

Geophysical relationships between albedo and surface temperature of targets in Garanhuns-PE

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Abstract

This study aimed to carry out a multi-temporal analysis of the thermodynamics of the targets' surface and albedo, in Garanhuns-PE municipality. Geotechnologies from Remote Sensing and Geographical Systems (GIS) were used. To this end, images from the Landsat 5 satellite TM sensor, related to the years 1987, 2001 and 2010, provided by the National Institute of Spatial Research (INPE) were used. The vector data were provided by the Brazilian Institute of Geography and Statistics (IBGE). A georeferenced and geochronological database was created, which enabled the thematic mapping. This kind of theoretical and methodological procedure maximizes the degree of reliability of the data that were generated. Data which are essential to management of anthropogenic activity in nature. It was found that anthropogenic interference altered the profiles of thermal and reflectance dynamics, resulting in well-defined heat islands.

Keywords: thermodynamics, albedo, geotechnology, remote sensing, GIS, thematic mapping.

1. Introduction

Society's ability to modify landscape is increasing in time intervals that always tend to decrease. So, monitoring these actions and their consequences is an underlying need. Ergo, these anthropogenic interventions may put the population at risk (including life-threatening) and cause environmental damage of difficult or even irreparable recovery.

According to Veyret and Richemond (2013), environmental risks are results of a combination between natural risks and the ones resulted from natural processes compounded by human intervention and land use. Both risks have

similar features but are still distinct phenomena. The first is sensed, perceived and endured by a given social group or individual susceptible to the possible action of a physical process. While the second risk, comes from the effects of human activity and land use.

It should be noted that risk is a product of perception, in a way that risk is a socio-spatial process; in other words, it only exists if men is in context. The fact that every environment has a natural susceptibility of change, and that it doesn't qualify as a risk, should also be noted.

Geotechnologies, more specifically from Remote Sensing and Geographical Information Systems – GIS, strongly contribute to

monitoring, analysis, intervention and preparing of cartographic products related to this issue. Methodological criteria conducting the handling, interpretation and products resulted from these geotechnologies should be taken into consideration.

In accordance with Fitz (2008), one of the interferences noted in the decision-making process during use of GIS, is related to the formulation of criteria in the application of geoprocessing techniques. To understand the decision-making process as a choice between several alternatives the researcher has to have in mind that said alternatives require safe enough criteria for the results to be as reliable as possible.

Geographical databases, no matter how robust, along with the GIS that will interpolate its data are not enough to explain reality provided by nature. Because of the intrinsic complexity of landscape elements, not only in relation to their position or spatial distribution, but also the way they interact with one another, and the effects of these interactions on the landscape. Therefore, it is up to the researcher to choose variables and rank them according to the needs of the research.

Thus emerges another unfavorable technical, operational and methodological factor, since the choice and weight of these variables relies on the perception of the researcher. However, this fact does not belittle the modeling procedures; on the contrary, it only reinforces the need for process improvements. History has shown that whereas difficulties arise in science, new concerns are born which sooner or later culminate into new advances.

To Christofletti (1999), modeling can be considered as an instrument among the methodological procedures of research. Justification relies on the fact that construction of models related to environmental systems is an expression of a scientific hypothesis which needs to be validated as a theoretical enunciation about the studied environmental system.

Geostatistics' vital role, both in data collection by sensors in satellites as in interpolation procedures of the data is important to highlight, since use or analysis of these geotechnologies without knowledge of the geostatistical methods, culminate in dubious results. A problem which is increasingly

worsening. Craving for findings, researchers skip critical steps, opting for automatic procedures to save time.

According to Ferreira (2014), many of the new professionals who currently use GIS to solve problems of spatial origin, are supposedly unaware of the significance of geospatial analysis. Perhaps, because they have found this technology through fast and less consistent ways such as: reading and accessing manuals on the internet through chats, tutorials... Which are more focused on performing the procedure than explaining/contextualizing the underlying theoretical concepts in these routines.

Kriging was the geostatistical method used in this study. Due to its data flexibility feature, unlike IDW, which is characterized as a deterministic method, in which the result is based on inverse distance, where the minimum and maximum values introduced in the database are never extrapolated.

Silva (2014) points out that Kriging, often translated as Krigagem, is a regression method used in geostatistics to approximate or interpolate data. Kriging can be understood as a linear prediction or a form of Bayesian Inference (uncertainties about the estimated amounts). It is derived from the idea that points close in space tend to have more similar values than more distant points. Kriging assumes that collected data from a given variable is correlated in space.

From this theoretical and methodological foundation, this study had as goal the multi-temporal analysis of the geophysical phenomena: albedo and thermodynamics of the surface of Garanhuns-PE municipality, since these two variables directly affect the population (thermal comfort, heat islands formation, dehydration of vegetation), and are sensible to anthropogenic changes on the landscape.

2. Materials and methods

Matrices from the Landsat 5 TM (Thematic Mapper) sensor were used, with a coverage of 185/185km per scene and spatial resolution of 30m per pixel, channels: 1, 0,45 to 0,52 μm , blue; 2, 0,52 to 0,60 μm , green; 3, 0,63 to 0,69 μm , red; 4, 0,76 a 0,90 μm , far infrared; 5, 1,55 to 1,75 μm , medium infrared; 7, 2,08 to 2,35 μm , distant infrared. These matrices are related to the temporal intervals of 13/08/1987,

22/10/2001 and 29/09/2010. Vector data from Brazil's digital grid made available by the Brazilian Institute of Geography and Statistics (IBGE) were also used. Since corrections/adjusts were needed on the aforementioned data, post-processing was done through the following procedures:

- Atmospheric (TerraView v. 4.2.2)
 - Creation of a geographical database (Arquivo/Banco de Dados/Criar), import of the rasters (Arquivo/Importação Simples do Raster), correction of the atmospheric interferences (Plugins/Processamento de Imagem/Funções/Restauração), export;
 - Temperature (Idrisi v. 17) – Import band 6 (File/Import/Governmente - Data ProviderFormats/GeoTiff), conversion of gray layers in temperature (ImageProcessing/Transformation/Thermal) and export (File/Export/Desktop PublishingFormats/GeoTiff);
 - Datum (Global Mapper v. 16) - Matrices provided by the National Institute of Spatial Researches (INPE), have datum WGS84 by default, but Brazilian regulations require geographic information to use SIRGAS 2000 as the default datum. Due to this, the following procedures were realized: import of the data (File/Open Data File(s)), datum exchange (Tools/Configure/Projection) and export in Geotiff format (File/Export/Export Raster - Image Format);
 - Georeferencing (SPRING v. 5.3)
 - A geographical database was elaborated (Arquivo/Banco de Dados) along with a project (Arquivo/Projeto/Projetos). Then the data that were pro-processed in TerraView and Global Mapper were open in the Impima module (Arquivo/abrir) and then exported (Arquivo/Salvar Como). Importing of the images was the next step (Arquivo/Importar/Importar Imagens Registradas); Correction of georeferencing (Arquivo/Registro de Imagem/Teclado/Imagens); import of the rectified rasters (Arquivo/Importar/Importar Imagens Registradas); colored composition in false color – b3 (b), b4 (g) and b5 (r), correction of channels – shades of the histograms (Imagem/Contraste/Canal), synthetic image creation

(Imagem/Contraste/Sintética); export of rasters in Geotiff format (Arquivo/Exportar/Exportar Dados Vetoriais e Matriciais/Monocromático);

- Albedo - According to Allen et al. (2002 apud Moreira; Nóbrega, 2011, p. 0778), Computation of the planetary albedo; in other words, the albedo not adjusted to atmospheric transmissivity, is obtained by linear combination of the monochromatic reflectance of the reflective channels from Landsat TM 5. Measured by the equation:

- $A_{toa} = 0.293 * b1 + 0,274 * b2 + 0,233 * b3 + 0,157 * b4 + 0,033 * b5 + 0,011 * b7.$

- Therefore the images were added to the GIS environment (Add Data). To obtain the above equation, ArcGIS' raster calculator was used (ArcToolbox/SpatialAnalyst Tools/MapAlgebra/Raster Calculator). Albedo of the surface was obtained by the equation: a (surface's albedo) = a_{toa} (albedo at the top of the atmosphere) - a_p (planetary albedo) / T_{sw}^2 (Atmospheric transmissivity oscillating from 0.025 to 0.04, (better atmospheric conditions have a higher value) given by the equation:

- $T_{sw} = 0,75 + 2.10^{-5} * Z$. Where Z is the average of the pixels altimetry.

Upon completion of these procedures a table (Excel) was elaborated with the following columns A - X (longitude), B - Y (latitude), C (description), D (control points), E (temperature - 1987), F (albedo - 1987), G (temperature - 2001), H (albedo - 2001), I (temperature - 2010) and J (albedo - 2010). Data represented in the table were collected through field work, using a *Garmin* GPS (quad helix style Antenna), where 21 control points were collected and imported to ArcGIS v.10.2.1 to collect the information. Afterwards using *Surfer* v. 12, an information grid was generated (*Grid/Data*), and layout confection of the thematic maps and data analysis was done.

However, for the data interpretation procedure to have scientific backing, the use of an interpretation key is necessary; if this procedure is not performed, the evaluations will only be mere assumptions, derived from common sense.

Images obtained through remote sensors, regardless of the forming process, record the energy from the desired target surface. Regardless of resolution and scale, the matrices present key elements to interpretation and analysis, from which data of objects, areas or phenomena are extracted. These elements or variables are: shade/color, texture, size, shape, height, standard and localization (Florenzano, 2011).

2. 1 Description of the study area

2.1.1 Location

The State of Pernambuco (PE), is located in the northeastern region of Brasil, which has an area of 156.109,240 km², partitioned by the states of Alagoas (2.780,760 km²), Bahia (56.635,500 km²), Ceará (14.885,300 km²), Maranhão (33.586,100 km²), Paraíba (5.652,420 km²), Pernambuco (9.819,230 km²), Piauí (25.271,800 km²), Rio Grande do Norte (5.286,710 km²) and Sergipe (2.191,420 km²). Pernambuco is divided into five mesoregions: Sertão (3.793,410 km²), São Francisco (2.447,150 km²), Agreste (2.456,100 km²), Mata (842,702 km²) and Metropolitana de Recife (279,861 km²).

Agreste is subdivided into five regions: Alto Capibaribe (178,311 km²), Brejo Pernambucano (255,406 km²), Garanhuns (518,471 km²), Médio Capibaribe (176,353 km²), Vale do Ipanema (537,636 km²) and Vale do Ipojuca (789,925 km²).

Garanhuns' area is delimited by geographic coordinates -8° 51' 37" / -8° 55' 40" and -36° 26' 06" / -36° 30' 52". Bordering 11 Pernambuco municipalities (Figure 1), Capoeiras and Jucati to the north; Correntes, Lagoa do Ouro, Brejão, Terezinha to the south; São João, Palmeirina to the east; Saloá, Paranatama, Caetés to the west.

Garanhuns has two main routes to the

capital of PE. The first through BR 101, covering a stretch of 242 km; while the second goes through two BRs 423/232, crossing 80,6 km through 423 to São Caetano-PE, plus 151,4 km in 232 to Recife, amounting to 232 km. Choosing the first route results in an addition of 10km to the trip, passing through a landscape marked by vegetation of hot and humid environments; The second route, allows contact with Caruaru-PE, an important commercial hub at a regional level, and appreciation of the distinct landscape, from evergreen to xerophile.

2.1.2 Main physiographic features

Although situated in the polygon called northeastern drought (secas nordestinas), the study area presents itself as an exception since it is under Mesothermal climate of Tropical Altitude.

According to the National Institute of Meteorology – INMET (2013), its average annual rainfall is greater than 80 mm, July is the month with highest average rainfall of 155,8 mm and November the smallest with 23 mm. The period with most rainfall goes from May to August, with an average of 132,2 mm, while the quarter with least rainfall starts in September and ends in December, with an average of 34,7 mm. With mild temperatures, the area's average annual temperature is 21,6°C, the coldest period goes from June to September with an average of 19,6°C, and the highest temperatures are from December to March with an average of 23,3°C.

The area has a wavy patterned terrain in the shape of hills (Figure 02), with altitudes exceeding 1.000 m, as in the hill summit surface of Magano (L 772937,56 m / S 9017673,73 m), the average altitude of the municipality is 850m. Among these shapes, open valleys with steep slopes and flattened ends are found. As these valleys move away from the urban area they soften until coming into contact with flattened features.

Originally the area's main vegetation consisted of Atlantic forest at windward and evergreen caatinga at leeward. This phenomenon happens because the municipality is in a transition zone between Agreste and Sertão. Currently there are only remnants of such vegetation. The intense process of deforestation was driven by urban sprawl and replacement of coffee production by implementation of dairy livestock.

The municipality is located in the Mundaú Basin (Figure 03). This hydrographic network is distributed between Pernambuco and Alagoas, covering an area of 4.090,39 km² of which 2.154,26 km² are in PE and is equivalent to 2.19% of its area. The portion in Pernambuco's territory is delimited by the

parallels 08° 41' 34" / 09° 14' 00" S and meridians 36° 03' 36" / 36° 37' 27" W.

According to the Company of Research of Mineral Resources – CPRM (2014), Garanhuns-PE is situated under the fields of geological units Belém do São Francisco; Cabrobó 2, 3 and 4; and by a small group of indiscriminate granitoids (Figure 04).

Belém do São Francisco's geological unit is composed by the rock types, amphibolite, migmatite, metadiorite, granodiorite orthogneiss, tonalitic orthogneiss; being under the domains of the granulite-migmatitic and gneiss complexes; with clay and silty-sandy as predominant textures; with porosity ranging from 0 to 15%; having low and dissected hills as predominant terrain; occupying an area of 2.806,25 km².

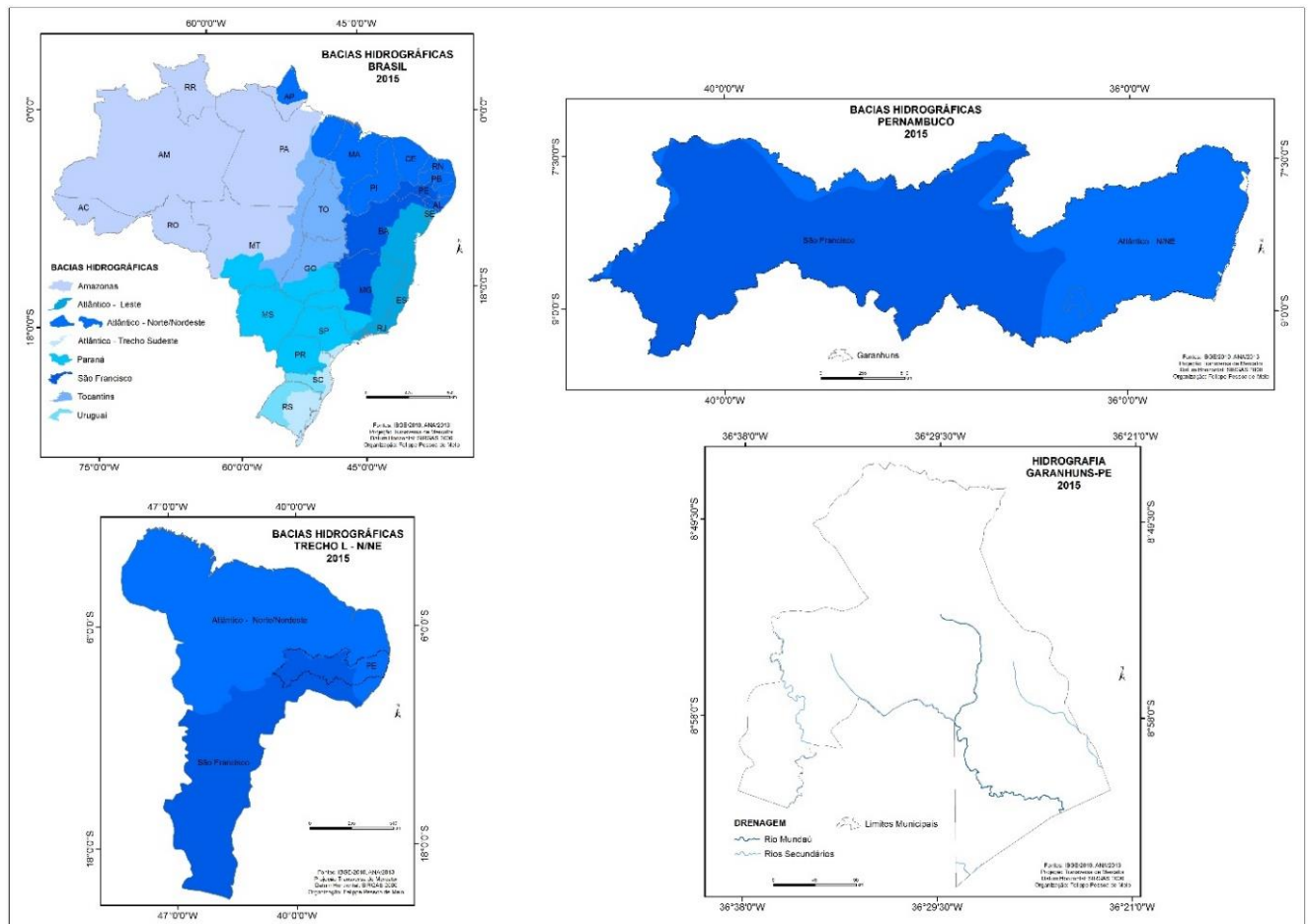


Figure 3 - Hydrographical network.

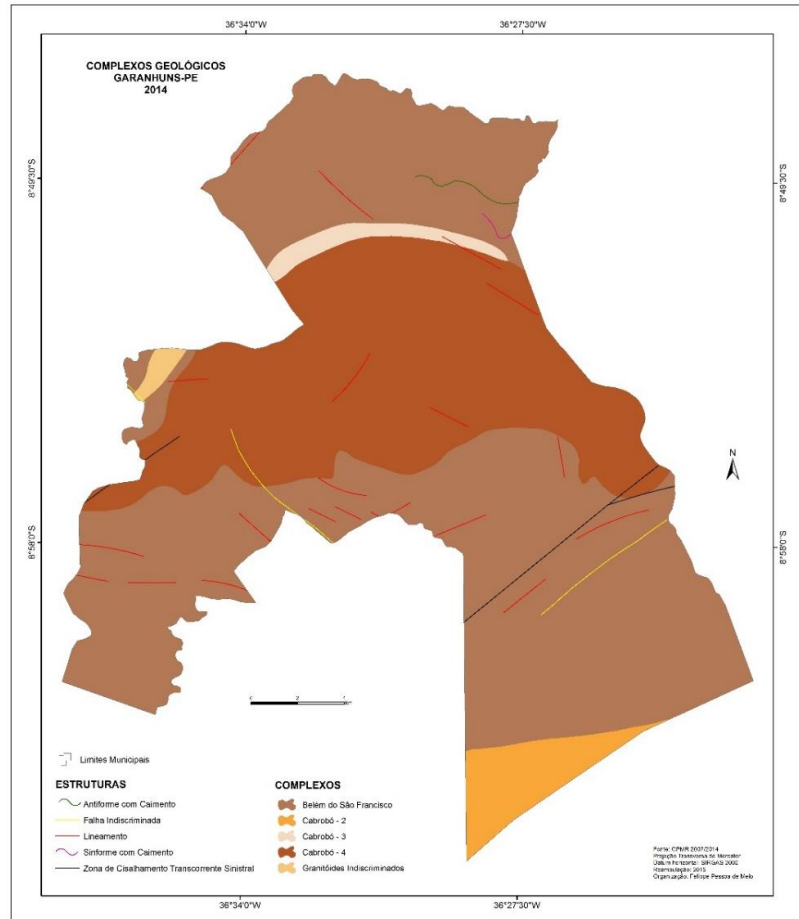


Figure 4 - Geological features.

Unit 2 of the Cabrobó Complex consists of the rock types, biotite and muscovite schist gneiss, leucognaisse, metagraywacke, migmatite and layers of quartzite, amphibolite and marble; located under the domains of proterozoic folded volcano-sedimentary metamorphosed from low to high grade sequences; presenting the same porosity, terrain and texture as the geological unit of Belém do São Francisco, occupying a perimeter of 180,44 km². Unit 3 is formed by the rock types, kyanite-garnet turbiditic metagraywacke; located under the domains of proterozoic folded sedimentary metamorphosed from low to high grade sequences; presenting same texture and porosity to the aforementioned unit 2; with a terrain consisted of plateaus, occupying an area of 69,56 km². Unit 4 consists of the rock types, micaceous quartzite, quartzite-feldspathic, and banded meta-arkose interlayered with calcium silicate rocks; presenting same domain, texture, porosity and terrain and

conformity as unit 3, and a mountainous terrain distributed over 1.510,46 km².

3. Results and discussion

The infeasibility of analysing the municipality in its entire spatial dimension, was determined as a technical and operational problem. Therefore it was decided to perform the analysis through samples, but, taking into account the dimensions of the sensor's pixels. To this end, the chosen control points didn't have equidistance as basic principle, but its representation as a whole; in other words, they were chosen based on the thematic classes, aforementioned in the multi-temporal graphs related to the thermodynamics and albedo.

However, it is known that the distance between the points is an important factor in the geostatistical procedures. The further the result is

from the collected control point, the greater are their chances of being distorted. Due to this, the introduction of a pair of coordinates (plus its referred data), at a certain point will have a result that can be mutable with a simple shift to N, S, U or O. This condition cannot be resolved, since the choice of these control locations is linked to the subjectivity of choice from the locations that are theoretically more compatible with the phenomenon that will be represented. These locations can be easily mistaken since they depend on a series of sensory elements of the researcher, which vary according to his perceptions in the course of space/time. For neither the product nor the results to be hampered, the presence of a matrix to spatialize the data is necessary (Tables 01 and 02). Showing that the results originate from an array of data distributed in space to the given distances.

Another important fact is the geochronology of the data. Ergo, the results are geostatistical answers to a set of control points at a certain time of the space/time relation. Based on this principle, it can be stated that data originated from interpolation processes, are georeferenced and also geochronological, that is, the relations between time and space are

inseparable. Therefore, analysis of the results should take place while taking into consideration these parameters. If it does not, the interpretations will be further distorted, since a significant fraction of the information was not taken into consideration. Inducing the researcher and the future readers of such data, to conduct analyses that can clash with reality.

The terms "possibility, probability, error and uncertainty" will always exist implicitly or explicitly in the modeling procedures. As already mentioned, it is impossible to organize a full model, considering all of its variables properly. So this task goes beyond the intellectual and technological limits of humanity. In the specific case of technology, more specifically the GIS, interpolations of the variables are made taking into account Euclidean distances. Based on the principle, that the shortest distance from a point to another is a straight line. Principle that geographic information does not tend to follow. For that, just think of a gated community next to a slum (separated only by a wall). Following the Euclidean principle they are nearby. But taking into account the existing social barriers between these classes, there is a seemingly insurmountable barrier; in other words, a socioeconomic impedance.

Table 1 - Spatial matrix of the rural perimeter of Garanhuns-PE. Source: Field work performed by the authors, 2015

Urban perimeter – Distance in Km												
---	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10	P 11	P 12
P 1	0	0,19	5,13	3,55	1,99	0,78	0,70	0,52	0,42	0,99	4,02	2,31
P 2	0,19	0	5,04	3,52	1,83	0,69	0,64	0,48	0,41	1,01	4,01	2,17
P 3	5,13	5,04	0	1,65	3,36	4,38	4,43	4,61	4,73	4,19	1,18	5,35
P 4	3,55	3,52	1,65	0	1,75	2,77	2,90	3,08	3,16	2,68	0,91	3,74
P 5	1,99	1,83	3,36	1,75	0	1,20	1,37	1,53	1,60	1,36	2,46	2,21
P 6	0,78	0,69	4,38	2,77	1,20	0	0,17	0,31	0,40	0,54	3,34	2,16
P 7	0,70	0,64	4,43	2,90	1,37	0,17	0	0,18	0,27	0,44	3,39	2,30
P 8	0,52	0,48	4,61	3,08	1,53	0,31	0,18	0	0,09	0,54	3,54	2,31
P 9	0,42	0,41	4,73	3,16	1,60	0,40	0,27	0,09	0	0,61	3,65	2,36
P 10	0,99	1,01	4,19	2,68	1,36	0,54	0,44	0,54	0,61	0	3,05	2,68
P 11	4,02	4,01	1,18	0,91	2,46	3,34	3,39	3,54	3,65	3,05	0	4,61
P 12	2,31	2,17	5,35	3,74	2,21	2,16	2,30	2,31	2,36	2,68	4,61	0

Table 2 - Spatial matrix of the rural perimeter of Garanhuns-PE. Source: Field work performed by the authors, 2015.

Rural Perimeter – Distance in Km									
---	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9
P 1	0	9,55	6,86	9,69	21,14	5,40	14,89	8,27	6,87
P 2	9,55	0	3,71	12,91	27,39	4,68	24,47	11,56	9,05
P 3	6,86	3,71	0	9,77	26,62	2,08	21,43	11,54	8,54
P 4	9,69	12,91	9,77	0	30,38	9,92	17,01	17,96	15,72
P 5	21,14	27,39	26,62	30,38	0	24,80	21,34	15,84	18,86
P 6	5,40	4,68	2,08	9,92	24,80	0	19,94	9,59	7,11
P 7	14,89	24,47	21,43	17,01	21,34	19,94	0	19,56	19,81
P 8	8,27	11,56	11,54	17,96	15,84	9,59	19,56	0	2,77
P 9	6,87	9,05	8,54	15,72	18,86	7,11	19,81	2,77	0

To Ferreira (2014), spatial impedance can be associated with displacement vectors whose lengths are larger than the minimal effort or lower cost vectors – this being the so-called Euclidian Distance vector. The concept of dissimilarity between distances triggers a duality between the Euclidean (isomorphic and regular) and geographical space (heteromorphic and irregular).

The geospatial synthesis carried out above, aimed to situate the reader in relation to the theoretical and methodological foundation that this paper follows. Thus making the reading and analysis of information, less complex and more plausible. Therefore, it was important to carry out a theoretical line of thought that reflects the uncertainties or gaps, between the variables. But not for the purpose of questioning or even minimizing the value of geostatistical data, but in order to make clear and evident that the numerical truth (derived from geostatistical processes) does not exist. What may exist is a possible reality, for a specific set of variables and provided that they follow the same behavioural pattern, expected by the researcher who modeled them. From this theoretical foundation, the correlation between albedo and temperature occurred in line with the established temporal intervals for analysis of these two variables in an inseparable way.

In 1987, the isotherms recorded a minimum temperature of 15 and maximum of 35°C (Figure 5A). As for the albedo, the lowest rate was 2.6 and the highest 5.6% (Figure 5B). Upon examination of the results from the thematic mapping through a panoramic manner, it was possible to find a progressive spatial distribution of the contours, similar to the effect of waves, having the southeast quadrant as centre of diffusion while the contours disperse to the northeast quadrant. Within the limits of the municipality's area, temperatures between 23 and 35°C stand out, setting up a temperature range of 12°C. In the geometric centroid of the feature, where the main urban perimeter is situated, the highest temperatures were found, ranging from 27 to 35°C, with thermal variation of 8 ° C between classes. It is clear that the highest temperatures are located precisely in the areas with higher anthropogenic interference. In this case, this interference is the maximization of the urban perimeter.

Regarding the albedo, the contours specialize in horizontal and vertical direction, but with emphasis on the latter. However, the spread occurred in sub-quadrants SSO/SSE. Within urban areas, reflectance between 2.6 and 3.2% are prevalent. It appears that the albedos have higher rates, as they move from the locations of greatest anthropogenic interference

with values ranging from 3.8 to 5.6%. Correlating the albedo and temperature variables, it was found that areas with higher anthropogenic interference showed higher temperatures and less able to reflect sunlight. Creating a unique thermal setting in relation to areas with a lower degree of interference; in other words, it created a heat island.

According to Mendonça and Monteiro (2013), formation of intra-urban climatic conditions, coming directly from the heterogeneity of both the site as the structure, morphology and urban features, can generate parallel to the climate of the city/local/urban, different climatic pockets, among which are heat islands.

In the subsequent time interval (2001), the change of the geophysical phenomena profile is clear. Regarding the thermodynamics (Figure 6A), the temperatures range from 17 to 28.5°C, with 22.7 °c as average, and an amplitude of 11.5°C. Comparing with data from 1987, it was observed a reduction in temperature of 3.7°C, when only comparing the differences between the thermal mediums.

However, after analysing the data thoroughly, it is clear that even if 1987 presented higher averages than in 2001, 1987's isotherms were distributed more spatially, and the temperatures tended to drop 4°C, as they moved from southeast to northwest; in other words, the lowest temperatures were in the areas where the Atlantic Forest predominated, and the highest in the areas of xerophile vegetation. It is necessary to remember that the municipality is located in an ecotone, being a transition place between Zona da Mata and Sertão.

The isotherms in 2001, present two dominant classes that have temperatures ranging from 19.3° to 23.9°C. Showing the presence of two heat islands, the first located at coordinates UTM 9018238 m and 775,049.8 m, with a minimum temperature of 23.9 and maximum of 28.5 ° C; the second is situated at 9020566 m and 7788274.8 m, with temperatures ranging from 23.9° to 26.2°C. Both located on the outskirts of the main urban site, in densely populated areas, this spatial phenomenon occurs mainly, due to proximity of this sector to the main commercial center.

Climate is one of the dimensions of urban environment and its study has provided

significant contributions to the addressing of environmental issues in municipalities. The climatic conditions of these areas, seen as urban climate, are results of changes in the natural landscapes, to detriment of anthropized environments (Mendonça and Monteiro, 2013).

It is logical and clear that mankind since its origin is making changes to nature, regardless of the functionalities linked to these new spaces. However, due to the lack or inadequacy of planning, the environmental conditions of the areas that are within range, materialize an unstructured and chaotic geoenvironmental setting.

Regarding the albedo of 2001 (Figure 6B), the lowest value was 3% and highest was 6.5%, resulting in an average of 4.7%, and amplitude of 3.5%. Comparing with the reflectance in 1987, an increase of 0.6% is noted. However, this increase does not mean a higher thermal comfort, as already explained by thermal data. But this doesn't make sense, since more light is being reflected the temperatures should lower. In order to confront this disparity, an on-site visit to the points collected using a GPS was performed, and it was found that: in the urban area, the oldest residences used brown roof tiles, but throughout the years these brown roof tiles were replaced by roofs with lighter shades; while in rural areas two situations occur, both related to removal of vegetation causing exposure of the soil; the first situation, is the exposure of soils with a large presence of sand derived from crystalline or milky quartz (in the transition to Sertão), and the second situation, is the introduction of secondary vegetation with milder green tones than the primary.

In 2010 (Figure 7A), the temperatures range from 18 to 30,5°C, with an average of 24,2°C and an amplitude of 12,5°C. Compared to 2001, the overall average is higher by 2,5°C, and a higher spatial distribution of the dominant isotherm between 23 and 25,5°C is noted. Regarding the two heat islands from 2001, they merged and formed an area with temperatures ranging from 25,5 to 30,5°C. It was also observed that temperatures increased along with the residential density. Validating the statements made above, regarding the intrinsic relationship between growth and consolidation of the urban area and expansion of temperatures, including formation of heat islands.

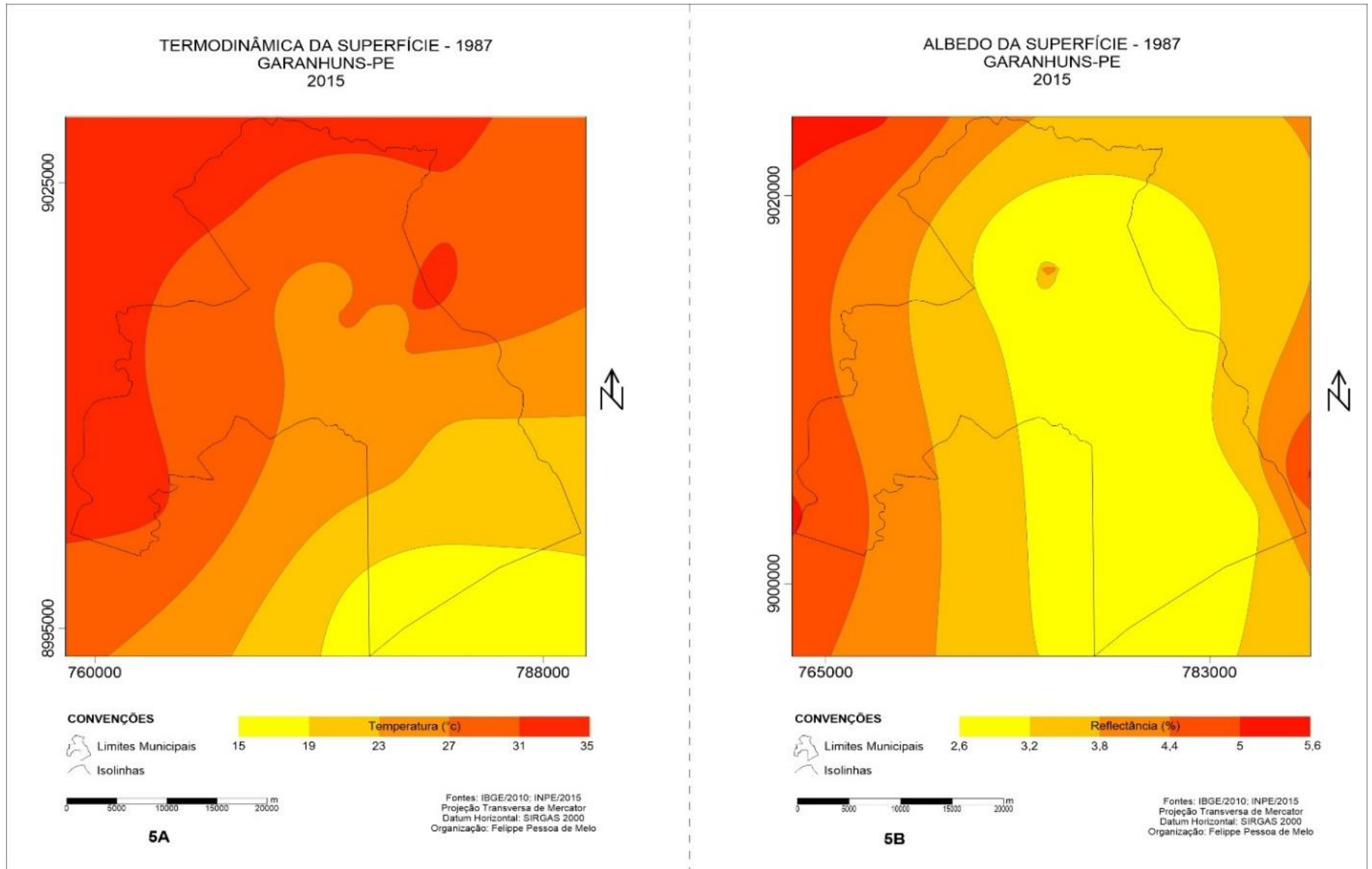


Figure 5 - A, isotherms of the surface and surroundings; B, reflectance of the surface and ravines.

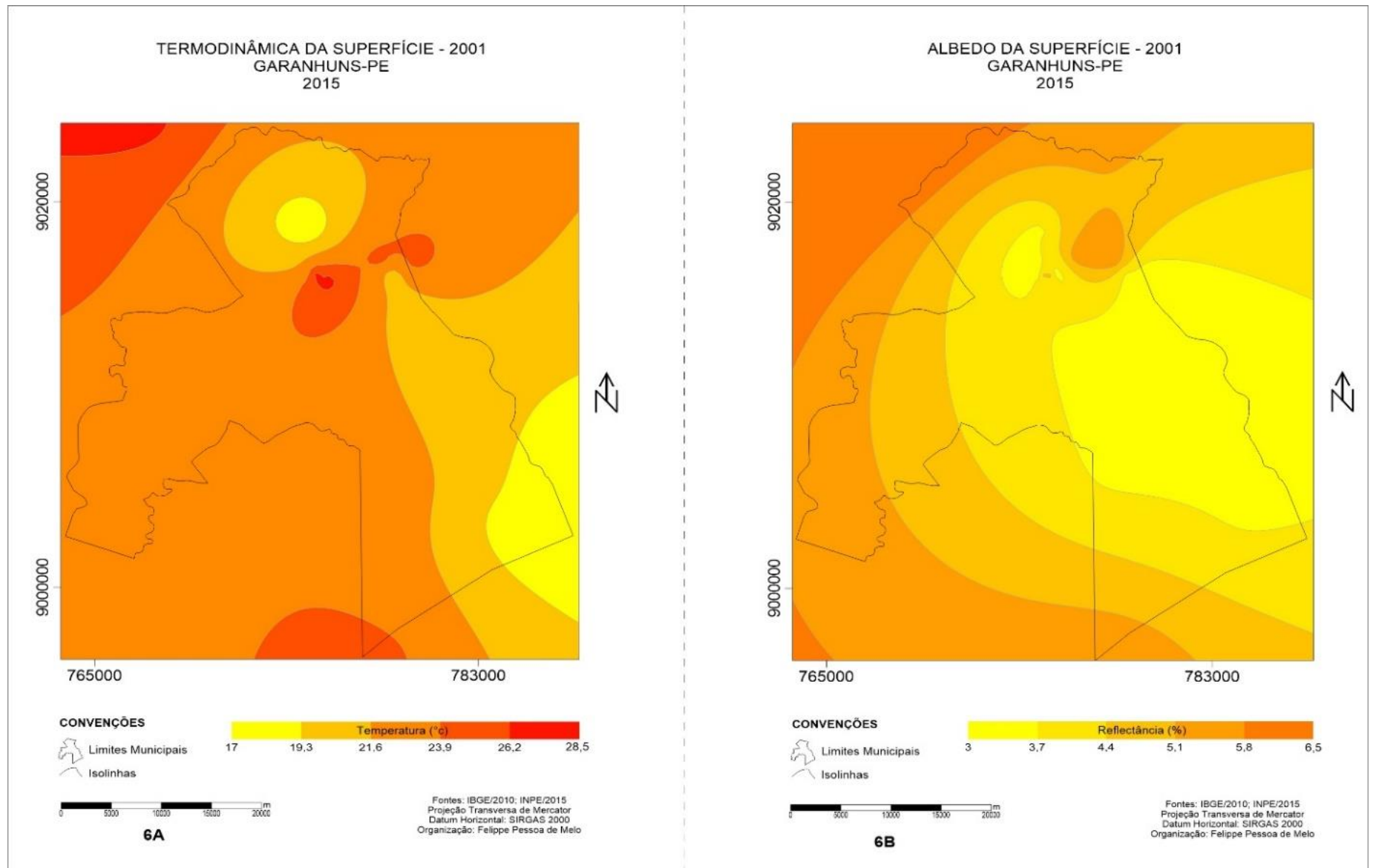


Figure 6 - A, isotherms of the surface and surroundings; B, reflectance of the surface and ravines.
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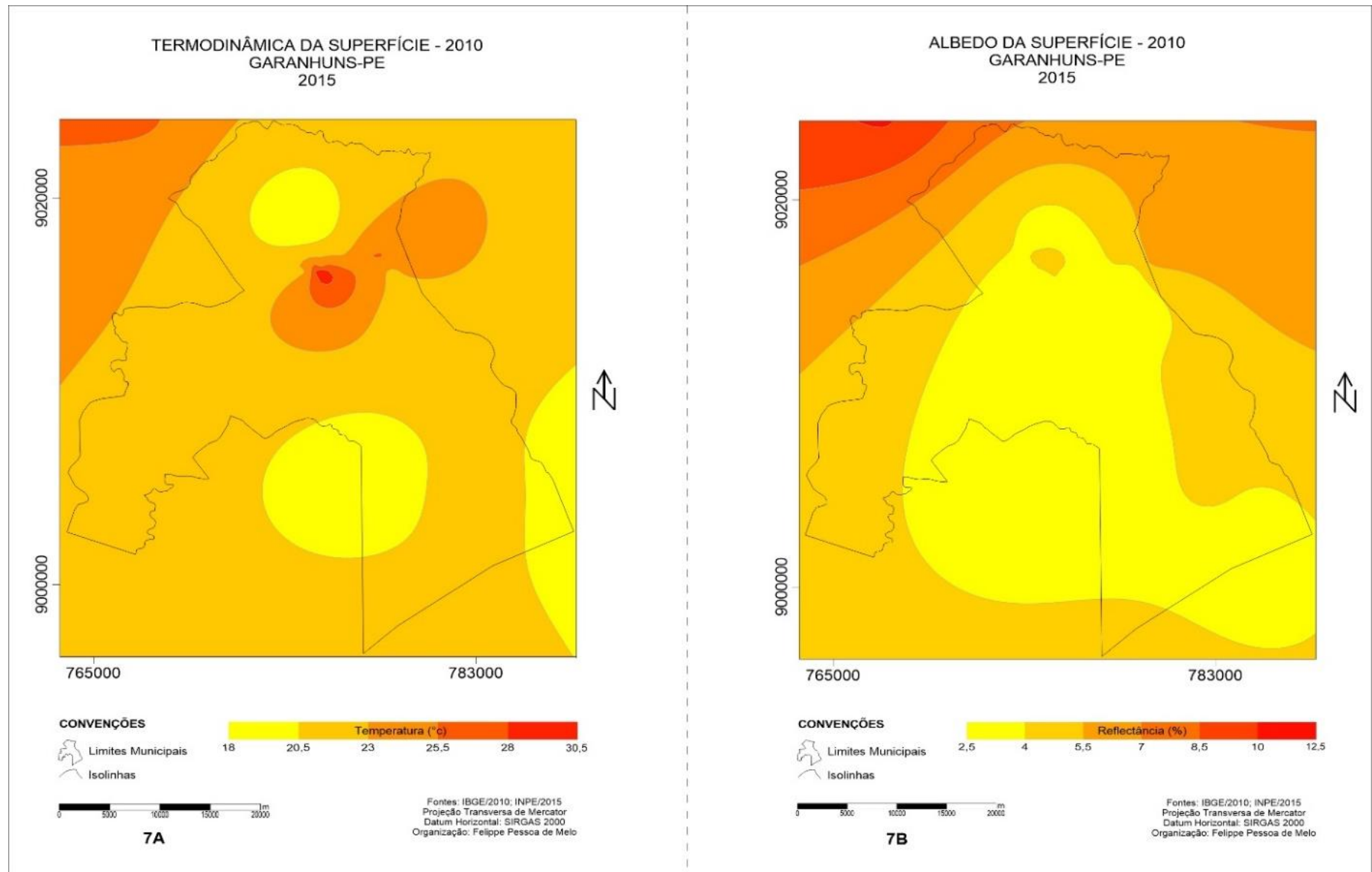


Figure 7- A, isotherms of the surface and surroundings; B, reflectance of the surface and ravines.
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The albedo in 2010 (Figure 7B) had 2,5% as lowest value and 12,5% as maximum, giving rise to a 10% disparity of the reflectance and 7,5% as average, featuring an increase of 2,8% when compared to 2001. Upon analysis of the data, it is clear that this time interval also follows same trend as the 2001 interval where reflectance increases with temperature. It should be made clear that, the increase of the albedo is not synonymous with rise of temperature, much to the contrary. But in this case there were changes in physical and chemical properties of the targets. However, if the features had been retained, maximizing the albedo would imply a decrease in temperature.

4. Conclusion

Geotechnologies from Remote Sensing and Geographical Systems (GIS), allowed the thematic multi-temporal mapping (1987, 2001, and 2010) of the following geophysical phenomena: albedo and surface temperature (targets). Making comprehension of the intrinsic relations, between urbanization and the above geophysical phenomena possible.

The possibility of performing geochronological thematic mappings is an important subsidy for decision-making related to geospatial phenomena, since it facilitates, streamlines and maximizes the reliability of decisions related to anthropogenic interference on the landscape.

In the studied area a single phenomenon occurred, which was the increase of reflectance capacity of the spatialized materialities in the landscape, parallel to the rise of temperature. It should be noted that problems such as these reinforce the need of on-site visits. Therefore, fieldwork made it possible to ascertain that the increase in thermal averages in parallel to the albedo was due to the physicochemical changes on the targets. Thus for the reflectance to agree with the thermodynamics, preservation of the targets' physiochemical properties is necessary.

This is a fact that reinforces the need of multi-temporal monitoring, since the anthropogenic ability to modify the landscape, in dwindling chronological intervals is contributing to disrupt the geoenvironmental setting. Which is making the monitoring of anthropogenic actions in nature more important than ever.

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