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Heat islands monitoring employing images of medium spatial resolution

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A B S T R A C T

The goal of this study aimed to evaluate the heat islands and their relationship with land use and land cover in the urban area of Santa Maria between 2005, 2010 and 2015. For the years 2005 and 2010 the images of the TM/Landsat 5 and OLI/Landsat's 8 for the year 2015 were used. The mapping of land use and land cover was performed based on the NDVI index. For the creation of the temperature maps the thermal bands were used, being band 6 for Landsat 5 and 10 for Landsat 8, performing the radiometric calibration. The emissivity was acquired by associating NDVI index parameters and later, calculations of temperatures in degrees Celsius were performed. The Camobi district presented lower temperature ranges when compared to the Downtown district. Moderate temperatures areas were harbored, whereas the exposed soil encompassed higher temperature ranges in both neighborhoods. It has come to the conclusion that the Camobi district presents a higher degree of cooling than Downtown district, being that of 1 °C in the years 2010 and 2015. It also shows that forests are fundamental in the reduction of heat islands in urban areas.
Keywords: Remote sensing. NDVI. Thermal bands.

Monitoramento de ilhas de calor utilizando imagens de média resolução espacial

R E S U M O

Objetivou-se avaliar as ilhas de calor e a sua relação com o uso e cobertura da terra na área urbana do município de Santa Maria entre os anos 2005, 2010 e 2015. Utilizou-se para os anos de 2005 e 2010 imagens TM/Landsat 5 e imagens OLI/Landsat 8 para o ano de 2015. O mapeamento do uso e cobertura da terra foi realizado com base no índice NDVI. Para a criação dos mapas de temperatura utilizou-se as bandas termais, sendo elas a banda 6 para Landsat 5 e a banda 10 para Landsat 8, realizando a calibração radiométrica. A emissividade foi obtida associando parâmetros de índice NDVI e posteriormente, foram realizados os cálculos de temperaturas em graus Celsius. O bairro Camobi apresentou faixas de temperaturas inferiores quando comparadas ao bairro Centro. As áreas com temperaturas mais amenas possuíam vegetação arbórea, enquanto que o solo exposto englobou faixas de temperaturas mais elevadas em ambos os bairros. Conclui-se que o bairro Camobi apresenta um grau de resfriamento maior que o Centro, sendo esse de 1 °C nos anos de 2010 e 2015. Evidenciando ainda que as florestas são fundamentais na redução das ilhas de calor em áreas urbanas.
Palavras-chave: Sensoriamento remoto. NDVI. Bandas termais.

Introduction

For long man has been migrating from the countryside to the cities, leading to their growth, often fast and disorderly (Pivetta and Silva Filho, 2002), interfering, especially, in the quality of life of the urban population. According to Amorin (2005), the transformations in the cities, constitute the most evident form of natural landscape.

The constant interference of human action in the urban environment through buildings, paving, pollution and suppression of vegetation is directly responsible for the formation of the urban climate and its products, such as heat islands, microclimates, among others (Rovani et al., 2012). According to Gonçalves (2003), the innumerable changes in the local climate resulting from urbanization, has compromised the atmosphere of the cities, giving rise to the urban climate.

Remote sensing has been used for planning of urban areas, allowing evaluation of urban heat island phenomenon. Thus, orbital products are important in the classification of land use, as well as in models of atmospheric changes and urban surface (Voogt and Oke, 2003).

The use of remote sensing for the mapping of land surface temperature and land use and coverage, allows a better analysis of the phenomena related to forest dynamics and urban growth, covering large areas. Remote sensing is of great assistance in the evaluation, handling, administration and management of natural resources. Thus, in studies related to the environment, these data are of great importance, since they make it possible to provide different types of products, among them, vegetation indexes (Matos et al., 2015).

Santa Maria is one of the warmest cities in Rio Grande do Sul because of its low altitude. However, in the winter months it is prone to weak and moderate frost. The exponential increasing in urbanization has contributed to the intensification of heat islands, especially in Downtown and Camobi districts.

In this perspective, the lack of planning and high urban growth has a great impact in relation to the microclimate of the city, surveys of information about heat islands are very important to soften these impacts. In this way, with the techniques of Remote Sensing it is possible to analyze dynamically, practically and in a short space of time. According to Saydelles (2005), the city of Santa Maria needs studies aiming the understanding of environmental aspects, especially the expansion of the urban area, which, in many cases, parallels the degradation of the physical-natural environment.

In this sense, the goal of this study was to evaluate how heat islands and its relationship with urban growth in years 2005, 2010 and 2015 use spatial resolution media images.

Material and methods

Characterization of the study area

The study area comprises the Downtown and Camobi districts, both belonging to the urban area of Santa Maria city, located in the central region of Rio Grande do Sul state (Figure 1), between the central coordinates of south latitude 29º43'00" and west longitude of 53º49'00". The city of Santa Maria displays rise in the relative humidity of the air throughout the year.

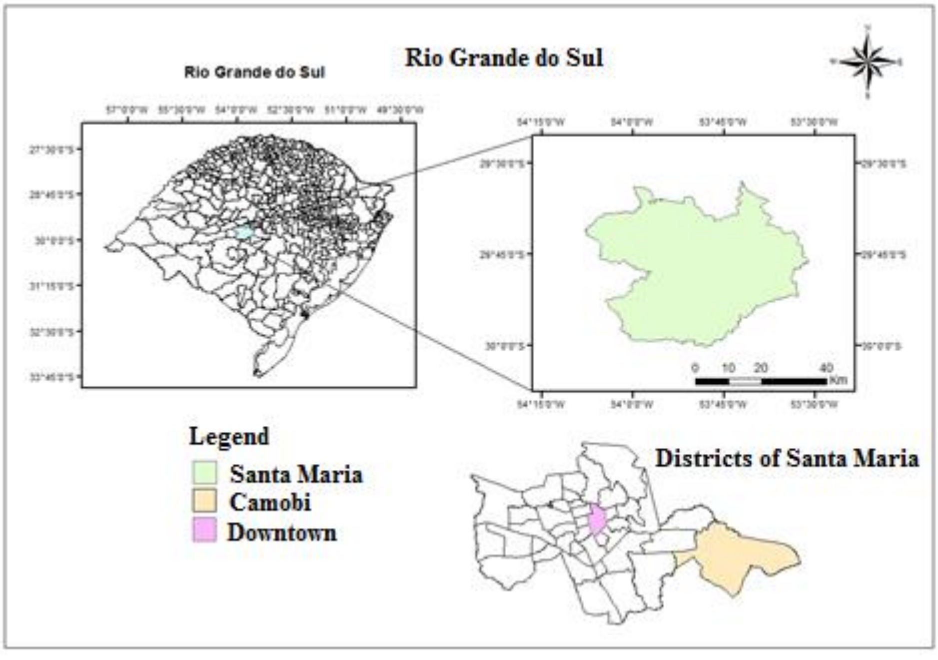


Figure 1. Location of the study area in the city of Santa Maria, RS.

The mesothermal and humid climate of the region in defined, according to the Köppen classification, as the Cfa fundamental type, characterized as subtropical, humid with hot summers, with no dry season limited. At an average annual temperature of 18 °C, it is at a maximum average of more than 32 °C and lowest temperatures of 9 °C, precipitations, however, are distributed throughout the year, with an annual average of 1700 mm (Buriol et al., 1979). The region has as local wind so called North wind known as São Martinho, resulting from the general and secondary circulation of the atmosphere that acts in the State of Rio Grande do Sul (Heldwein et al., 2009).

Methodology

The TM/Landsat 5 images were basis for mapping in the years 2005, dated on January 26 and 2010 dated on February 9. For the year 2015, the study encompassed OLI/Landsat 8 images, dated February 7. The images belong to the orbit-Point 223-081 and 223-080. The database establishment and the processing of the images were made in the Georeferenced Information Processing System SPRING, in version 5.2.1 (Câmara et al., 1996). For the present work, cylindrical cartographic projection and reference Datum WGS-1984 (World Geodetic System, 1984) were adopted.

Historical data of the maximum daily temperature, measured in the meteorological station of Santa Maria, were used in the respective dates of image capture in the present study. Rainfall data, obtained from the same meteorological station, were used to justify the results found, since these data constitute a consistent historical series of events that makes possible the safety with the occurrence of rainfall in the region (Buriol, 2006).

Radiometric callibration

Reflectance is defined as being a ratio between the flux of solar radiation reflected by surface and global solar radiation flux. The process of converting gray levels to reflectance in Landsat 8 images is different from the Landsat 5 process. Thus, Equation 1 and 2 demonstrates calculations for obtaining the reflectance at the top of the atmosphere and converting the NDs into radiance for Landsat 8, respectively.

$$\rho=\frac{M\rho*Qcal+A\rho}{\text{Sin }\theta_{SE}} \quad (1)$$

Where: ρ = planetary reflectance; Mρ = specific band multiplicative scaling factor; Aρ = band-specific additive resizing factor; Qcal = Quantized and calibrated value of the pixel in gray level (DN); θSE = Solar elevation angle.

$$L_\lambda=M_L Q_{CAL}+A_L \quad (2)$$

Where: Lλ = Spectral radiance (W/m².sr.m); ML = Multiplicative factor for resizing the band (3.3240E-04); Qcal = Quantized and calibrated value of the pixel in gray level (DN); AL = Additive factor for resizing the band (0.100).

The radiometric calibration process for Landsat 5 is based on the conversion of ND's to radiance and then reflectance. Thus, the radiance was obtained by means of Equation 4 and reflectance based on Equation 3.

$$L_\lambda = L_{\lambda min} \frac{L_{\lambda max} - L_{\lambda min}}{255} * DN \quad (3)$$

Where: Lλ = spectral radiance (W/m².sr.µm); Lλmin = Minimum 5/Landsat (W/m².sr.µm) spectral radiance; Lλmax = Maximum 5/Landsat (W/m².sr.µm) spectral radiance; DN = corresponds to the intensity of the pixel, ranging from 0 to 255.

$$\rho_{\lambda i}=\frac{\pi \times L_{\lambda i}}{K_{\lambda i} \times \text{Cos } Z \times d_r} \quad (4)$$

Where: ρλi = apparent reflectance; Lλi = spectral radiance of each band; Kλi = solar spectral irradiance of each band at the top of the atmosphere ($Wm^{-2}\mu m^{-1}$); Z = solar zenith angle; dr = 1 + 0.033 * cos (date of the image on Julian days * 2π / 365).

Land use and land cover

In order to obtain information on land use and land cover in the Camobi and Downtown districts, for the years 2005, 2010 and 2015, the difference between the reflectance in the near infrared (NIR) and the reflectance in the (RED) of the visible spectrum, divided by their sum, for normalization.

Surface temperature

Initially, the proportion of vegetation (Pv) was calculated by NDVI values. Thus, Pv was found according to the technique described by Carlson and Ripley (1997), being estimated by means of the threshold method NDVI (Equation 5).

NDVI values <0.2 are associated with bare soil with emissivity of 0.97, NDVI> 0.5 are considered vegetation, assuming 0.99 emissivity.

$$Pv=\frac{NDVI\text{-}NDVImin}{NDVImax\text{-}NDVImin} \quad (5)$$

Where: NDVI = Value of NDVI generated; NDVI min = Minimum value for pure naked soil; NDVI max = Maximum value for pure vegetation.

The emissivity was obtained based on the methodology proposed by Sobrino et al. (2004), which associates NDVI values with emissivity. According to the proposed method, it was necessary to define typical values of vegetation and soil emissivity. For this purpose, Sobrino et al. (2004) adopted values of vegetation emissivity of 0.99 and for soil 0,973, which refers to an average of 49 samples of this use (presents greater variation than the vegetation) with a standard deviation of 0.004. The final expression is given by Equation 6.

$$\varepsilon=(0,004 * Pv) + 0,986 \quad (6)$$

To determine the surface temperature values (Ts), the radiance values of the thermal band (Landsat 5 and Landsat 8) and the emissivity obtained in the previous step were used. Equation 7 was adapted for the conversion of Kelvin to degrees Celsius.

$$Ts=\left(\frac{K2}{\ln\frac{\varepsilon * K1}{L\lambda}+1}\right)- 273,15 \quad (7)$$

Whereby: Ts = Surface temperature (°C); K1 and K2 = are TM and OLI thermal band calibration constants; Lλ = radiance of the thermal band (W / m².sr.µm); ε = emissivity of the bodies.

After generating the maps of land use, land cover and temperature, cross-linking between these thematic maps were performed, checking the classes that stand out in each type of cross-linking and relate to the results found.

Results and discussion

Earth use and coverage

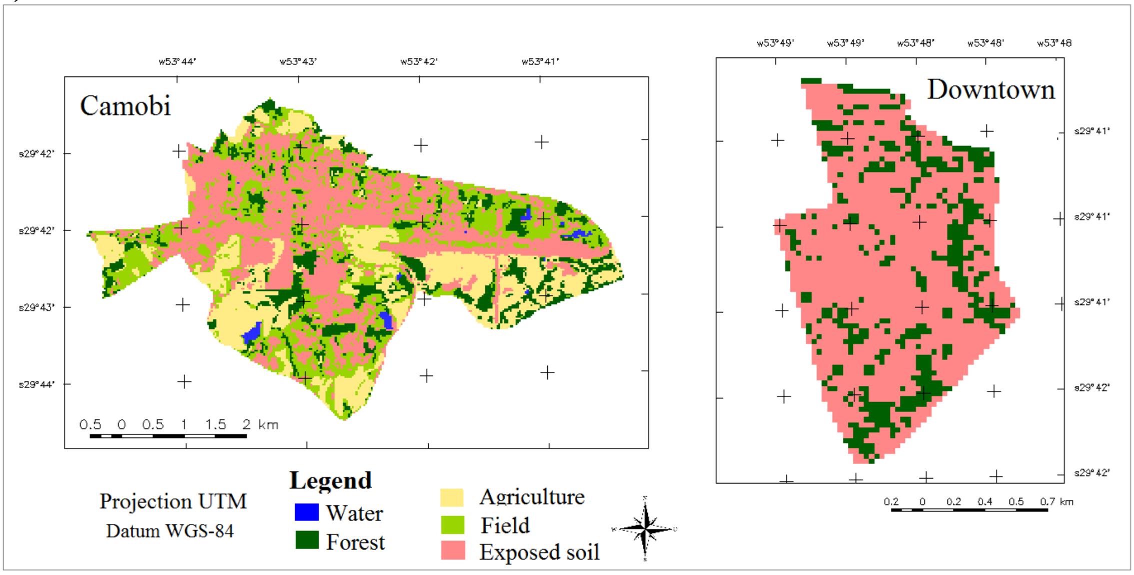
The mapping of land use and coverage for the Camobi and Downtown district in 2005, 2010 and 2015 can be seen in Figure 2. In addition, it was observed that the Camobi district presents a greater diversity of uses and coverage when compared to Downtown, higher degree of afforestation, especially in the South and East of the district.

By means of the analysis of Table 1, it was noted that Downtown district presented only the thematic classes exposed soil and forest, so that the exposed soil corresponds to the built-up areas and the forest class refers to the green areas present in the urban centers. In the Camobi district, the exposed soil class presented low modifications during the period from 2005 to 2015, while in Downtown it was observed an increasing on this class, demonstrating that in this period, the central area underwent an expansion of 12.96 ha.

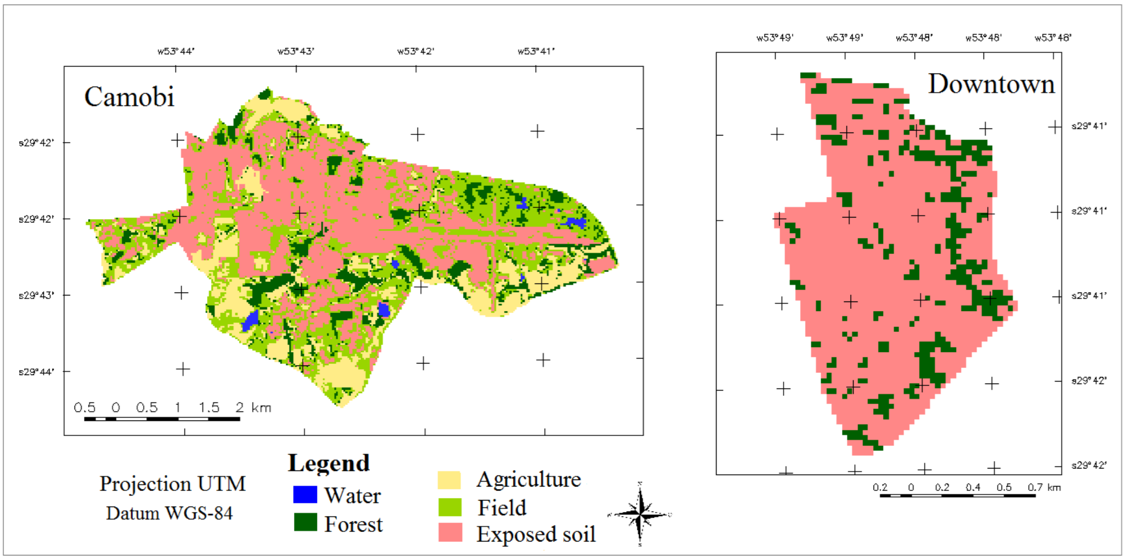
In 2010, Camobi presented increasing in the exposed soil class in relation to 2005, occupying 804.24 ha of the district. In the same way, the field class also presented the same behavior, have coming to occupy 609.21 ha in 2010. These facts can be related due to the growth of the neighborhood caused by constructions of houses and buildings and increase of pavings. In contrast, the agriculture class lost area, going from 456.48 ha to 344.25 ha in that period.

In 2015 the values obtained for the Camobi district showed a reduction of 58.14 ha of the area occupied by exposed soil, emphasizing that this class refers to the paved areas and the ones under preparation for agricultural crops. Thus, this reduction may be associated with the date of the image collection in 2010, which may have coincided with the harvest period of some crops, thus exhibiting naked solos. The field class presented a value similar to that of 2005 and a decreasing in relation to 2010. However, the agriculture class returned to have a greater representation, accounting for the year 2015 468.27 ha. The Forest has expanded, covering in 2015 an area of 287.37 ha. This was the use which displayed the greatest increasing area for Camobi district in the considered period, highlighting greater concern and urban planning regarding afforestation.

a)


Camobi
Downtown
0.5 0 0.5 1 1.5 2 km
Legend
Projection UTM
Datum WGS-84
Water
Forest
Agriculture
Field
Exposed soil

b)


Camobi
Downtown
0.5 0 0.5 1 1.5 2 km
Legend
Projection UTM
Datum WGS-84
Water
Forest
Agriculture
Field
Exposed soil

c)

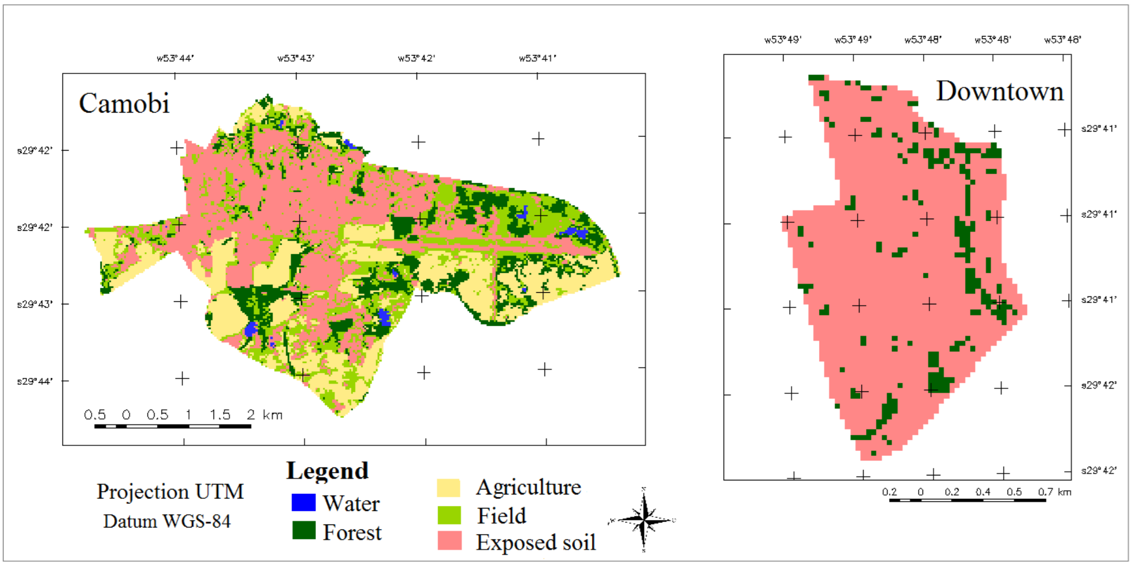

Camobi
Downtown
0.5 0 0.5 1 1.5 2 km
Legend
Projection UTM
Datum WGS-84
Water
Forest
Agriculture
Field
Exposed soil

Figure 2: Land Use and Coverage for the Camobi and Downtown district in the city of Santa Maria in the years 2005 (a), 2010 (b) and 2015 (c).

Table 1: Thematic classes occupation area to the years of 2005, 2010 and 2015 to Camobi and Downtown districts belonging to the urban area of Santa Maria city, RS.

Thematic classes	Area 2005 (ha)		Area 2010 (ha)		Area 2015 (ha)	
	Camobi districts	Downtown districts	Camobi districts	Downtown districts	Camobi districts	Downtown districts
Exposed soil	743.49	147.69	804.24	160.65	746.10	173.52
Agriculture	456.48	-	344.25	-	468.27	-
Field	513.27	-	609.21	-	468.72	-
Forest	258.30	46.26	213.21	33.30	287.37	20.43
Water	15.30	-	15.93	-	16.38	-

The Downtown district showed an expansion of exposed soil class and decreasing of forest areas from 2005 to 2015. In that period, the soil class exhibited an increasing of 25.83 ha, occupying in 2015 an area of 173.52 ha, representing a gradual expansion of the urban environment. However, the mapping of land use and land cover evidenced decreasing of 25.83 ha of the Forest class, demonstrating trees concentration in the streets or squares.

These results highlight the process that in the last decades has devastated the small regions of Brazil, the rural exodus. Thus, individuals opt for more urbanized cities searching for better job offer and the expected financial stability. This factor, coupled with the ease of access to public education, has possibly caused hundreds of young people to migrate to the city of Santa Maria, especially the Downtown district.

Against this trend, we can see that forested areas are constantly reducing the quality of life of the population. The increasing of pavements and buildings occupy areas that were previously intended for green spaces and leisure of individuals. These results illustrate the pattern of development of the large centers, where increasingly, these environments are having built up areas, with great population density, which causes suppression of green areas.

The dynamics of the uses present in the Camobi district in the analyzed period, demonstrate constant behavior. The values presented by thematic classes in 2005 and 2015 were similar, with minor changes in the year 2010. However, an increasing in forest concentration was identified, a behavior different from that observed for the Downtown district.

Surface temperature

The surface temperature, obtained by the TM/Landsat 5 and OLI/Landsat 8 sensors, for the Camobi and Downtown districts in the years 2005, 2010 and 2015 is shown in Figure 3. The Camobi district presented a thermal amplitude of 12°C, while the Downtown of Santa Maria comprised temperatures between 26 °C a 35 °C in the period of 2005 to 2015.

In Camobi, the highest temperatures were concentrated in the central part, which represent built-up areas, since the other regions of this district have lower intensity of sidewalks, buildings and greater presence of green areas.

The quantification of areas occupied by the temperature types for the Camobi district is shown in Table 2, displaying that in 2005, the temperature class of 30 to 32 °C showed a greater predominance in the region. However, in the year 2010, the predominant temperature class in the study area was 24 to 26 °C and the temperature class of 26 to 28 °C was more representative in the analysis for the year 2015.

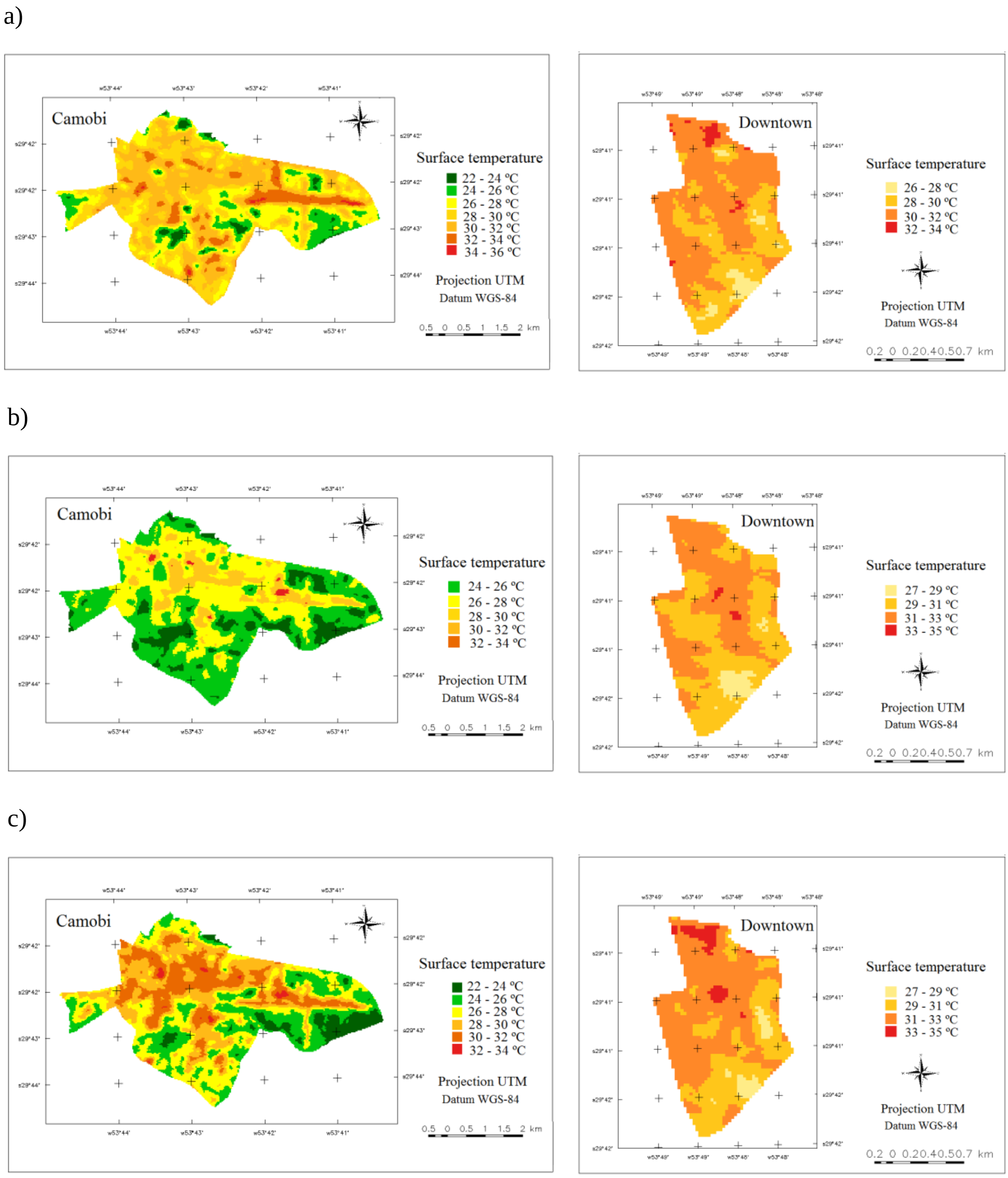


Figure 3. Surface map temperature in the Camobi and Downtown districts, Santa Maria, from 2005 (a), 2010 (b) and 2015 (c).

This study showed higher temperatures in 2005, corroborating with the results obtained by Sousa Junior et al. (2010), when they observed the drought in the southern region of Brazil. In the summer of 2005 the authors identified more than 40% of the area occupied by the State of Rio Grande do Sul showed anomalies in vegetation and high intensity drought. Hence, Brazil in 2005 was under influence of El Niño climate phenomenon (INPE, 2016), aggravated by the Atlantic Ocean colder waters. This phenomenon resulted in irregular rains from spring having its apex in the months of February and March, provoking one of the largest crop failures in history, in which even with the occurrence of El Niño, the South region faced drought, since this phenomenon caused irregular rains (Ridesa, 2017).

Table 2. Quantification of the temperature of the Camobi districts in the years of 2005, 2010 and 2015.

Temperature (°C)	**Year of 2005**		**Year of 2010**		**Year of 2015**	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
22-24	41.31	2.10	230.94	11.60	130.14	6.60
24-26	201.51	10.10	809.01	40.70	454.95	22.90
26-28	422.55	21.30	693.90	34.90	523.98	26.40
28-30	545.04	27.40	242.19	12.20	498.06	25.10
30-32	609.48	30.70	-	-	365.67	18.40
32-34	158.58	8.00	-	-	14.04	0.70
34-36	8.37	0.40	-	-	-	-
Total	**1,986.84**	**100.00**	**1,986.84**	**100.00**	**1,986.84**	**100.00**

Sousa Junior et al. (2010) states that in the summer of 2005 there were low values of cumulative-mean precipitation in the Rio Grande do Sul state, accounting for approximately 280 mm. Thus, areas with lower precipitation coincided with areas of occurrence of vegetation anomalies.

Likewise, 2009/2010 was marked by the effects of the El Niño phenomenon, but of low intensity (INPE, 2016), corroborating with the results demonstrated in this study, where the maximum temperature for the period was 30 °C in the Camobi district. Sousa Filho et al. (2010) identified that in summer 2009 the state of Rio Grande do Sul had 34.41% of its area affected by vegetation anomalies and high intensity drought. In the year 2015 the maximum temperature detected by the OLI sensor was 34 °C and according to INPE (2016) this year was marked by the El Niño phenomenon.

The quantification of areas occupied by the temperature classes for the Downtown district is shown in Table 3. For the year 2005 temperatures predominated in the range of 30 to 32 °C were observed, whereas in 2010, represented by the class of 28 to 30 °C. In 2015 the most representative temperature range was 31 to 33 °C. The values found are close to the temperatures obtained by the Santa Maria Meteorological Station, which were 27.4 °C for 2005, 31.0 °C for 2010 and 29.4 °C for 2015. However, the images diverged from the reading time of the temperature, in addition, the surface temperature is higher than the air temperature, which resulted in some variations in the results obtained between the surface and air temperature.

The Santa Maria city in January 2014 presented temperatures ranging from 26 to 46 °C according to studies carried out by Alba et al. (2016). According to the authors, the highest prevalence class corresponded to the range of 32 to 34 °C, comprising approximately 36% of the city.

Table 3. Downtown district temperature quantification in the years of 2005, 2010 and 2015.

Temperature (°C)	**Year of 2005**		**Temperature (°C)**	**Year of 2010**		**Year of 2015**	
	Area (ha)	**%**		**Area (ha)**	**%**	**Area (ha)**	**%**
26 - 28	9.63	5.0	27 - 29	9.54	4.90	8.19	4.20
28 - 30	67.86	35.0	29 - 31	94.05	48.60	64.62	33.30
30 - 32	112.05	57.8	31 - 33	88.29	45.60	111.96	57.70
32 - 34	4.41	2.30	33 - 35	1.65	0.80	9.18	4.70
Total	**193.95**	**100.00**	**Total**	**193.95**	**100.00**	**193.95**	**100.00**

The Table 4 show Cross-linking data of temperature with land use maps and the land cover for the Camobi district. It is possible to observe that forest areas have concentrated low and medium temperatures throughout the monitored period. Areas with the presence of agricultural vegetation present similar behavior with the forest vegetation, while exposed soil areas have included the highest temperature classes.

Table 4. Cross-linking data of temperature with land use and land cover in the Camobi district.

Temperature	22-24°C		24-26°C		26-28°C		28-30°C		30-32°C		32-34°C		34-36°C	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
2005														
Exposed soil	0.00	0.0	1.26	0.2	19.53	2.6	171.00	23.0	409.68	55.1	134.64	18.1	7.38	1.0
Field	0.18	0.0	16.92	3.3	117.09	22.8	203.76	39.7	150.66	29.4	23.67	4.6	0.99	0.2
Forest	20.25	7.8	82.35	31.9	94.86	36.7	53.10	20.6	7.74	3.0	0.00	0.0	0.00	0.0
Agriculture	20.88	4.6	98.73	21.6	179.46	39.2	115.92	25.3	41.40	9.1	0.9	0.2	0.00	0.0
2010														
Exposed soil	-	-	1.08	0.1	88.83	11.0	485.91	60.4	218.07	27.1	10.35	1.3	-	-
Field	-	-	46.71	7.7	370.44	60.8	168.39	27.6	23.22	3.8	0.45	0.1	-	-
Forest	-	-	83.79	39.3	110.52	51.8	18.45	8.7	0.45	0.2	0.00	0.0	-	-
Agriculture	-	-	97.65	28.4	225.0	65.4	21.15	6.1	0.45	0.1	0.00	0.0	-	-
2015														
Exposed soil	0.09	0.0	5.13	0.7	65.07	8.7	324.45	43.5	337.50	45.2	13.86	1.9	-	-
Field	6.93	1.5	78.39	16.7	215.55	46.0	140.31	29.9	27.36	5.8	0.18	0.0	-	-
Forest	43.02	15.0	152.55	53.1	70.65	24.6	20.52	7.1	0.63	0.2	0.00	0.0	-	-
Agriculture	79.38	17.0	209.43	44.7	166.68	35.6	12.69	2.7	0.09	0.0	0.00	0.0	-	-

According to Rovani et al. (2012), geoecological factors such as the presence of afforestation and field vegetation in the Camobi district are important determinants of temperature behavior and humidity values. The study showed that the southern portion with predominance of field, tree vegetation and agricultural areas, was less heated than the urbanized part.

The relationship between land use and land cover and the surface temperature for Santa Maria’s Downtown area is shown in Table 5. The built-up areas represented in this study by exposed soil predominated in the temperature ranging from 30 to 32 °C for the year 2005 and in the interval of 31 to 33 °C for the years 2010 and 2015. The forests present in the district displayed cooler temperatures than the exposed soil, except for the year 2005, in which the temperature range of 30 to 32 °C was the predominant for both the exposed soil and the forest.

Alba et al. (2016) carried out surface temperature studies for the municipality of Santa Maria in January 2014, relating land use and land cover with temperature classes designated low, medium and high. It was observed that the urban area presents the highest temperatures, since 21,24% of the area of this class identified high temperatures, while the highest percentage obtained in the class of low temperatures corresponded to the forest.

For Mendonça and Monteiro (2003), the urban climate is derived from the alteration of the natural landscape and its replacement by a built environment. Many aspects of urban morphology influence the urban climate.

For Givoni (1998), the main morphological factors that contribute to the urban climate formation are: location of the city within the region, the size of the cities, the density of the built area, the ground cover, the height of the buildings, orientation and width of the streets, division of lots, existence of parks and green areas and special details in the design of buildings.

Table 5. Cross-linking data of temperature with land use and land cover in the Downtown district.

Thematic classes	2005							
	ha	%	ha	%	ha	%	ha	%
	26-28°C		28-30°C		30-32°C		32-34°C	
Exposed soil	3,42	2,3	48,78	33,0	91,62	62,0	3,87	2,6
Forest	6,21	13,4	19,08	41,2	20,43	44,2	0,54	1,2
	2010							
	27-29°C		29-31°C		31-33°C		33-35°C	
Exposed soil	5,94	3,7	72,00	44,8	81,00	50,4	1,62	1,0
Forest	29,79	50,0	21,6	36,3	8,19	13,7	0,00	0,0
	2015							
Exposed soil	4,59	2,6	54,18	31,2	106,11	61,2	8,64	5,0
Forest	3,60	17,6	10,44	51,1	5,85	28,6	0,54	2,6

According to Spirn (1995), as cities grow in size and density, the changes they produce in the air, soil, water and life, inside and around them aggravate the environmental problems that affect the well-being of each inhabitant. Sodoudi et al. (2014) in a study of temperature identified that wooded areas present a cooling of up to 4,20 °C in relation to paved areas without afforestation.

These results contribute to urban planning, aiming to achieve a balance between all these aspects, which requires a dynamic and constant dialogue between different interests. At present, it is necessary to consider aspects such as the maintenance of biodiversity, water and soil quality, landscape, together with the need to maintain production, economic benefits, tourism, among others.

Conclusions

The Downtown area district showed higher surface temperature classes in the years 2010 and 2015 when compared to the Camobi district, which presented a cooling of 1 °C in these dates, attributed to the greater presence of wooded areas in this region, as well as lower concentration of buildings.

The surface temperature detected by the TIRS sensor was higher in areas with predominance of exposed soil, while areas with milder temperatures present some type of vegetation. The Camobi district presented a greater range of temperature bands, reaching milder ranges in relation to the Downtown district.

These results demonstrate the great importance of urban afforestation for reducing the temperature of built-up areas, improving the quality of life of the population. In this sense, contribution development of studies related to the occurrence of climate change at the local level, and, therefore, use the example for global scales.Agradecimentos.

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