Amorim, 2019).

The theme of landscape planning is linked to environmental issues, in order to think about nature and culture in an integrated way. All of this is with the aim of finding solutions to plan and intervene in the city based on nature, with the landscape as the foundation (Sant'Anna, 2020).

It is important to emphasize that the landscape must be studied and treated as infrastructure in the urban context, verifying its structural construction, physiology and natural processes that recur in urban morphology. This way of valuing existing infrastructure highlights the ecological functions of the environment and the ecosystem of the urbanized basin, prioritizes sustainable stormwater management and contributes to sustainable environmental planning (Bonzi, 2015).

In this way, to mitigate these impacts, free spaces must be studied, in search of their uses and functions for the creation of a green infrastructure that must be planned in harmony with urban spaces. Therefore, it is important to create and innovate in design solutions for a given environment (Amoroso, 2015).

As, the study of urban heat islands, where high sealing and intense land use, and temperature changes, contribute to the emergence of the heat island. Being that there is a link between the forms of use and occupation of the will have of urban areas with the variation of air temperature, that is, the areas with more open spaces, vegetation and proximity to water bodies, temperatures decline (Lombardo, 1985).

It is evident that urban climate has been studied at different spatial scales (micro, local and regional) in order to verify the influence of the surface in contributing to this warming, which we can call the heat island effect (Arnfield, 2003).

In this work, geotechnologies were used for mapping. Geotechnologies cover the collection of spatial and non-spatial data, models, analysis and data processing. The use of GISs is important, both because of the vastness and complexity of their attributes for processing and analyzing spatial data, and with recent improvements in graphic interfaces and the spread of geo-referenced data, and because their thematic maps and satellite images have contributed to the popularization of this technology (Reibel, 2007).

Attention should also be paid to the green area chosen for the urban area. The trees must be resilient, have urban suitability and be drought intolerant. With this planning, the planting of trees, and checking their species and location, is necessary to achieve a successful Urban Forest (Morzillo et al., 2022).

The study of the landscape has the challenge of providing new green spaces in the city, in order to take advantage of free spaces with a planning strategy planning strategy with benefits and in an intelligent way to solve the lack of infrastructure (Sanches; Pellegrino, 2016).

To apply a nature-based solution to the implementation of urban greenery, it can be defined as a network of urban green areas that are maintained or implemented, strategically planned, and managed to benefit the population by favoring environmental quality of life (Kantartzis, 2019).

In the study of the landscape, multiple issues are involved. This research aims to analyze the urbanization of the Municipality of São Paulo—SP, where a multifaceted scenario predominates. It also includes the goal of mapping land use and occupation, thermal field, and Vegetation Index in the municipality of São Paulo, SP, using technologies, including GIS, for the year 2020.

The maps of the thermal field could be analyzed in this work to analyze the urban heat Island on the surface, and then related to the Vegetation Index and with the land and use occupation to have an outlook of the landscape in São Paulo, SP.

Thus, the work hypothesises that, through an analysis of the landscape, solutions could be found to implement urban greenery with an emphasis on urban afforestation in areas lacking these green areas, to form an urban forest in the study area in the search for Nature-based Solutions, and to adapt environmental planning in a sustainable way.

2. Materials and Methods

It is noteworthy that the Geographic Information System (GIS) as a mapping tool to obtain answers to questions about the collection of data from the physical environment, in order to analyze changes in the environment and thus assist in the planning and management of existing natural resources (Fruehauf; Lombardo; Pellegrino, 2019). In the landscape, it could be used to obtain land use and occupation, Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) in the year 2020.

In this research, it was used the GIS software, named QuantumGIS (QGIS). QGIS stands out for being a widely used free and open-source software that fits into GIS and accepts numerous vector, matrix and database data formats. It allows you to generate, visualize, manage, edit and analyze data, as well as compose maps in various formats (Pereira; Guimarães; Oliveira, 2018).

The CBERS4A satellite, with a resolution of 2 meters, took the land use of the study area and classified it into 11 uses: tree canopy, grass, exposed soil, asphalt, river/lake, swimming pool, light tile, dark tile, gray tile, and ceramic tiles.

The 2020 images were obtained free of charge from the INPE website, and have a resolution of 2 meters for the satellite image, which emerged from a union between the governments of Brazil and China signed in 1988, with the partnership of the National Institute for Space Research (INPE) and the Chinese Academy of Space Technology (CAST), where two advanced remote sensing satellites were built, called the Sino-Brazilian Earth Resources Satellite/China-BrazilEarth Resources Satellite (CBERS Program). Specifically in this work, CBERS 4A was used, which emerged as a continuation of the program, launched on December 20, 2019, and built in partnership with the Chinese CAST (EMBRAPA TERRITORIAL, 2018).

In the thermal field, a Landsat 8 image from August 19, 2020, was analyzed to see the heat island form. There are a variety of sensor systems designed to provide data from the Earth's surface, most notably Landsat 8 launched on February 11, 2013, which is a joint venture between the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS) (Oliveira et.al., 2017).

It should be noted that the heat island is a phenomenon characterized by warmer temperatures in urban regions compared to the surrounding rural environments (Roth, 2013).

The study of land use and occupation associated with LST aims to study the reality of the landscape and the phenomena that occur in it as the Urban Heat Island. Thus, it is reported that the large appropriation of land use in city centers, as well as its expansion without planning, results in a biologically sterile and aesthetically depressing urban landscape. As an alternative, it becomes necessary to understand natural processes in the urban context, and their relationship with city planning and design and to seek solutions (Lombardo, 1995).

About the NDVI, we could analyze the green area of São Paulo, and could also see what a lack of green areas the city has. As Lourenço and Landim (2004) point out, large-scale vegetation is where the NDVI is commonly used, as it relatively compensates for the difference in lighting conditions, inclination of the surface and aspects of the sensor due to the considerable orbit width (2,700 km).

The most widely used vegetation index in mapping is the NDVI (Cohen et al., 2003). The NDVI is presented by calculating the difference between the Near Infrared and Red bands, normalized by the sum of the same bands proposed by (Rouse et al., 1973), (Zanzarini et al. 2013) as follows:

$$NDVI = (IVP - V) \div (IVP + V)$$

Where:

NDVI = normalized difference vegetation index value IVP = reflectance value in the near-infrared band

V = reflectance value in the red band

It should be noted that NDVI, used in several environmental and agricultural studies that tend to monitor natural resources, has a scale ranging from -1 to 1, the closer the value of -1, the smaller the vegetation and +1 (Rouse et al.,

1973), would be greater vegetative vigor, so in addition to expressing the density of vegetation also reflects its health/vigor. (Ponzoni; Shimabukuro, 2009).

Therefore analyzing the land use, thermal field and NDVI maps, the urban landscape of the city of São Paulo can be verified as a basis for proposing improvements through nature-based solutions in the urban planning of São Paulo and as an example for other cities in the search for resilience and sustainability.

3. Results

The land use and occupation of 2020, follows Figure. 1 and a relationship was made in the percentage of the land uses of the Municipality of São Paulo in Table. 1.

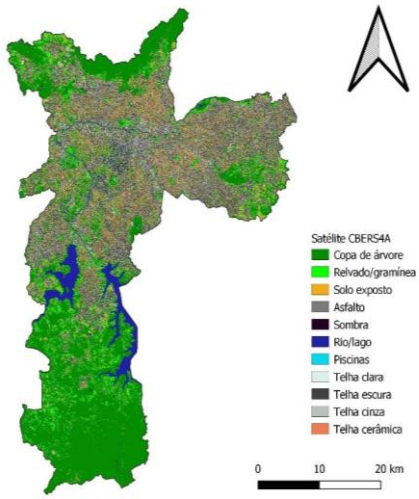

Figure 1: Map of land use and occupation of the Municipality of São Paulo, 2020 (Reference: The authors, 2022.)

Table 1: Percent of land use (Reference: The authors, 2022)

Classification	**Percent (%)**
Tree canopy	36,7
Lawn/gramínea	7,7
Exposed soil	9,5
Asphalt	12,8
Shadow	1,7
River/lake	5,7
Swimming pool	0,5
Light tile	3,74
Dark tile	13,45
Gray tile	5,7
Ceramic tile	2,6

In the analysis of the classification obtained Kappa for this map of land use and occupation was 96.96%, presented a classification with high accuracy. According to Landis and Koch (1977), the value of the Kappa statistic indicates the accuracy of the classification, and from 80% to 100%, the classification is excellent.

In São Paulo municipality, the tree canopy area corresponds to 36.7% of the total area, with the highest concentrations occurring in the extreme south, in the subprefecture of Parrilheiros and the mountainous part, in the north in the subprefectures of Perus and Jaçanã/Tremembé; in the east, the São Mateus subprefecture stands out; in the west, some patches of afforestation occur in the Butantã, Lapa and Pinheiros subprefectures and also in the M'Boi Mirim subprefecture near the Guarapiranga dam, located in the southwest. In the case of lawn and grass (7.7%), it is distributed throughout the area, but with little representation.

The exposed soil (9.5%) and asphalt (12.8%), present a distribution throughout the urban area, where it is characterized by the high rate of soil sealing. The built area corresponds to 27.19% (shade, light tile, dark tile, gray tile and ceramic tile) of the total. Demonstrating, a high rate of urbanization with a dome shape, with the highest rates of built area occurring in the city center towards the periphery. Intense verticalization also occurs in the central area and is distributed to the outskirts.

The NDVI map shows the distribution of vegetation in the study area on August 19, 2020, Figure. 2., after the LST in the same period Figure. 3.

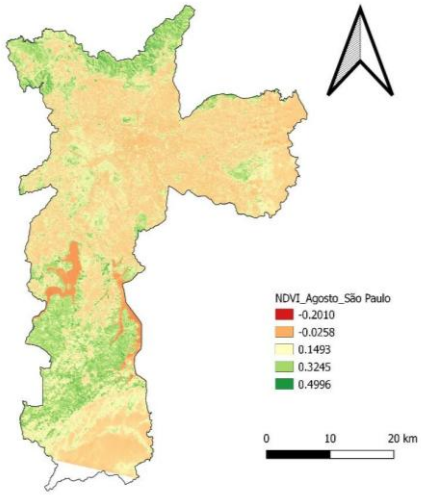

Figure 2: NDVI of the Municipality of São Paulo, 2020. (Reference: The authors, 2022)

In this analysis of NDVI, it is observed due to the water deficit, and low exuberance in the expression of vegetation either in vigor or canopy, thus obtaining the highest index of 0.49 and the lowest index of - 0.2. Therefore, there is inequality in the distribution of vegetation, where there are higher rates in the south of the municipality and in the north, in the following there are patches of higher rates, in the west of the sub-prefecture of Butantã, Lapa and Pinheiros. And in the east zone, concentrated in the area of “Parque do Carmo”.

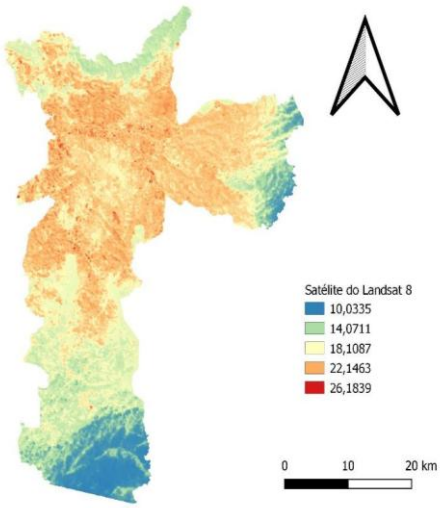

Figure 3: LST of the Municipality of São Paulo, 2020. (Reference: The authors, 2022.)

It can be seen from the LST map that the UHI is pronounced throughout the built-up area. The maximum temperature was 26.18 ºC and the minimum 10.03ºC, having a surface temperature variation of 16.15 ºC. Observing the occurrence of UHI, where there is a rise in temperature, in a more concentrated manner in the city center, with expansion considered in the east zone and slightly in the west zone.

The results are consistent in maps that present the landscape analysis, a special inequality with regard to land use, vegetation index and land surface temperature in the Municipality of São Paulo, SP. There is a lack of green areas in the city center, which extends into the eastern part of the city. In these areas, there is a degradation of the landscape with a greater intensity of the urban heat island.

As such, the construction of a Smart Landscape is needed with an emphasis on the implementation of green areas throughout the Municipality of São Paulo, with the aim of achieving nature-based solutions to improve the city's environmental quality.

4. Discussion

In the land and use it could be noted that we could demonstrate the landscape of São Paulo with 200 to 300 samples of each class made in QGIS, using the polygon tool to obtain the percentage of each class for the year 2020. It could be observed that the greening areas are concentrated in the north and south of the municipality. The high urbanization is in the center and east of the city, but it spread in the west and also now in the north. Then we can compare it with the NDVI which shows the high index in the extreme north and in the extreme south.

NDVI stands out as one of the most important indicators for analyzing vegetation cover in different periods using remote sensing. Its advantage is that it allows monitoring of temporal changes, such as verifying the stage of vegetation growth, and changes in land use caused by anthropogenic activities and its development (Barros; Farias; Marinho, 2020).

Therefore the concentration of the Urban Heat Island is in the central and west of the city. So it is important to improve green areas, cool those hot spots, and also contribute to the quality of life of the population.

From the analysis of the maps of land use and occupation, Land Surface Temperature, and vegetation index, it was possible to verify the dynamics of the landscape of the year 2020, of the Municipality of São Paulo, the intensity of urbanization, the decrease of green areas and the increase of the Urban Heat Island.

It could be seen that the vegetation how poorly distributed it is in the municipality of São Paulo. It is concentrated in the north and south of the municipality. As a result, the temperature is cooler in these vegetated areas, on the other hand in the central area of São Paulo and the east zone there is a high density of construction to the detriment of vegetation, collaborating with the UHI phenomenon.

In this way, it is important to implement the green area in the big city of São Paulo, to benefit the environment and the population, contribute to the recreation, refresh the city, and collaborate with the fauna and flora of the urban area. So it could be a model that analyses the environmental planning.

5. Conclusions

This research aims to expand the application of Urban Greenery and knowledge of urban foresty since there is a need to deepen this science and thus be able to advance in the operationality of the principles of SbN in urban areas, thus contributing to public policies and search for a Smart Landscape to reduce climate impact.

With the analysis of the maps of land use and occupation, LST, and vegetation index, it was possible to verify the dynamics of urbanization, the decrease in green areas, and the increase in UHI in 2020, the municipality of São Paulo - SP. In terms of spatial distribution, the highest NDVI and consequently the lowest TST occurred in the far north, in the Serra da Cantareira, and the far south, in the Parelheiros Subprefecture including the surroundings of the Billings and Guarapiranga reservoirs. So the research emphasizes the need to map an area to know the landscape and therefore think about solutions to increase UHI, like planting trees.

The work can contribute to rethinking urban planning, with emphasis on Planting trees in cities to improve air quality, and reduce heat island effects, to build a smart landscape that aims to mitigate negative environmental and climate impacts, for the entire Municipality of São Paulo and thus meet the Nature-based Solutions.

In this way, in the future, we intend to continue the research involving the bases of geotechnology with the dynamic monitoring of the data obtained from the maps of land use and occupation, vegetation index and continuous land surface temperature of the Municipality of São Paulo, in the search for sustainability. This study can serve as a basis for analyzing and monitoring other urban landscapes.

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Ethics Approval

Not applicable.

Conflict of interest

The authors declare there is no conflict.

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