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Identification of urban canyons in the City of São Paulo from Landsat 8 images

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Abstract: Cities in the last century have been suffering from the disorderly and unplanned growth of urban centers. Consequently, innumerable environmental problems started to plague these regions, one of them is the alteration of the surface temperature through the generation of heat islands and the urban canyons caused by the alterations in the natural landscape. Based on OLI and TIRS images from the Landsat 8 satellite, a soil cover map was generated, an image of Surface Temperature (ST) and the NDBI index, which highlight built-up areas, verifying and identifying urban canyon regions of São Paulo. From the results of the correlation of low, medium and high waterproofing areas generated by the soil cover map with the soil temperature images and the NDBI index, areas of medium waterproofing that had a (ST) similar to the areas of low waterproofing (28 ° C to 31 ° C). In this case, the areas of medium waterproofing should resemble the regions of high waterproofing (34 ° C to 37 ° C). Such regions have as main characteristic a low index of trees and a greater number of constructions, which causes an increase in temperature (heat islands). In this case, it is observed that the regions of medium waterproofing are influenced by the height and spacing of the buildings, which generate wind corridors and shading of the surface, decreasing the temperature of the region and generating urban canyons. Thus, it is concluded that it is possible to identify regions of urban canyons through multispectral and thermal images. The methodology used allows a diagnosis of the islands of heat islands and urban canyons and to evaluate actions taken in these areas in order to mitigate the problems that such phenomena can cause, mainly related to the population's climate and health.

Keywords: Remote Sensing, Urban Canyons, Surface Temperature.

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1. Introduction

Nowadays our cities have a high growth in their area, due to the population increase and the rural exodus that has been happening over the years. This population growth in urban centers, when it occurs in an uncontrolled and planned way can lead to problems in urban planning of cities, with that many problems start to plague these regions, such as infrastructure problems, problems with shortages and resource management for all , with housing and environmental problems [1].

When it comes to this urban growth of a region, one of the environmental problems that can be generated are the heat islands, which consist of an increase in the temperature of the region caused by the way that humans use this region, where areas with greater density urban areas tend to reach higher temperatures than more wooded areas and with less construction. This phenomenon occurs due to the waterproofing of the soil through insulating materials (concrete, asphalt, metal, stones etc.) and causes the phenomenon of heat islands, where there is an increase of some degrees in the region due to human interference in this area. [2]

Another phenomenon that can occur in large urban centers is that of islands of freshness, defined by the decrease in temperature in a region and caused by characteristics of the city's morphology. This morphology ranges from the afforestation of a region and the presence of water bodies, as well as the influence of height and spacing that large buildings can have. This position of the buildings, in addition to forming a wind corridor, can also generate shading of the surface. This morphology leads to a decrease in the temperature of these regions [3], [4] and [5].

The phenomenon of islands of freshness in many methodologies is also called an urban canyon, since the buildings surrounding it start to have the behavior of the geological formation of a canyon, where valley areas would be created by the buildings that would represent the walls of this canyon. This valley, due to the shading that the buildings cause, has access to reduced solar irradiation and with that its surface temperature tends to decrease, making that region colder than the other regions of a city [6].

When addressing the subject of surface temperature, it must be understood that it is related to the wavelength of the infrared. Our eyes are not able to detect differences in this range of the spectrum, so, for the determination and analysis of soil temperature sensors have been developed, capable of detecting the thermal infrared radiation allowing to evaluate the temperature of objects taking into account the heat flow given depending on the energy that reaches and leaves a specific target. With the use of this technology, we are able to evaluate and monitor soil temperature values in certain regions, important information to study the thermal conditions of the environment and their relationship with the type of soil cover and how human interference can modify the environment [7] and [8].

Given the above, the present work aims to identify and understand the phenomenon of urban canyons in a region of the city of São Paulo - SP, from the ground cover map, an image of Surface Temperature (TS) and the NDBI index, generated from multispectral (OLI) and thermal (TIRS) images from the Landsat 8 satellite.

2. Experiments

This work was developed in the city of São Paulo, Brazil, which is in the state of the same name and has a territorial area of 1,521,110 km². The municipality has an estimated population of 12,252,023 inhabitants and is considered one of the largest urban densities in the country with a demographic density of 7,398.26 inhabitants /km², the country's financial center and one of the largest cities in Latin America [9]. More specifically, the study area involves areas that belong to the Central Zone of São Paulo and the neighborhoods surrounding that region, mainly neighborhoods belonging to the West, East and South Zone that border the neighborhoods in the Central Zone of the city.

According to the Köppen Climate Classification, the city of São Paulo is classified as type Cwa (subtropical or tropical altitude climate), having as main characteristic a summer characterized as a hot and humid season with high rainfall, having moderately high temperatures (with an average of 22.8 ° C). The city has a winter marked as a dry season with low rainfall and moderately low temperatures (with an average of 16.7 ° C) [10].

In this study, multispectral bands acquired by the OLI sensor and the thermal band acquired by the TIRS sensor were used, both from the Landsat 8 satellite. The images were acquired free of charge on the USGS website (https://earthexplorer.usgs.gov/) and the date Chosen was January 21, 2019, the middle of the summer season and one of the hottest months of the year. According to INMET (National Institute of Meteorology) during the day 21/01/2019 the temperature of the city presented an average of 23 ° C and throughout the day it registered a maximum temperature of 33 ° C and minimum of 22 ° C [11].

To identify and carry out the analysis of the formation of urban canyons in the city of São Paulo, image processing was carried out in the Geographic Information System QGIS 2.18.20.

In the first step, the Land Surface Temperature Plugin complement algorithms were used to convert digital numbers (ND) into radiance and surface brightness values, both starting from band 10 (thermal). Parallel to the brightness temperature data, an image of NDVI (Normalized Difference

Vegetation Index) was generated through the multispectral bands 4 (red) and 5 (near infrared) and from the NDVI data, the surface Emissivity was estimated through the mathematical algorithm "Zang, Wang etal's LSE algorithm". In the sequence, the values of the surface brightness temperature and emissivity were applied in the Planck Equation, generating a surface temperature map of the studied region [12], [13] and [14].

The flowchart below exemplifies the process of generating a ST (surface temperature) image.

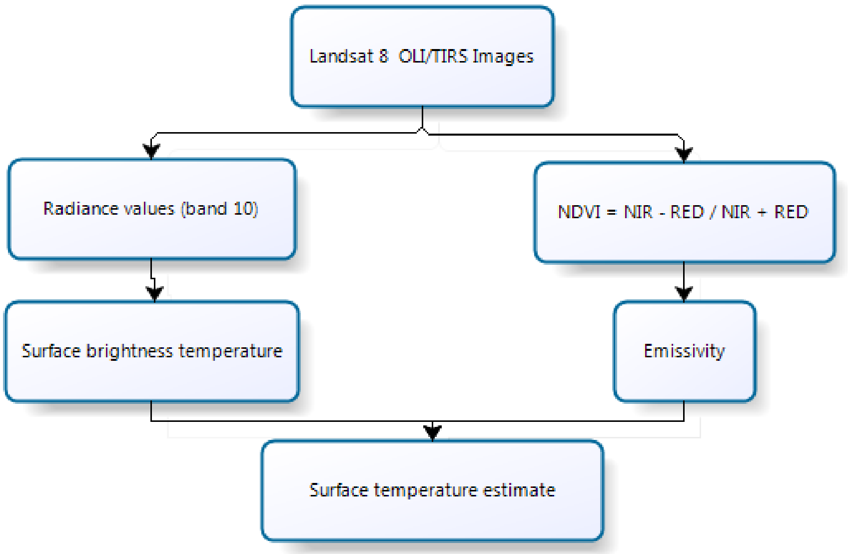

Figure 1: Methodological flowchart.

The second stage dealt with the image classification process by producing a land cover map. For the classification, the plugin Dzetsaka Classification Tool was used in Qgis and the bands 4 (red), 5 (near infrared) and 6 (near infrared) of the Landsat 8 satellite. Next, the RGB composition was performed and the classes to be mapped were defined , they were: water body, vegetation, low waterproofing, medium waterproofing, high waterproofing. The supervised classification was carried out using the model of Gaussian mixtures and for that, polygonal samples were selected that represented the classes of interest [15].

In sequence, the classes of interest are characterized.

Water body

Regions of water bodies in the image, featuring rivers, lakes, ponds in the region.

Figure 2:: Example of water body area (Pinheiros River)

Vegetation

Regions with dense vegetation, with characteristic areas of forests, forests, parks, environmental preservation areas.

Figure 3: Example of vegetation area (Ibirapuera Park)

Low waterproofing areas

That would be areas with characteristics of regions predominantly of low buildings, a large afforestation, large areas of vegetation and little waterproofing of the soil.

Figure 4: Example of low waterproofing area (Cidade Jardim neighborhood)

Areas of medium waterproofing

That would be characterized in mixed areas where they have bigger constructions, an average afforestation, having the presence of some trees and vegetation.

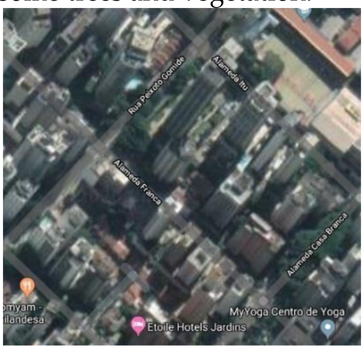

Figura 5: Example of medium waterproofing area (Jardim Paulista neighborhood)

High waterproofing areas

It is characterized as densely populated areas, with the presence of little or no vegetation, the presence of large buildings, a high waterproofing of the soil with concrete, steel, asphalt.

Figura 6: Example of high waterproofing area (Brás neighborhood)

In the third stage, the NDBI spectral index (Normalized Difference Built-Up Index) was generated, which aims to highlight the areas where there is greater spectral reflection, better demarcating areas of human construction of an image. The NDBI produces an image with values from -1 to 1 where the highest values represent the built areas and the lowest values represent non-built areas [16, 18]. The NDBI calculation was performed on the Qgis raster calculator using the values of bands 5 (near infrared) and band 6 (medium infrared). The NDBI index is defined by the equation::

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} \qquad \begin{matrix} NIR = band\ 5 \\ SWIR = band\ 6 \end{matrix}$$

3. Results and Discussion

In this item, the results obtained from the processing will be presented and discussed. Figure 7 represents the land cover classification map from bands 4, 5 and 6, for the date of January 21, 2019.

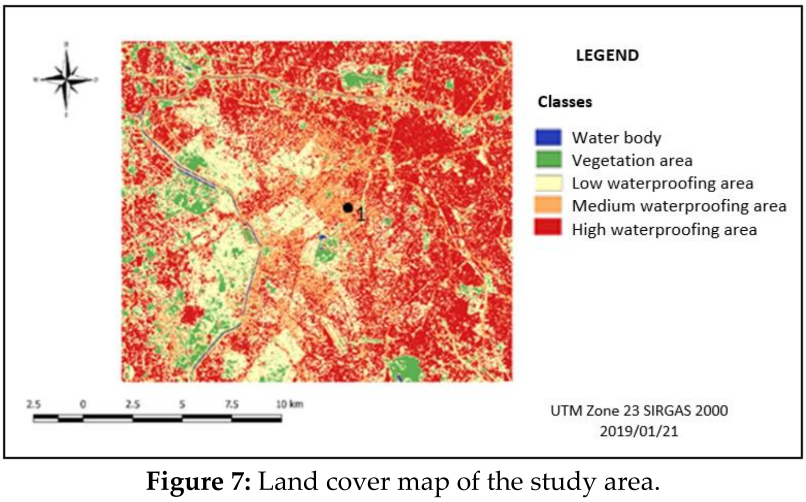

Figure 7: Land cover map of the study area.

Figure 8 represents the NDBI index from bands 5 and 6, for the date of 21 January 2019.

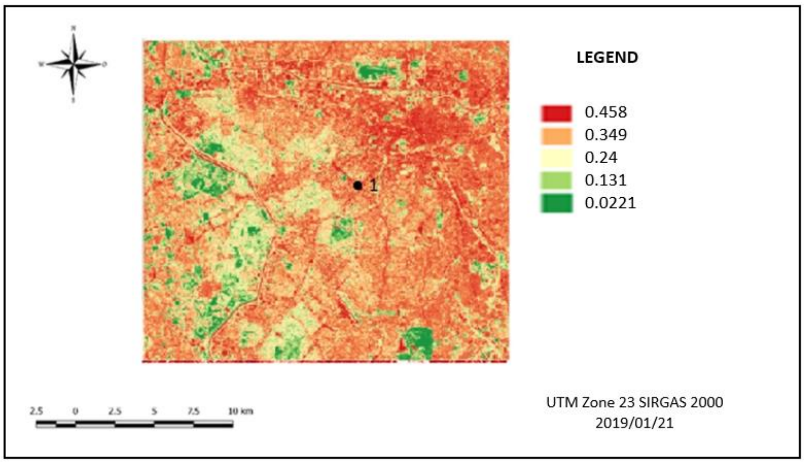

Figure 8: NDBI index of the study area.

Figure 9 represents the surface temperature map (ST) generated from a thermal image, for the date of January 21, 2019.

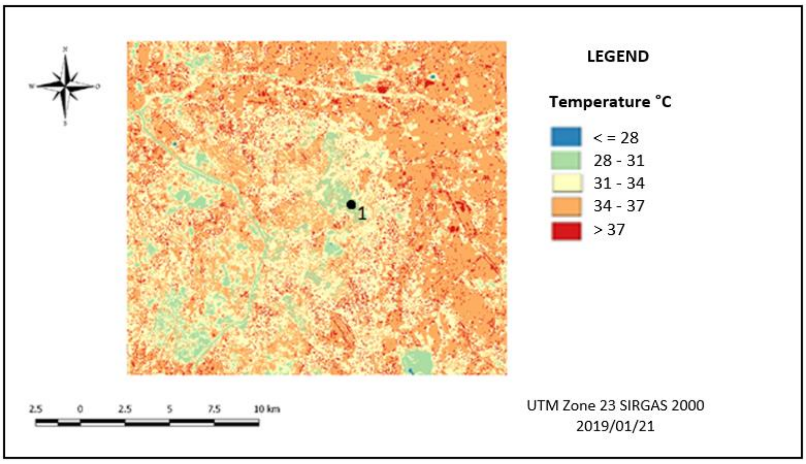

Figura 9: ST map of the study area.

According to INMET, the municipality of São Paulo had an average temperature of 23 ° C on January 21, 2019 [11]. When analyzing the ST map generated in the QGIS software for the image of January 21, 2019, temperature values between 28 ° C and 37 ° C were identified in the study area (Figure 9). Note the predominance of areas of temperatures between 34 ° C and 37 ° C. When looking for these same areas in the soil cover map (Figure 7) and in the NDBI index (Figure 8), it is observed that the areas were classified as high waterproofing, which has little or no afforestation and presented an urbanization index (NDBI) ranging from 0.349 to 0.458. This high temperature is a result of the materials used in construction, which are characterized by high heat retention. Due to the removal of vegetation from the region and the substitution by materials that waterproof the soil, such as concrete, glass, asphalt, metal, there is a specific increase in temperature in the area [7].

When identifying the regions of temperatures between 31 ° C and 34 ° C (Figure 9), in the soil cover map (Figure 7) it appears that these were classified as areas of average waterproofing and presented values between 0.349 and 0.458 in the index NDBI (Figure 8).

When comparing regions in Figure 9, where temperatures between 28 ° C and 31 ° C were found, with the soil cover map (Figure 7), it is noted that these regions were classified as areas of low waterproofing and vegetation and when comparing with the NDBI index, we found values between 0.131 and 0.0221 (Figure 8).

But there are some exceptions to the situation described above. In Figures 7, 8 and 9, point 1 located in the Avenida Paulista region was highlighted. When we analyze this region on the TS map, we find values between 28 ° C and 31 ° C, which was the temperature found in the low waterproofing and vegetation classes, however, when analyzing point 1 on the soil cover map, we verify that the area average waterproofing was classified (Figure 7). Analyzing the behavior of the phenomenon of heat islands, areas of medium waterproofing should have temperatures more similar to those of high waterproofing areas than those of low waterproofing or vegetation, since they are characterized by having little or no vegetation and large constructions, making it resemble areas of high waterproofing.

The phenomenon observed in point 1 is called an urban canyon or an island of freshness, since the buildings around it start to behave in the geological formation of a canyon, where valley areas would be created by the buildings that would represent the walls of that canyon. This valley, due to the shading that the buildings cause, has access to reduced solar irradiation and, as a result, its surface temperature tends to decrease, making that region colder than the other areas of medium waterproofing in the city [6] and [17].

5. Conclusions

The analyzes carried out by of thermal images from Landsat 8 made it possible to identify a region of urban cold island in the study area (Point 1 of Figures 7, 8 and 9). It was possible to verify an urban canyon, in an area such as Avenida Paulista, characterized by the greatest urban density. This is due to the high buildings and the little spacing among them, which create passageways and causes the temperature values of this area on the ST map to be lower than those of surrounding regions also classified as average waterproofing.

The method presented in this work allows the diagnosis of areas with urban canyons and heat islands, as well as the evaluation of actions taken to mitigate these effects. The applications of this study can impact studies that deal with urban planning, thermal comfort and health, especially respiratory problems.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

ST: Surface Temperature
USGS: United States Geological Survey
OLI: Operational Land Imager
TIRS: Thermal Infra-Red Scanner
Qgis: Quantum GIS
NDBI: Normalized Difference Built-Up Index
NDVI: Normalized Difference Vegetation Index

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