OPEN JOURNAL SYSTEMS
ISSN:2237-2202

Available on line at Directory of Open Access Journals

Journal of Hyperspectral Remote Sensing v.03, n.01 (2013) 032-044.

Journal of Hyperspectral Remote Sensing
www.ufpe.br/jhrs

USE OF TOOLS GEOPROCESSING FOR IDENTIFICATION OF URBAN HEAT ISLANDS IN TERESINA- PI

Felipe Ferreira Monteiro*, Lidiane Cristina Félix Gomes**, Ana Lúcia Ribeiro Camillo da Silveira***, Glauciene Justino Ferreira da Silva****, Virginia Mirtes de Alcântara Silva*****

* Federal University of Rio Grande do Norte-UFRN, Department of Geographic Science, Campus Universitário Lagoa Nova-Lagoa Nova, Natal-RN-Brasil. Phone: 55+84 3215-3388. E-mail: felipefmonteiro@gmail.com
**Federal University of Ceará-UFC, Department of Geographic Science, Av. da Universidade, 2853 - Benfica, Fortaleza-CE-Brasil. Phone: 55+85 3366 7300. E-mail: lidiane.geo@gmail.com
*** Federal University of Piauí-UFPI, Department of Construction and Architecture, Campus Universitário Ministro Petrônio Portella - Ininga, Teresina-PI-Brasil. Phone: 55+86 32155698.
****Federal University of Paraíba-UFPB, Department of Geographic Science, Av. Contorno da Cidade Universitária-Castelo Branco, João Pessoa-PB-Brasil. Phone: 55+83 32167200.
***** Federal University of Campina Grande-UFCG, Department of natural resources, Av. Aprígio Veloso, 882 – Bodocongo, Campina Grande-PB-Brasil. Phone: 55+83 21011000.

Received 05 July 2013; revised 11 Sept. 2013; accepted 21 Sept. 2013

Abstract

The land cover suffer constantly modifications caused by human activities or natural processes. The unplanned urban expansion is considered an aggravating factor for changes in local climate and possible formation of urban heat islands. Considering the importance of changes in land cover and its influence on the surface temperature, we performed a spatio-temporal analysis of Waterproof Surface Area (ISA), land use and its thermal field, using remote sensing techniques to the following neighborhoods: Ininga, Fatima, Joquei Club and Grooms in Teresina, PI. In parallel we could assess the evolution of the emergence of new asphalt roads, using data provided by the city planning department. It was observed a strong correlation between building materials and paving with the temperature rise of about 4^0C in the region, due to the increase in the use of materials such as concrete and asphalt. One of the factors observed was the intense waterproofing of the area, therefore the removal of vegetation cover and an increase of 134% asphalt coverage, and the construction of major projects in the region.

Keywords: Urban Climate, Remote Sensing, Use and Land Cover.

Introduction

Climate change is a major global concerns, where many of them are attributed to human actions on the environment. Urban areas are today the great environment of humanity living and where changes are perceived more. Many of these changes are coming from the human activity on the environment, such as the vegetation suppression, soil sealing and inadvertent use of asphalt paving.

According Gomes et al., (2012) urban growth unplanned or poorly articulated been generating changes in local climate due to uncontrolled use and occupation of land. The air high temperature is sensed with intensity in the center of cities, where most suffer from this imbalance. These conditions hinder evaporation and consequently the availability of humidity in the air and reduce the power of dispersion of air pollutants, bringing thermal discomfort and health problems for the population.

From the point of view of atmospheric sciences, changes occur in the radiation balance of the surface, causing changes in the absorption, transmission and reflection, and the characteristics of the local atmosphere (Carneiro, 2007).

One of the major impacts on urban area landscape changes with temperature increase is the decrease in humidity caused by a lack of coverage of the vegetable mass by constructive and increasing high density that prevent vertical ventilation. The urban atmosphere has particular characteristics, for it is influenced by the materials making up urban areas that have a thermal capacity higher than that of the materials of the areas not built. Urban areas also have higher roughness, causing greater friction and changes in wind direction, as well as greater diffusion of energy reflected and radiated by materials. That way, the replacement of natural materials for a large number of houses and buildings, asphalted streets and a series of other buildings produce a larger local heating, resulting in the formation of heat islands in urban centers. According oke (1978) in urban air layer is usually warmer than in neighboring areas vegetated. Confirming their observations, Gartland (2010) states that the heat islands are areas where the air and surface temperatures are warmer than the surrounding suburban areas vegetated.

The urban vegetation, understood as a set of species of arboreal, shrub and herbaceous, has also major contributions such as: reduction of thermal amplitude, reduction and driving winds, noise reduction, stable microclimate (JUNIOR LOPES, 2004).

Thus, when the spatial distribution of vegetation in the urban environment is reduced due to unplanned occupation of the soil, the environmental problems carted by this fact, can be perceived the short and long term. Causing changes in local environmental balance and quality of life for inhabitants.

Still according to Lombardo (1985), the presence of vegetation entails a change of the energy balance, due to the need for plants absorb solar radiation as a function of their vital processes. However, the removal of vegetation to give rise to buildings, and paved surfaces affect the environmental conditions, reducing, for example, shadowing, which prevents air heating derived from reissuance solar radiation by the surfaces. The consequences for human health arise due to warm and dry air, which contributes to the increase of uncomfortable feeling and promotes the incidence of respiratory problems (Gartland, 2010). Figueiredo (2009) points out that society is driven by economic and technological development, putting great pressure on the environment. In this context direct human exploitation of the resources has led to numerous changes in landscape, exposing more and more population to the action of numerous disease-causing agents, which are then in a problem of distribution of the phenomena of health and disease.

With this can be perceived as Silva et al. (2005) to evaluate the dynamics of land use in the counties is of great importance in intention of reflect on monitoring environmental and changes their socio-economic regions.

The city of Teresina has shown an accelerated process of growth and densification. According to IBGE (2010), the city of Teresina has 814 230 inhabitants and about 94% live in urban areas. With rapid urban growth and densification of the city to meet the need for housing, there has been significant changes in the urban landscape.

How changes in the use and coverage of urban land occur at an accelerated rate to meet the needs of the development of cities has been increasing use of techniques that enable the monitoring of this dynamic. The Remote Sensing, eg, spatio-temporal analysis allows identifying the changes that occur in urban soil, reliably and efficiently ensure the extraction of information necessary to subsidize urban planning and environmental protection policies.

The use of satellite data in studies of urban gained prominence in recent decades with the the creation of increasingly sophisticated sensors capable of capturing a large amount of data on the Earth's surface and the greater availability of these data to the scientific community.

Novo (2009) defines the Remote Sensing as the joint use of sensors, data processing equipment, data transmission equipment placed on board an aircraft, spacecraft, or other platforms, aiming to study events, phenomena and processes that occur the surface of the Earth from the record and analysis of interactions between electromagnetic radiation and substances that compose in its more diverse manifestations.

With the aim to identify changes in land use and its influence on the formation of heat islands within the city of Teresina - PI, we performed a spatio-temporal analysis Waterproof Surface Area (ISA), land cover and their respective thermal field in the neighborhoods of Ininga, Fatima, Joquei Club and Noivos, between the years 1990 and 2010. To this end used remote sensing techniques, and also data SEPLAN - Secretary of Planning of the Municipality of Teresina, for delineation of neighborhoods and tracking evolutionary scenario of building asphalt roads in the region.

2. Material and Methods

2.1 Study Area

Teresina is located 05 ° 05 'south latitude and 42 ° 48' west longitude, in the macro-region of the mid-north of the state of Piauí (Figure 1). The climate is characterized by having two distinct seasons. During the first six months the climate is hot and humid, with average maximum temperatures between 30-32 ° C and relative humidity between 75-85%. In the second semester, there is practically no rainfall, the climate is hot and dry, with average maximum temperatures between 33-36°C and relative humidity between 55-65%. (Silveira, 2007).

The object of study are the neighborhoods Ininga, Fatima, Jockey Club and Noivos, neighborhoods that were initially marked the occupation of the east, starting from the decade 1960s, when of the inauguration of the first allotments in the region. This region was then gradually being urbanized, with the incorporation of other neighborhoods, subdivisions and housing developments, changing land use and the gradual replacement of the areas covered by green built and paved surfaces.

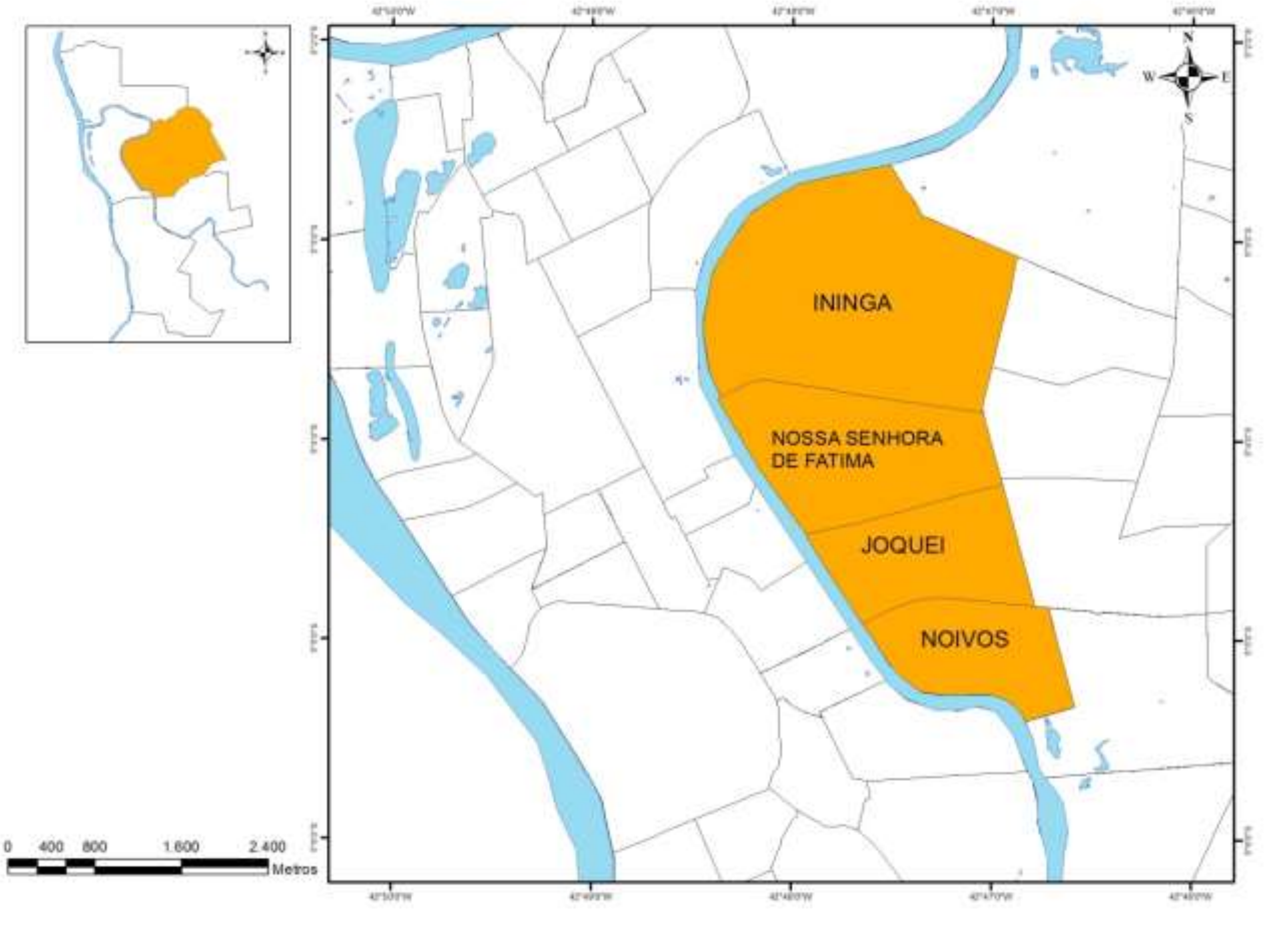

Figure 1. Area - Neighborhoods Ininga, Fatima, Jockey Club and Noivos in the city of Teresina-PI.

For the realization of this study we used the images from the Landsat 5 - TM, in orbit 219, ponto 64, in the years 1990 and 2010. For the processing and manipulation of images was used SPRING Software, developed by the National Institute for Space Research (INPE), which enabled through LEGAL tool, generate products NDVI (Normalized Vegetation Index Difefference), Waterproof Surface Area (ISA), surface temperature (TS) and through supervised classification of targets, map use and occupation of land.

Was obtained NDVI, which according PONZONI & SHIMABUKURO, (2009) has been widely employed and exploited in different approaches in agricultural studies, forestry and climate. In which is obtained through the ratio between the difference in reflectivity of near infrared (ρ_{IV}) and red (ρ_V), and their respective sum, as shown in Equation 1:

$$NDVI = \frac{\rho_{IV} - \rho_V}{\rho_{IV} + \rho_V} \qquad (1)$$

The reflectivities (ρ_{IV}) and (ρ_V) correspond respectively bands 4 and 3 from Landsat TM -. Obtaining the NDVI data was necessary second method proposed by Carlson and Arthur (2000) to get the index of Impervious Surface Area) (ISA). According to Gutierrez et al. (2011) this method shows the relationship between NDVI and fractional vegetation cover to get to the ISA, indicating the surface that does not allow water infiltration into the soil.

The ISA was calculated according to Equation 2 and basically consists of supervised classification of pixels and sub-pixels.

$$ISA = [\, 1 - (\frac{NDVI - NDVI_0}{NDVI_S - NDVI_0})^2 \,]_{DEV} \qquad (2)$$

The NDVI indicates the values for dense vegetation, NDVI 0 represents the values for exposed soil and DEV index indicates that the formula must only be used for areas classified as urban. In this case, the nearer one the number, the greater the impermeable surface (CARLSON & Arthur, 2000).

For the analysis of change of surface temperature, was utilized the band 6, which captures data in the thermal infrared band. These images were obtained by quadratic regression equation of Malaret et al. (1985), which allows your gray levels obtained, are converted into the surface temperature recorded during the imaging, according to Equation 3.

$$T = 209{,}931 + 0{,}834\ DN - 0{,}00133\ DN^2 \qquad (3)$$

Where, T is the temperature in Kelvin scale and DN represents the number Digital each pixel. After the conversion a new subtraction was performed by 273,15 to obtain temperature values in degrees Celsius and then applied to a color scale to better identification of temperature variations.

For the preparation and analysis of the use map and land were used images of bands 2, 3 and 4 for RGB color composite. Was performed a supervised classification of satellite images, which were identified classes: vegetation, urbanized area, asphalt, exposed soil, metal cover and water, as well as the measurement of the occupied areas.

On the observance process of evolution asphalt road construction, data were obtained in the form shapes the Planning Secretariat of the city of Teresina, where maps were constructed evolutionary scenarios for the period 2000-2010 for a better evaluation of soil sealing.

3. Results and Discussion

The images of Landsat satellite-5 TM were classified, delimiting the areas occupied by asphalt, exposed soil, vegetation, urban area, for each year studied (Figure 2). After execution of the classification was possible to estimate the area occupied by each class, and thus observe the process of changing land use in the study area.

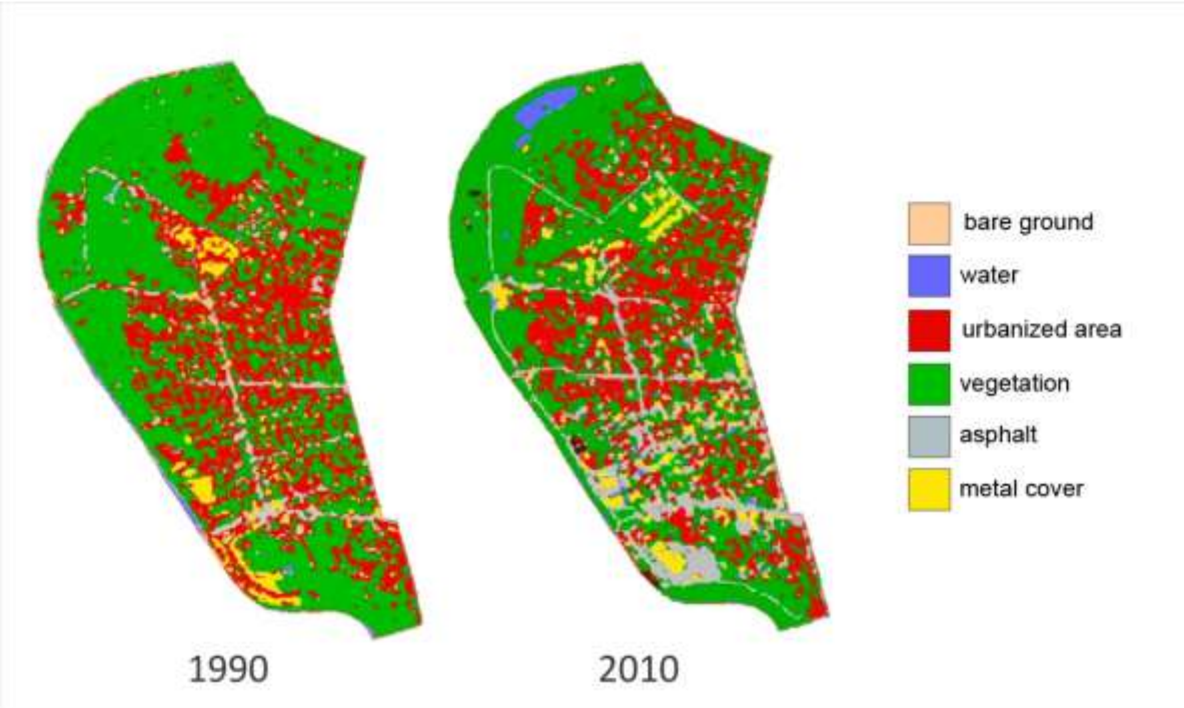

Figure 2. Thematic Map Use and Land Cover for the years 1990 and 2010 of Neighborhoods Ininga, Fátima, Joquei Club and Noivos in Teresina - PI.

Figure 2 shows the sharp urban growth in the region north and south of the map. The asphalted areas acquired new proportions on which the increase of this class is shown in the central and south of the image. It was checked also reduced proportionally vegetation and an increase in urban areas.

One feature that stood out in the evaluation of land use, was the intensity of metal cover class. Table 1 presents the results in terms of percentage change in land use in the region.

Confirming the visual representation of the use and occupation of the neighborhoods Ininga, Fátima, Joquei Club and Noivos in Teresina - PI seen in Figure 2 was generated reports with numerical proportions, presented the most representative areas of the classes described in Table 1, where it was possible to check urban expansion of 6.18%, a sudden reduction of 99.15% of the vegetation, asphalted areas have gained higher proportions in their deployment, with 135.64% growth during the decades evaluated.

Table 1: Classes of Derived Thematic Maps of Use and Land between the years 1990-2010.

Category thematic	***Áreas - Km^2***		***Difference (Km^2)***	***Difference (%)***
	1990	**2010**		
Urban Area	29.549,00	31.375,00	1.826,00	6,18%
Water	726,00	2.040,00	1.314,00	180,99%
Bare ground	4.551,00	316,00	-4.235,00	-93,06%
Asphalt	617.800,00	1.455.800,00	838.000,00	135,64%
Vegetation	6.031.400,00	51.339,00	-5.980.061,00	-99,15%

Regarding the increase in the thematic class of water, on which derived a range of 180.99%, relates to the implementation of 4 large stabilization ponds (Figure 2), effluent treatment, set in an area of the Federal University of Piauí. Already in thematic class of exposed soil (Table 1), we observed a reduction of 93% over the 20 years analyzed, whereas in 1990 the study area showed an area of exposed soil and 4.551Km2 in 2010 showed only 316 km2.

In 1990 it is possible to realize a higher concentration of vegetation cover in the northern region of the study area (Figure 2), which corresponds to the campus of the Federal University of Piauí, in the neighborhood Ininga. A total of 50%, equivalent to 513.39 ha, the area occupied by the vegetation has an irregular distribution when compared among neighborhoods.

The areas covered with asphalt match the existing main roads and parking lots, especially the two major shopping malls in the region that have a minimum green space.

Visually urbanized areas are densified, class of metal roof matches the large commercial buildings in the neighborhoods as well as apartment buildings, which are gradually replacing the old homes and also increase the sealed area. As for the values found, the areas mapped metal roofing as either part of the anthropized areas, which together coverage the urbanized area and asphalt, totaling 48% of all the study area, equivalent to a total of 497.34 ha of total neighborhoods studied.

In the intention to check the increase of asphalt roads in the study area, was made two maps for the years 2000 and 2010. Figure 3 includes the spatial distribution of the tracks, according to data obtained in the city of Teresina - PI.

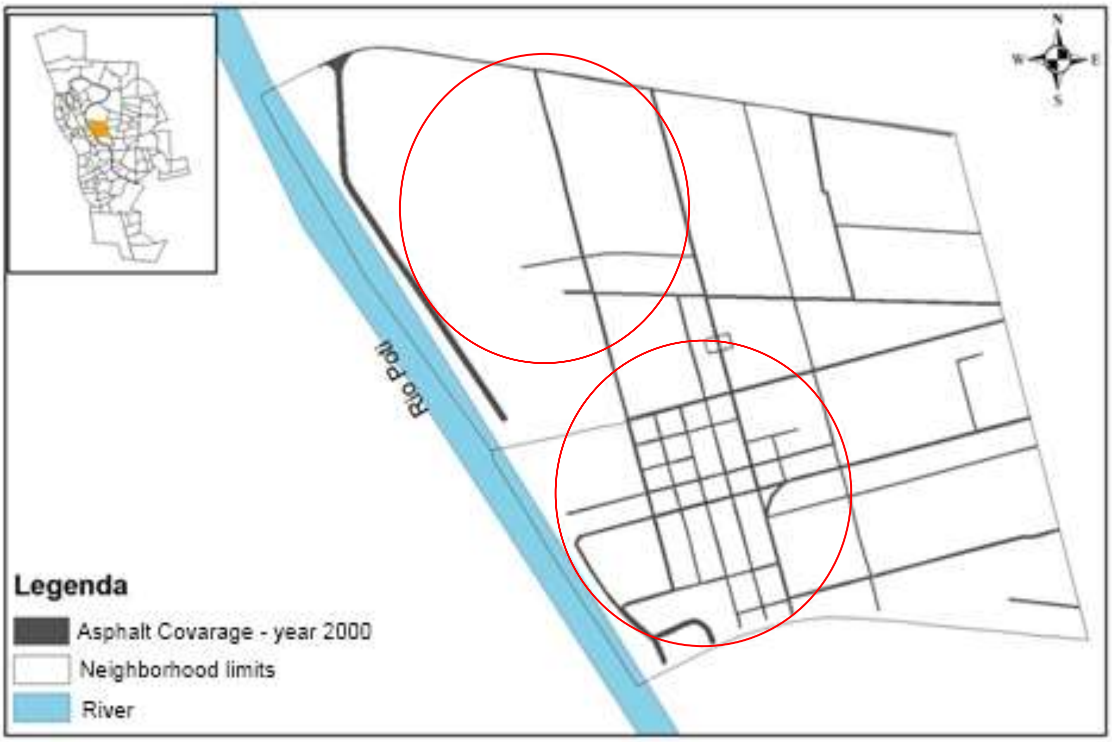

Figure 3. Spatial distribution of asphalt roads in 2000 of Neighborhoods Ininga, Fatima, Joquei Club and Noivos in Teresina - PI.

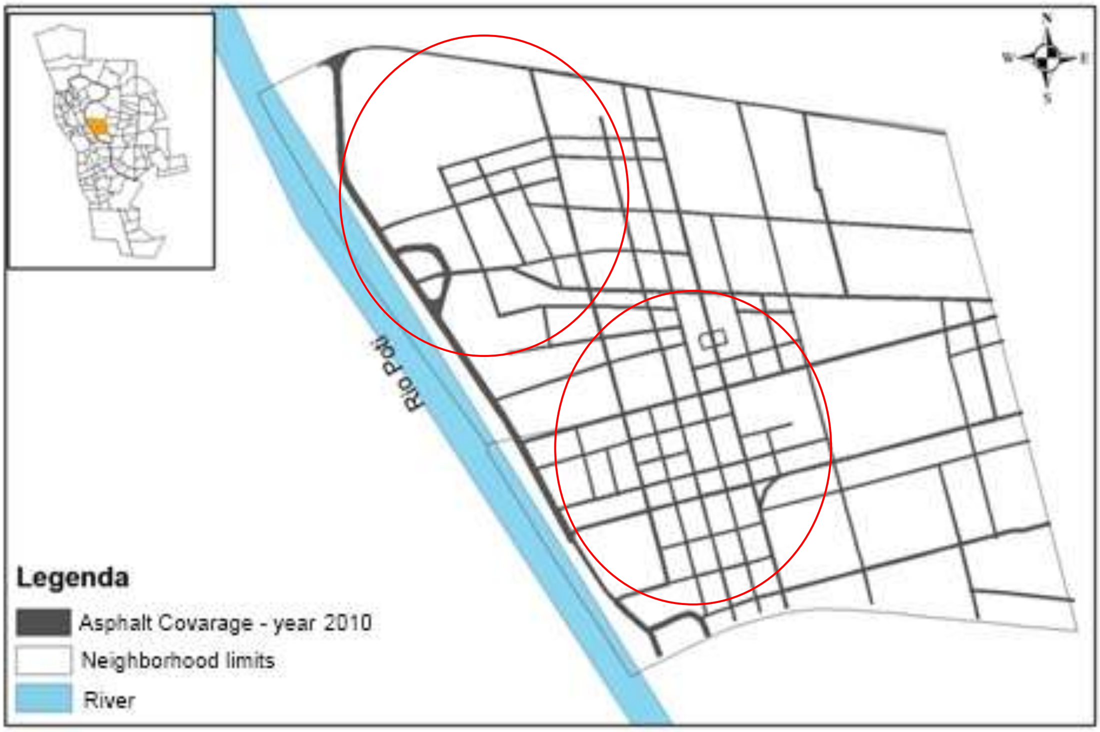

Figure 4. Spatial distribution of asphalt roads in 2010 of Neighborhoods Ininga, Fatima, Joquei Club and Noivos in Teresina - PI.

The areas circled in red represent areas where growth was most significant in 10 years within the region (Figure 3), and which were marked by the emergence of new ways, as can be seen in Figure 4.

Also in Figure 4, also highlighted with circles (north and south of the image), there is the territorial extent of the study area, as the appearance of new asphalt roads, new circuits interconnected traffic of people and vehicles. This emergence of new pathways is directly linked to the growth of neighborhoods, as well as the emergence of urban facilities, expansions in universities and recreational areas.

In Figure 5 can be viewed impervious surface area between the years 1990 and 2010 with variations between 0 and 100 (%), with a color palette representative, in which the shade of blue represents the values near zero and refers the regions with high permeability and a higher rate of infiltration, as can be observed a decrease of this class over the years.

Also in Figure 5 can be seen the areas that had a beige shade and medians indicate regions with intermediate levels as its permeability. Already the red shade is a high degree of impermeability and can be realized between the years 1990 and 2010 there was a significant increase in almost its entirety, with accentuated perception in northern and central regions of Figure 5, the district Ininga and Fatima also implies that the thermal changes as to temperature of the surface and the air in the city.

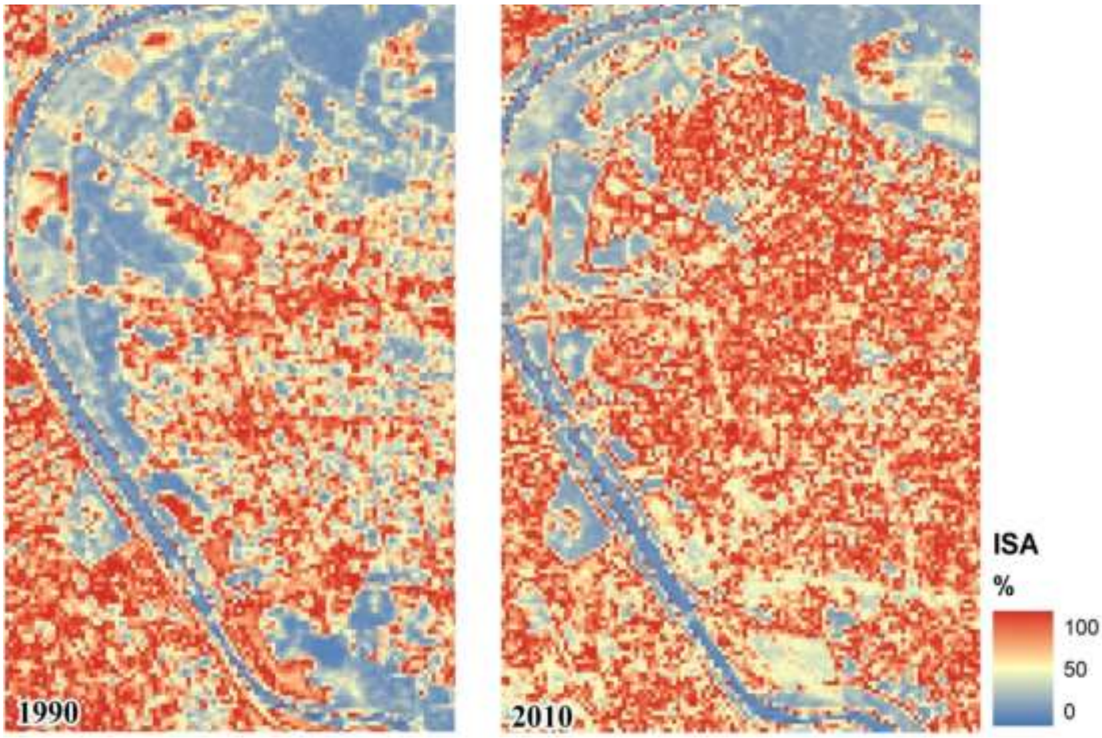

Figure 5. Impervious Surface Area (ISA) for the year 1990 and 2010 of Neighborhoods Ininga, Fatima, Joquei Club and Noivos in Teresina - PI.

In the climate study, can be observed surface temperature maps for the years 1990 and 2010 seen in Figures 6 A and 6 B showing throughout its territory a reflection of urban expansion, with a temperature increase resulting from modification of space city without the worry of using materials that change the temperature of the surface layer of the Earth.

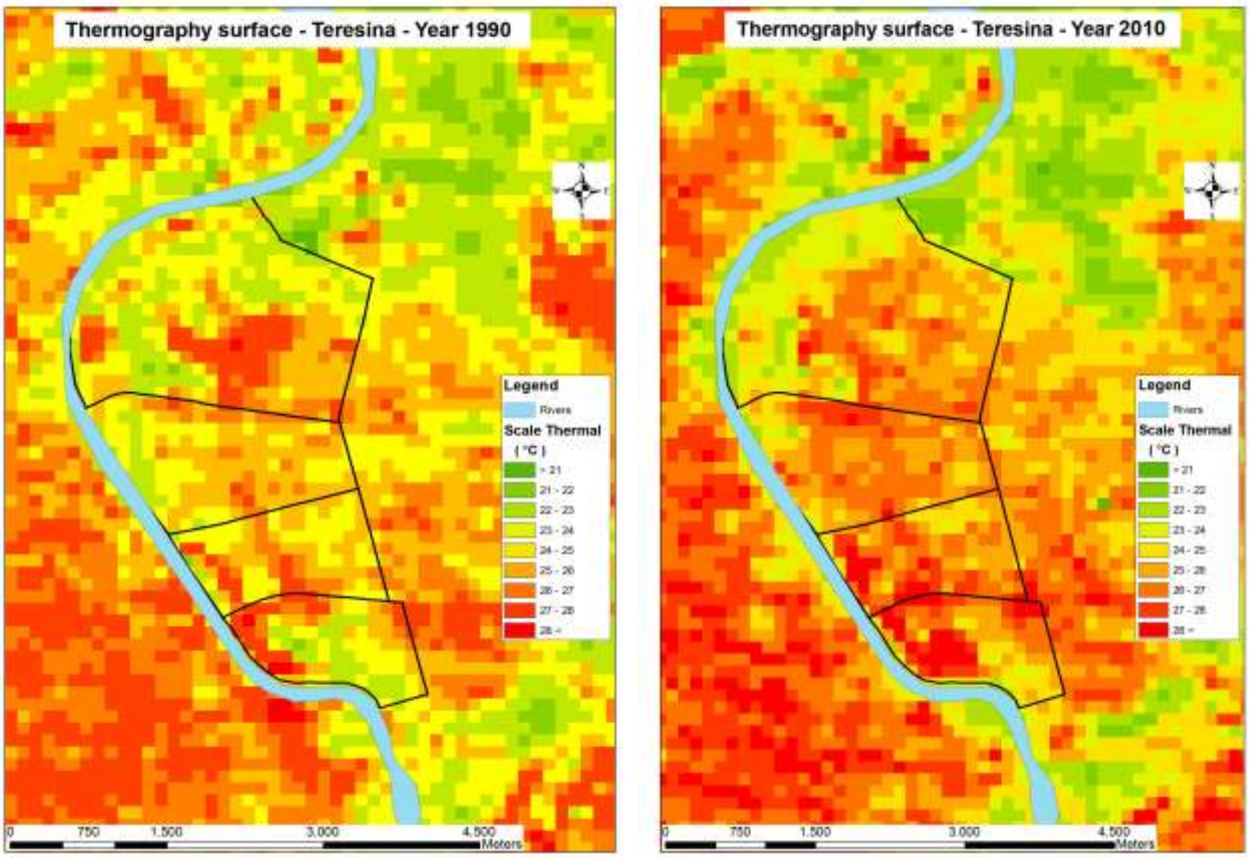

Figure 6. Thermal field for the year 1990 (a) and 2010 (b) of Neighborhoods Ininga, Fatima, Joquei Club and Noivos in Teresina - PI.

The thermal field for the year 1990 (Figure 6 a) showed milder temperatures, which can be linked to greater presence of vegetation cover in the area, as observed in map of land use. In the Ininga neighborhood, northern region of the map, is where there is a major focus of heat derived from the existence of large urban concentration and its materials that absorb a greater amount of electromagnetic radiation. In regions where they have the presence of riparian vegetation, the Poti river banks were observed colder areas, with temperatures between 23 and 21^{0}C.

In Figure 6 (b), which representing the specified year 2010, were areas with higher temperatures, pockets of high temperature distributed along the thermal field more homogeneous, especially areas south of the map, which correspond to the two largest city shopping malls, with large parking areas coated in asphalt, with average temperatures above 28° C. On the banks of the river Poti, on account of riparian vegetation and the presence and the river, there is a decrease in temperatures being below 21^{0}C.

Was observed in the neighborhood of Ininga, northern region of Figure 6 (b), a large area with the lowest temperatures in the range 21-22°C which corresponds to the large green area that still exists inside the campus of the Federal University of Piauí (Figure 7a) in the neighborhood of Ininga.

One of the most heated areas can be seen in Figure 7b, which highlights the Teresina shopping located in the Noivos, with an area around it completely waterproofed with bituminous material, generating an intense warming in surface temperature and consequently a reflection of the increase in air temperature.

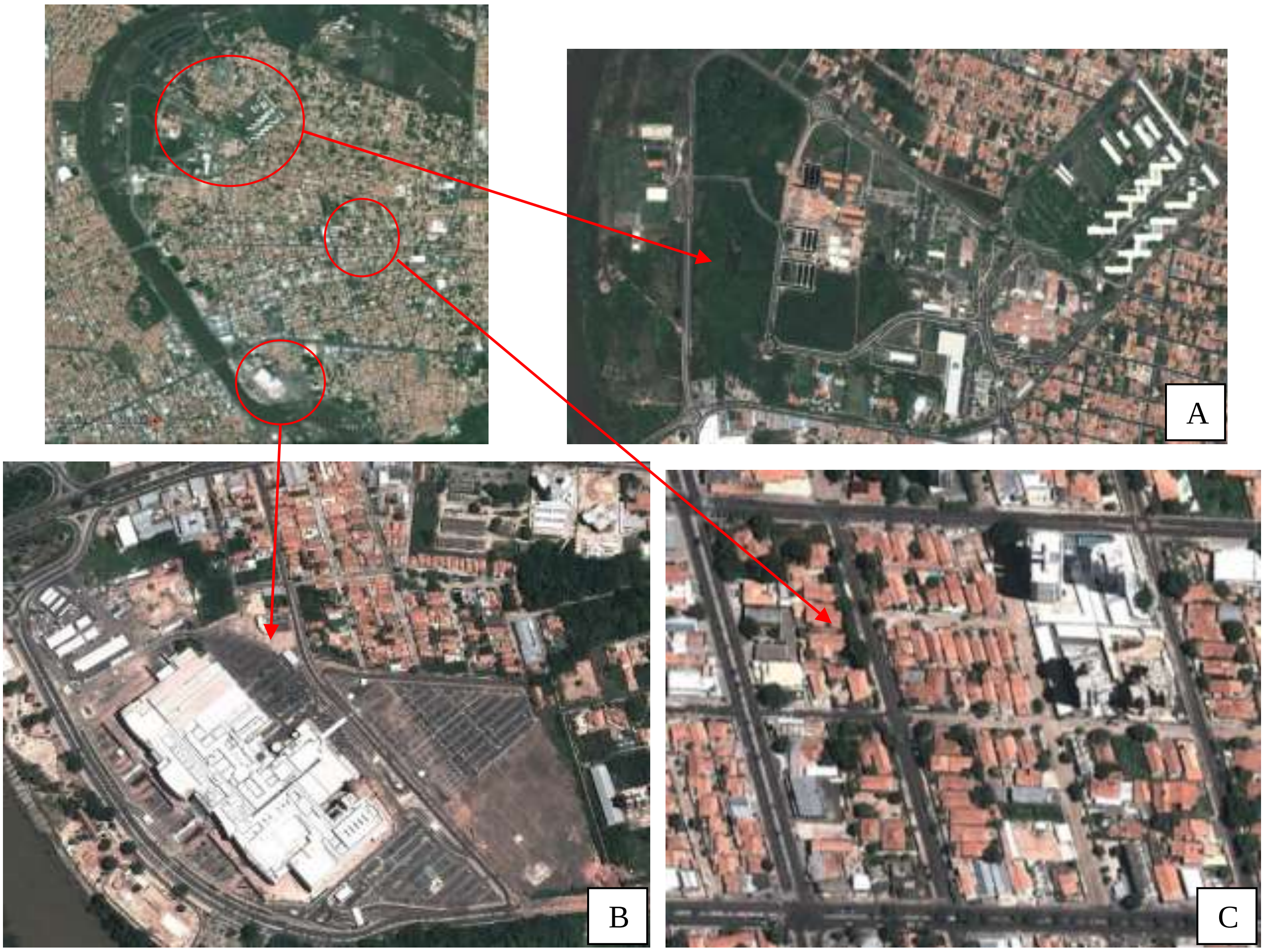

Figure 7. Scraps of Images of Google Earth for the year 2010.

Despite having buildings covered with lighter shades (Figure 7b and 7c), which result in higher reflectivity and lower absorption of electromagnetic energy, there is a predominance of pockets of heat in areas with large amounts of waterproofing and small amount or absence of vegetation cover.

A lot of buildings shown on Figure 7c depicts through the blocks and their elements built and waterproofed, there was an intense process of urbanization, which may explain the current thermal discomfort verified through analyzes of surface temperature maps.

4. Conclusions

The Remote Sensing have been used in overtime satisfactorily in environmental monitoring, climate and urban. The quantitative extraction of the classes observed was of fundamental importance in the assessment of urban growth in the neighborhoods of Ininga, Fatima, Joquei Club and Noivos.

The Maps of coverage and land use possible to verify that the vegetation class has decreased, in contrast to increased class urban area, as well as the paved roads have increased considerably in the neighborhoods analyzed, which designates a scenario of urban growth, this caused as the maps of temperature, a warming almost totally homogeneous in the study area of approximately 4^0C.

Analysis of Index proofing was of great importance for the study, because of its effectiveness in identifying the transformation of urban space, supporting the interpretation of the temperature increase in the region.

Front of the emergency situation which gives the area of study, since the exacerbated heating surface brings evil consequences to human health, are necessary urban interventions for there to mitigate these pockets of heat derived from unplanned urban growth, deployment green areas in the neighborhoods analyzed an alternative would be to make the spaces more pleasant to the population and provide greater thermal equilibrium.

5. Acknowledgements

We thank the Secretaria de Planejamento do Município de Teresina for files assigned to this work and Capes (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for the scholarship granted.

6. References

CARLSON, T. N., & ARTHUR, S. T. (2000). The impact of land use — land cover changes due to urbanization on surface microclimate and hydrology: a satellite perspective. In: Global and Planetary Change. V. 25. Págs. 49-65.

CARNEIRO, D. P., GENARI, H. F., MIYASATO, H. H., & MARTINS, R. J. (2007). Ilhas de calor no campus da Unicamp. In: Revista Ciências do Ambiente. V. 3. Págs. 43-48.

FIGUEIREDO, J. M. (2009). Análise Espaço-Temporal dos Casos de Dengue no Município de Ribeirão Preto (SP) pela Técnica de Geoprocessamento. Dissertação (Mestrado em Tecnologia Ambiental) - Universidade de Ribeirão Preto, UNAERP, Tecnologia Ambiental. Ribeirão Preto.

GARTLAND, L. (2010). Ilhas de Calor. São Paulo: Oficina de Textos.

GOMES, L.C.F.; SANTOS, C.A.C.; SILVA, V.M.A.; TAVARES, A.L.; SILVA, G.J.F.; RIBEIRO, C.A.M. (2012). Dinâmica da Temperatura da Superfície Utilizando Técnicas de Sensoriamento Remoto em Brasília – DF. XVII Congresso Brasileiro de Meteorologia.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Censo Demográfico 2010. Disponível em: http://www.ibge.gov.br. Acesso em 15 de abril de 2013.

LOPES JÚNIOR, W. M. (2004). Análise das áreas verdes da cidade de Bauru – SP, In: 1º Seminário Internacional, Ciência e Tecnologia na América Latina: A universidade como promotora do desenvolvimento sustentável, 2004, Campinas. Anais. Campinas, p 56-63.

Lombardo, M.A. (1985). Ilhas de Calor nas Metrópoles: o exemplo de São Paulo. São Paulo: HUCITEC, 244 p.

MALARET, E; BARTOLUCCI, L. A; LOZANO, D. F.; ANUTA, P. E.; MCGILLEM, C D. (1985). Landsat-4 and Landsat-5 Thematic Mapper data quality analysis In: Photogrammetric Engineering and Remote Sensing. Vol. 51, pp. 1407-1416. Sept.

NOVO, E. M. (2009). Sensoriamento Remoto - Princípios e Aplicações. São Paulo: Blucher.

OKE, T. R. (1978). Boundary Layer Climates. London: Methuem & Ltd. A. Halsted Press Book, John Wiley & Sons, New York, 372p.

PONZONI, F. J.; SHIMABUKURO, Y. E. (2009). Sensoriamento Remoto no Estudo da Vegetação. São José dos Campos: Parêntese.

SILVA, M. K.A.; BRITO, J.L.S.; ROSA, R. (2005). Mapeamento do Uso do Solo no Município de Pedrinópolis – MG. Anais XII Simpósio Brasileiro de Sensoriamento Remoto, Goiânia, Brasil, INPE, p. 285-291.

SILVEIRA, A. L.R. C. (2007). Parâmetros Bioclimáticos para Avaliação de Conjuntos Habitacionais Multifamiliares na Região Tropical Subúmida do Brasil. Tese (Doutorado em Arquitetura e Urbanismo) – Universidade de Brasília. Brasília.