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# The Use of Geotechnologies in the Analysis of Vegetation Index and Heat Island in the City of São Paulo, SP, Brazil

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## Abstract

There is a solid body of knowledge linking urban growth to the decline of green spaces in Brazilian cities. In this context, this research aims to analyse the heat island, landscape ecology, and ecosystem services and their associated green infrastructure in São Paulo's metropolitan area. Landscape Information will be applied to the open spaces and mapping will be done with the use of remote sensing techniques in Geographic Information System (GIS). High-resolution imagery will be used, including satellites World View-2 (panchromatic and multispectral from 0.5 to 2m), with the presence of the RGB bands and near infrared, pre-image processing will be done with filter Kuwahara. Subsequently, the classification will be supervised by MultiSpec 3.4 software, version 2010, with the following classes of land use: built area (including commercial area, residential multi-family, and single family, industrial area), asphalt, urban forest and other areas of vegetation and water surfaces. Also, the Kappa statistic will be used to calculate the accuracy of the classifications applied. Geotechnology will provide the basis for the examination of green infrastructure and the associated ecosystem services in the landscape. The vegetation index map was elaborated. The most widespread vegetation index is the Normalized Difference Vegetation Index (NDVI). The NDVI is used to characterize large areas on the density of vegetation. A thermal map will be produced in order to analyse possible heat islands in the study area. The NDVI index was related with the different temperatures in every subprefecture of the city of São Paulo. As a result of this research, it was found that areas with greater vegetation index feature lower surface temperatures. Therefore, it is intended to contribute to the local public policies emphasizing the importance of landscape planning in the pursuit of the population's quality of life in São Paulo, SP, Brazil.

## Introduction

The intense urbanization in Brazilian cities has accounted for a landscape transformation, originating changes in the land morphology, the riverbed, the environmental degradation, and the generation of the urban climate. Intense urbanization as a result of the metropolitan process has been occurring in Brazil since 1960. The process is characterized by land use and occupation without planning, especially in the countryside, in small and medium cities. It is noteworthy that because of the vegetation substitution by materials such as concrete, asphalt, the density of building, among others (Lombardo 1985), the climate variation between urban and rural areas is high.

The Sao Paulo Metropolitan Region (SPMR) is the most urbanized and industrialized area in Brazil, consisting of 38 cities. The state of Sao Paulo is the biggest state, with an estimated population of 44,035,304 habitants and a population density of 177.4 hab./km². These numbers represent 21.6% and 11%

of the population in Brazil and in the entire South America, respectively (Instituto Brasileiro de Geografia e Estatística 2014).

In addition, the municipality of Sao Paulo has an estimated population of 11,253,503 habitants, an area of 1,521 km², a demographic density of 7,898,2 hab./km², and 6,390,092 vehicles, approximately (Instituto Brasileiro de Geografia e Estatística 2010). It has the largest urban agglomeration and industrial park in South America, and while considered a megacity, it is characterized as an industrial macrosystem in a developing country.

The negative impacts caused in megacities such as Sao Paulo are the consequence of the appropriation of natural resources and environment degradation. The Urban Heat Island (UHI) is defined by higher temperatures in the central area which has the highest anthropic activities in comparison with the countryside. One factor that contributes to it is the materials used in civil construction responsible for heating storage and lack of afforestation (Oke 1974).

An alternative to attenuate the UHI may be through the use of medium to high vegetation. Vegetation may be applied in parks, public spaces and preservation areas. The trees are responsible for the evapotranspiration which refresh the environment, preserving and favoring conditions, diminishing the thermal amplitude and conditioning the urban climate (Silva Filho et al. 2005)

The Vegetation Index (NDVI) is a possible way to map the vegetation density. The NDVI is based on the opposite way of the vegetation reflectance in the visible region, that is, the higher the plant density, the less reflectance there is as a function of the absorption of the radiation by the photosynthesizing pigments, and the higher the density, the higher the reflectance, due to the spreading in the different layers of the leaves (Boratto & Gomide 2013).

Geotechnologies integrate Geographic Information System (GIS) with remote sensing, such that the GIS performs the computational processing of geographic data. The GIS includes programs, equipment, methodologies, data and users that integrate in order to make possible the collection, storage, processing and analysis of georeferenced data.

Therefore, this work aims to map the use of land, thermal field and vegetation index of the city of São Paulo, using geotechnologies. The spatial data was correlated in order to analyze the heat island and the vegetation index.

## Background and Literature Review

The Urban Heat Island is a thermal anomaly characterized by a temperature increase and reduced relative humidity in certain areas when compared with others. The areas of cities are characterized by higher temperatures when compared with rural areas. There are several factors that contribute to this anomaly, among them, the absence or low amounts of vegetation in urban centers and soil waterproofing, associated with air pollution in the municipality (Lombardo 1985).

According Rosenthal et al. (2008), the UHI increases due to the materials that retain more heat, such as concrete and asphalts, which are increasingly present in the cities, in addition to a lack of vegetation in the urban environment.

The urban geometry, air pollution, heat emission from buildings, traffic and metabolism of living organisms, soil cover and building materials, are among the main causes of the heat island of the urban atmosphere (Barros & Lombardo 2012). According Pellegrino (2000), it is necessary to realize sustainable projects in the cities. Therefore, it is necessary to have an ecological planning of the landscape in order to integrate society and nature, aiming that both thrive in the long term.

It is noteworthy that the urban green areas contribute to the maintenance of urban environmental quality, especially in cities where urbanization occurred in an accelerated way and with inadequate planning, having environmental degradation. Urban afforestation contributes to human comfort in the environment, because the trees provide several benefits, such as shadow for pedestrians and vehicles, reduced noise pollution, improved air quality, reduced thermal amplitude, shelter for birds and aesthetic equilibrium, which attenuates the difference between the human scale and other architectural components, such as buildings, walls and large avenues (Silva Filho, et al. 2002).

The authors Hamada and Golçalves (2007) quote that the use of GIS is fundamental to mapping studies that aim to use georeferenced information, keeping all the work in the digital form.

> *"The use of remote sensing allows one to obtain information of the objects present in the terrestrial surface, without the necessity of direct contact with them."*

According to Ponzoni (2001), remote sensing to detect the vegetation cover is the result of a complex process that involves many parameters and environmental factors. The modeling of the vegetation indices is based on the opposite behavior of the vegetation reflectance in the visible region, that is, the higher the plant density, the lower the reflectance as a function of the absorption of the radiation by the photosynthesizing pigments and the greater the plant density, the greater reflectance, due to scattering in the different layers of the leaves.

## Goals and Objectives

- Elaborate the thermal map to visualize the Heat Island and Vegetation Index to perform a spatial analysis of the vegetation cover and land use in order to demonstrate the urban geometry of the city of São Paulo, SP, with the use of geotechnologies and the software Quantum Gis (QGIS).
- To determine if there is a relationship between the vegetation index (NDVI) and the temperatures of the subprefectures in the city of São Pauo, SP.
- The work aims to assist in urban planning in order to contribute to public policies.

## Methods

In this study Geotechnology was used for a geo-referential analysis, with the mapping of land use and occupation, thermal map and vegetation index map (NDVI). Subsequently, the Kappa statistical survey of the vegetation index and temperature was made in order to correlate the relationship between the vegetation occurrence and the temperature dynamics and consequently heat island.

The Geographic Information System stands out as an instrument for mapping in order to obtain answers to the various issues about data collection of the physical environment data and environment planning, especially when describing the changes in environment, in addition to assisting in the planning and management of existing natural resources.

The geotechnology used was Quantum Gis (QGIS). QGIS has the advantage of being a free software and uses satellite imagery from GoogleEarth. QGIS was created by Open Source and Geospatial Foundation (OSGEO), and has been available in open source and free on the internet since 2009, to support and build geospatial programs. The thermal map allowed the visualization of the occurrence of the heat island in the city of São Paulo.

The UHI is caused by several factors, such as the surface characteristics, the urban atmosphere, among which is quoted: The high heat capacity of construction materials; The reduction of green areas with capacity of evapotranspiration; Long wave radiation retention due to increased atmospheric pollution (Gartland 2011).

According to Pollizel (2009), NDVI is used to verify large areas of vegetation density, providing a global view of the region and thus, locating the study. The NDVI consists of an equation, where the ratio between the difference of reflectivities of the bands in the near infrared and the red and the sum of the same reflectivities, thus:

**NDVI: IR – R / IR + R**

Being,
IR: Infrared
R: Red

**Results**

The municipality of São Paulo was mapped with digital orthophoto images with infrared and for the processing of images was used the filter Kuwahara. In order to analyze the classification of land use of the year 2010 (**Figure 1**), vegetation index (**Figure 2**) and thermal Map of the year 2018 **(Figure 3),** verifying the dynamics of the landscape. Subsequently, the analysis of the Kappa statistic was carried out using the QGIS software, obtaining the vegetation and temperature index, in order to correlate the relation of the vegetation occurrence with the temperature dynamics and consequently the Heat island (**table 1**).

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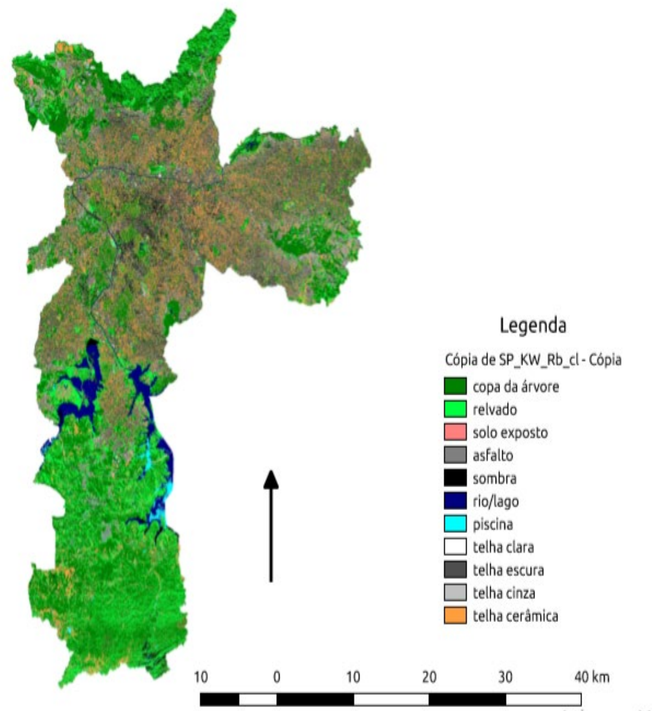


**Figure 1: Classification of land use.**
**Fonte: Amanda Lombardo Fruehauf, 2018.**

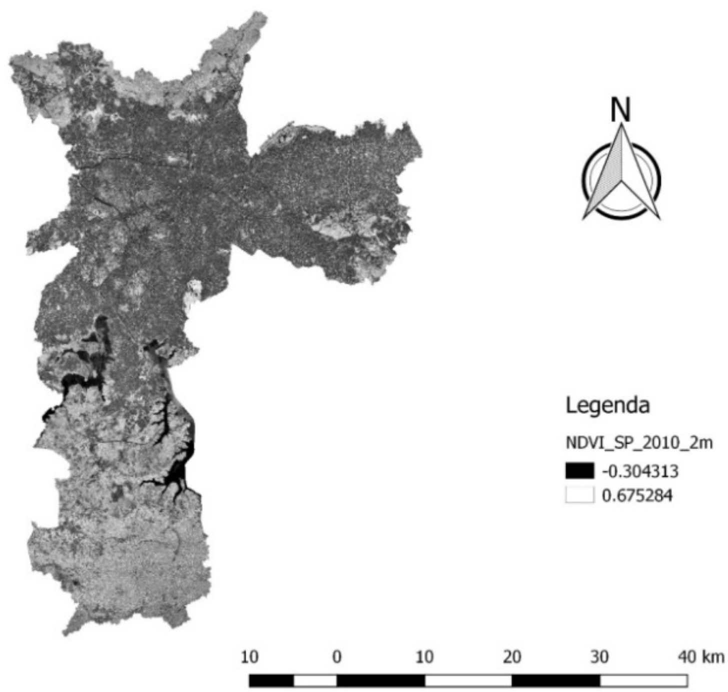


**Figure 2: Map of vegetation index.**
**Fonte: Amanda Lombardo Fruehauf, 2018.**

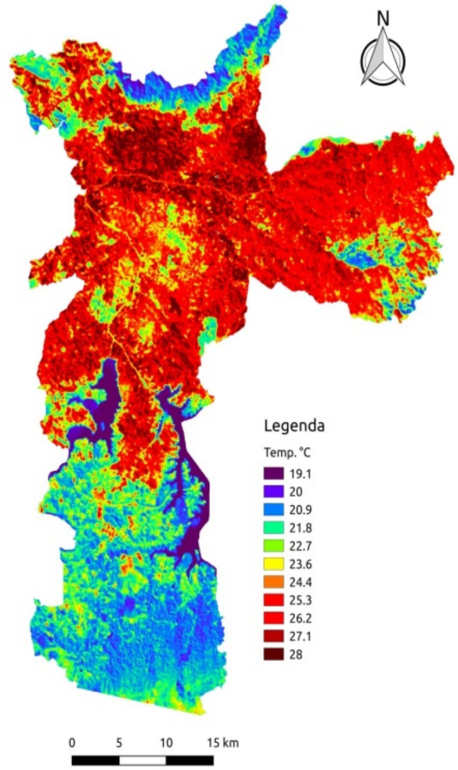


**Figure 3: Thermal map.**
**Fonte: Amanda Lombardo Fruehauf, 2018.**

**Discussion and Conclusion**

Based on the use of geotechnologies, the mapping of land use and occupation, thermal field and vegetation index showed a high spatial variation. The land use and occupation map highlight an intense dome-shaped urbanization of the city's initial landmark, "Praça da Sé" towards the outskirts of the municipality of São Paulo.

The city has expanded throughout its extension, highlighting the Eastern zone. The Vegetation index map presents the distribution of the green areas in the city. The areas with intense urbanization have the lowest vegetation indexes.

The thermal field map presents the spatial distribution of temperature variation, and the maximum (28 ºC) is recorded in the central area and in its surroundings, where high density of the constructed area and population occurs. The lowest temperature value (19 ºC) appears in the peripheral areas of the city, mainly in the southern zone, where the highest intensities of vegetation index and in the northern end of the "Serra da Cantareira" occur.

| Subprefecture | Thermal in ºC (mean) | NDVI (mean) |
|---|---|---|
| ARICANDUVA-FORMOSA - | 26,22 | 0,05 |
| BUTANTA | 25,46 | 0,13 |
| CAMPO LIMPO | 25,60 | 0,14 |
| CAPELA DO SOCORRO | 22,77 | 0,14 |
| CASA VERDE-CACHOEIRINHA | 25,70 | 0,10 |
| CIDADE ADEMAR | 24,62 | 0,09 |
| CIDADE TIRADENTES | 24,14 | 0,10 |
| ERMELINO MATARAZZO | 26,21 | 0,07 |
| FREGUESIA-BRASILANDIA | 25,20 | 0,14 |
| GUAIANASES | 25,06 | 0,11 |
| IPIRANGA | 25,84 | 0,10 |
| ITAIM PAULISTA | 25,85 | 0,11 |
| ITAQUERA | 24,46 | 0,15 |
| JABAQUARA | 26,29 | 0,07 |
| JAÇANA-TREMEMBÉ | 23,26 | 0,20 |
| LAPA | 26,41 | 0,07 |
| M'BOI MIRIM | 23,67 | 0,12 |
| MOOCA | 26,30 | 0,05 |
| PARELHEIROS | 21,59 | 0,25 |
| PENHA | 25,93 | 0,08 |
| PERUS | 24,12 | 0,19 |
| PINHEIROS | 24,78 | 0,08 |
| PIRITUBA-JARAGUA | 25,23 | 0,15 |
| SANTANA-TUCURUVI | 25,24 | 0,12 |
| SANTO AMARO | 25,55 | 0,12 |
| SAO MATEUS | 24,59 | 0,11 |
| SAO MIGUEL | 26,05 | 0,08 |
| SAPOPEMBA | 25,99 | 0,05 |
| SÉ | 25,53 | 0,05 |
| VILA MARIANA | 24,92 | 0,08 |
| VILA MARIA-VILA GUILHERME | 27,01 | 0,04 |

**Table 1: Kappa statistical survey of temperature and NDVI.**

The statistical analysis of the data showed that there is a correlation between the vegetation index (NDVI) and the temperature in the city of Sao Paulo. Since the NDVI with the closest value to 1 has a higher occurrence of vegetation and the closer to 0, the lower the occurrence of vegetation.

The subprefectures with higher temperatures are related to the lower density of the vegetation. The Sé subprefecture located in the center of the city has a temperature of 25.53ºC with the NDVI of 0.05. In the east, the subprefecture of Sao Miguel presents a temperature of 26.05ºC with NDVI 0.08; The Subprefecture Vila Maria/Vila Guilherme presents a temperature of 27.01ºC with the NDVI of 0.04; The

Jabaquara subprefecture has a temperature of 26.29 ºC with NDVI of 0.07. In the west, the Lapa subprefecture presents a temperature of 26.41 ºC with the NDVI of 0.07.

On the other hand, the subprefectures with the highest density of vegetation are related to the occurrence of lower temperatures. In the South Zone, the subprefecture of the Capela do Socorro, has approximately 90% of its extension located in an area of watershed protection, with a temperature of 22.77 ºC and NDVI of 0.14; The subprefecture of M'boi Mirim presents a temparute of 23.67 ºC with the NDVI of 0.12; The subprefecture of Parelheiros presents a temparute of 21.59 ºC with the NDVI of 0.25. In the north area due to the approximation of the Cantareira State Park, the Subprefecture Jaçana- Tremebe has a temperature of 23.26 ºC with the NDVI of 0.20 and also the subprefecture Perus with temperature of 24.12 ºC with the NDVI of 0.19.

The analysis of the spatial distribution of land use and occupation, the vegetation index as well as the thermal field of the city of Sao Paulo highlights the dynamics of the urban landscape with a high concentration of the population in the highly urbanized areas associated with a low occurrence and absence of vegetation, thus resulting in a high gradient of the urban heat island. In conclusion, this work can contribute to the urban planning and local public polices, aiming at the improvement of the quality of life of the population.

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