Multi-scale approach to quantify the influence of urban green spaces on climate behavior of the Viladecans-Gavà-Castelldefels conurbation in the metropolitan area of Barcelona

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Abstract

Literature widely recognize the strong influence of urban green spaces in the microclimatic regulation and its potential applications to mitigate warming in cities. Promote viable actions to the climate change adaptation from cities through vegetation and help to palliate the urban heat island effect (UHI) to reduce health risk during extreme heat episodes, requires accurate criteria for each context in its different scales. This study presents a multi-scale approach to quantify the influence of urban green spaces on climate behavior of the Viladecans-Gava-Castelldefels conurbation in the metropolitan area of Barcelona. For this purpose, first, air (Ta) and surface (Ts) temperature of 124 points located in the interior and surroundings of seven green spaces are registered through field measurement campaigns during day and night between July 26 and August 4 of 2018. Then, Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) from Landsat 8 and Sentinel 2 data imagery for a clear-sky day nearby to the measurement days are retrieved and complemented with the NDVI of the spring-summer period of 2018 (1m) available in the Cartographic and Geographic Institute of Catalonia (ICGC). Analytical methods departed from the UHI characterization of the three-municipal area, resulted in 1.63°C LST increase in the urban Corine land cover (CLC) in relation with the rural at the whole ambit. Then, an OLS model to predict LST is constructed with NDVI and distance to parks (spaces with NDVI>=0.30) in the whole ambit (R^2=0.59) and in the urban area (R^2=0.47). At this point, results indicate that increase a tenth of NDVI reduces 1.15°C the LST of the whole ambit and 0.73°C on the urban area ($p<0.01$); while for each 100m further from parks, the LST rises 0.61°C for the whole ambit and 1.81°C on urban area ($p<0.01$). Particularly for the seven study cases, field measurements registered coincident spatial distribution with LST and NDVI, as well as highlighted the UHI effect during night. The quantification of the intensity and extent of the cooling effect of the study cases, registered a maximum cooling intensity of 2.7°C with a 300m buffer area; as well as the cooling effect calculation through concentric rings resulted between 40 to 130m extents from the parks boundaries and cooling intensity from 0.29 to 2.15°C. In conclusion, even when the multiple-scale analysis present coincidences and discrepancies between the different approaches, the models and methods applied in this study resulted in values that allow starting to talk about adequate actions to adapt to climate change in the context of the metropolitan area of Barcelona. The present study is part of the "Urban-CLIMPLAN. The urban heat island: effects on climate change and modeling for territorial and urban planning strategies. Application to the metropolitan region of Barcelona", financed by the Ministry of Economy of Spain (MINECO) and the European Regional Development Fund (ERDF).

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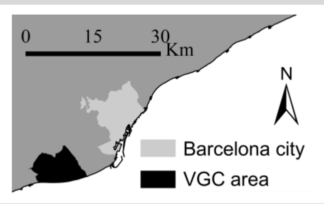
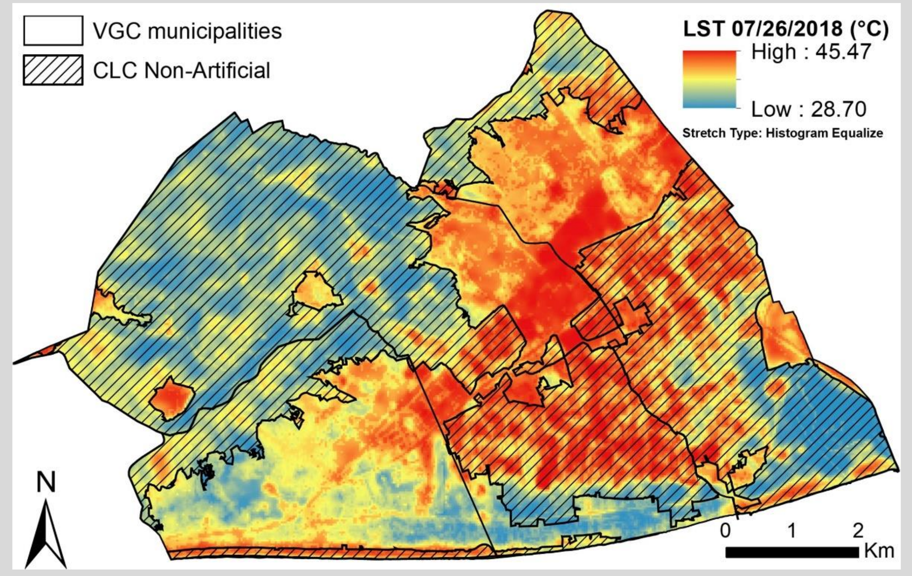
1. Introduction



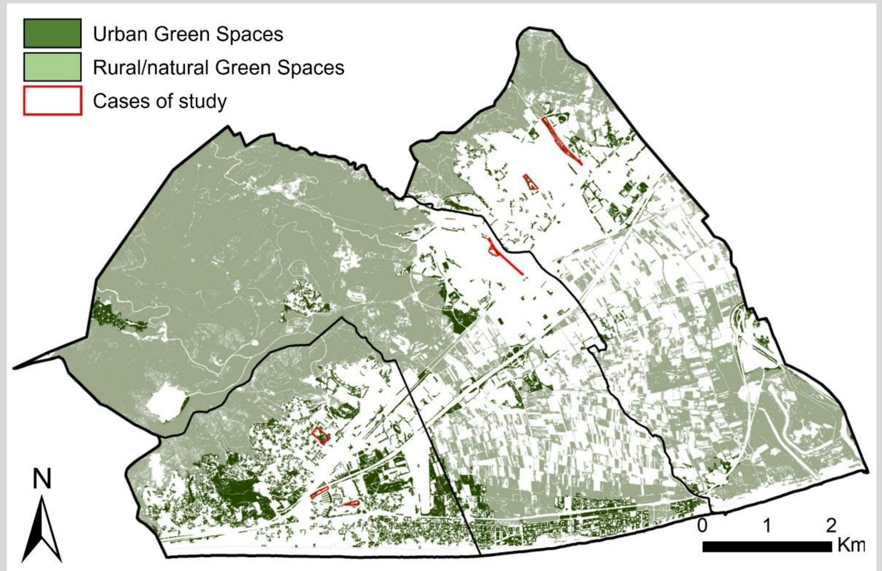
↑ Fig. 1. Location of VGC.

The aim of this study is to quantify the influence of the urban green spaces (UGS) in the climatic behavior of the Viladecans, Gavà and Castelldefels (VGC) conurbation in the metropolitan area of Barcelona. Framed in the studies on the Urban Heat Island (UHI) effect of Barcelona, this work presents a first approach to quantify the cooling effect of the UGS of this context. We selected analytical methods based in remote sensed and on-field data applied to multiple scales. This work allowed us to list considerations on the spatial definition of the cooling effect of green spaces and its potential inclusion in the criteria for climate sensitive urban planning and design.

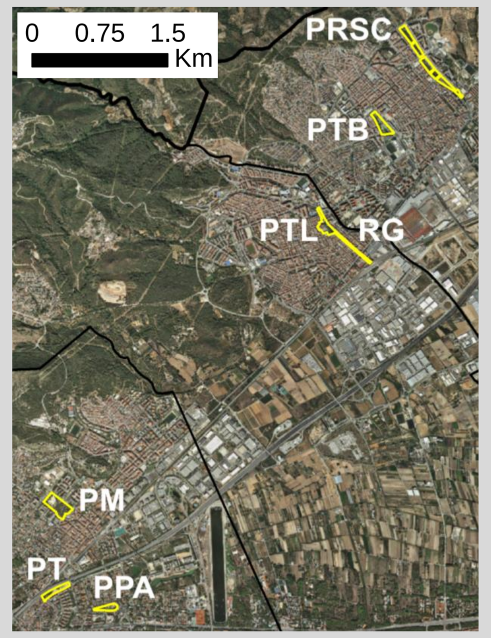
2. Data



↑ **Fig. 2. Land Surface Temperature (LST) from Landsat-8 of 07-26-2018** [1] **and Corine Land Cover (CLC) artificial surfaces** [2] **as urban areas**. LST retrieved from thermal-infrared 1 band (10) with the emissivity corrected LST equation [3] and surface emissivity derived from the NDVI threshold method [4] with emissivity values and shape factors for urban contexts [5].



↑ **Fig. 4. Green spaces (GS).** Areas with more than 1,000m² of continuous 1m-cell NDVI ≥ 0.30. Value defined as the lower limit of vegetated areas by the regional administration [7].

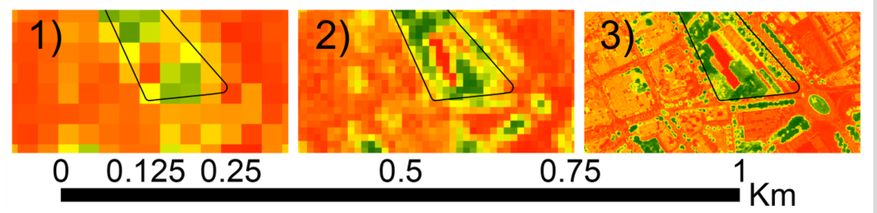


↑ **Fig. 6. Cases of study**

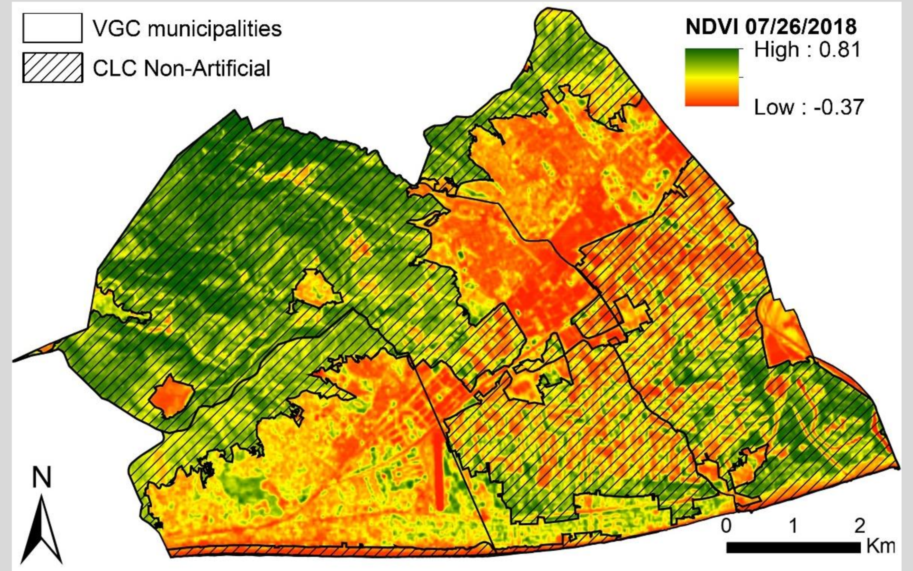
1) Viladecans
- PRSC. Parc de la Riera de Sant Climent
- PTB. Parc Torrent Ballester

2) Gavà
- PTL. Parc Torre Lluch
- RG. Rambla de Gavà

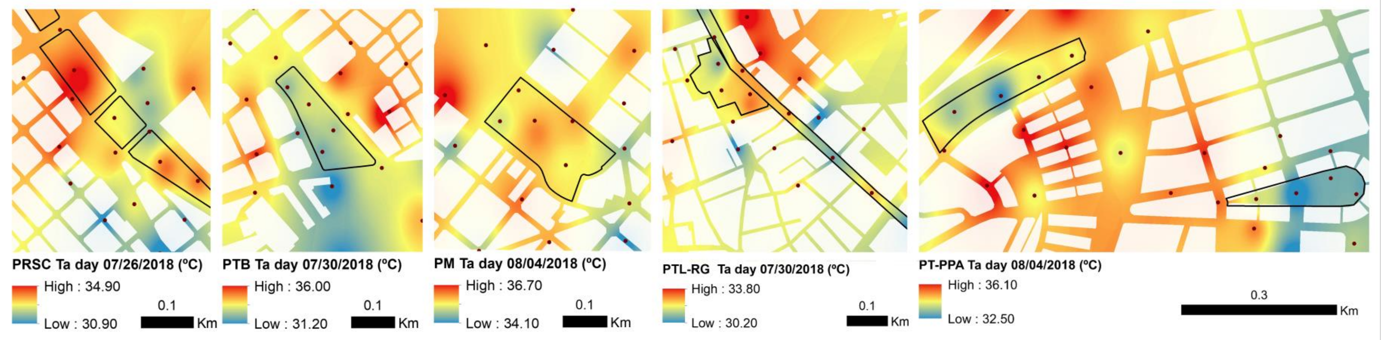
3) Castelldefels
- PM. Parc de la Muntanyeta
- PT. Parc dels Tellinaires
- PPA. Plaça d'Asturias



↑ **Fig. 5. Different resolutions of NDVI:** 1) Landsat-8 30m-cell 07/26/2018; 2) Sentinel-2 10m-cell 07/27/2018 [8]; and 3) 1m-cell spring-summer 2018 [7].



↑ **Fig. 3. Normalized Difference Vegetation Index (NDVI) from Landsat-8 of 07-26-2018.** The NDVI goes from -1 to +1, the lower the value the less the vegetation. It is calculated with the Top of Atmosphere (TOA) reflectance of near-infrared (NIR) and red bands [6] of Landsat-8 and Sentinel-2 imagery.



↑ **Fig. 7. Interpolation (IDW) of air temperature registered in field measurement points during day.** Air and surface temperature is registered by field measurements with portable instruments (EXTECH HT30 for air and FLIR E60 infrared camera for surfaces). Measurements are performed in five transects during day (+/-2hrs 15:00) and night (+/-2hrs 02:00) between 26 of July to 04 of August of 2018.

3. Analytical Methods

3.1. Local scale (VGC)

3.1.1. Surface Urban Heat Island intensity (SUHII)

- SUHII = $LST_{urban} - LST_{rural}$
- Artificial CLC = urban area

3.1.2. OLS regression

- Entire VGC area model: Dependent variable: LST; Independent variables: Landsat NDVI and Distance to GS
- Urban area model: Dependent variable: LST; Independent variables: Sentinel NDVI and Distance to UGS

3.2. Microscale (Seven cases of study)

3.2.1. Green Space Cooling Effect (GSC) through LST homogenization by concentric rings [9]:

- Dataset curve fitting of LST of 50 concentric rings of 10m-width in the urban surroundings
- GSC extent (L_{max}): Distance from UGS to farthest ring where the cooling curve ends
- GSC intensity (ΔT_{max}) = L_{max} LST – UGS LST

3.2.2. GSC by field measurements

- Air and surface temperature measurements at 124 points

4. Climatic behavior of the VGC area

↓ **Table 1. Mean LST of municipalities and the entire VGC area.** The SUHI resulted in 1.63°C for the VGC area. Highest LST in urban areas correspond to Viladecans and lowest to Castelldefels. Gavà registered the highest SUHII.

LST (°C) / ambit	Entire	Urban	Rural	SUHI
Viladecans	36.53	38.01	35.80	2.21
Gavà	35.22	37.11	34.70	2.41
Castelldefels	35.23	35.43	34.68	0.75
VGC conurbation	35.64	36.69	35.06	1.63

NDVI / cell	30m	10m	1m
Viladecans	0.28	0.16	0.19
Gavà	0.27	0.20	0.23
Castelldefels	0.30	0.23	0.26

← **Table 2. NDVI of urban areas by resolution.** The 10m and 1m NDVI point equal trend in the municipalities. However, the 30m NDVI registered different trend in the Viladecans municipality.

5. Distance to UGS, NDVI and LST

Classification of green spaces by the NDVI resulted in 1,213 polygons in the entire VGC area and 775 in the urban area. Urban green spaces represent the 16.46% of the total green spaces of the VGC area and the 23.84% of the entire urban areas.

The OLS regressions are performed with data located in 70,980 points (30 x 30m) for the entire area model and 229,737 points (10 x 10m) for the urban model.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.767[a]	0.589	0.589	1.792

a. Predictors: (Constant), Distance_to_GS, NDVI_30m

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	39.993	0.022		1833.39	0.00
	Distance_to_GS	0.006	0.000	0.077	25.98	0.00
	NDVI_30m	-11.496	0.047	-0.720	-243.36	0.00

a. Dependent variable: LST_VGCarea

↑ **Table 3. Entire VGC area model results.** Predictors of the model resulted in *p<0.01* significance. Even when the distance to GS resulted in the lowest coefficient, it implies that each 100m farther from a green space, the LST increase 0.61°C. As well as each tenth of NDVI reduce it 1.15°C.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.685[b]	0.469	0.469	1.786

a. Predictors: (Constant), Distance_to_UGS, NDVI_10m

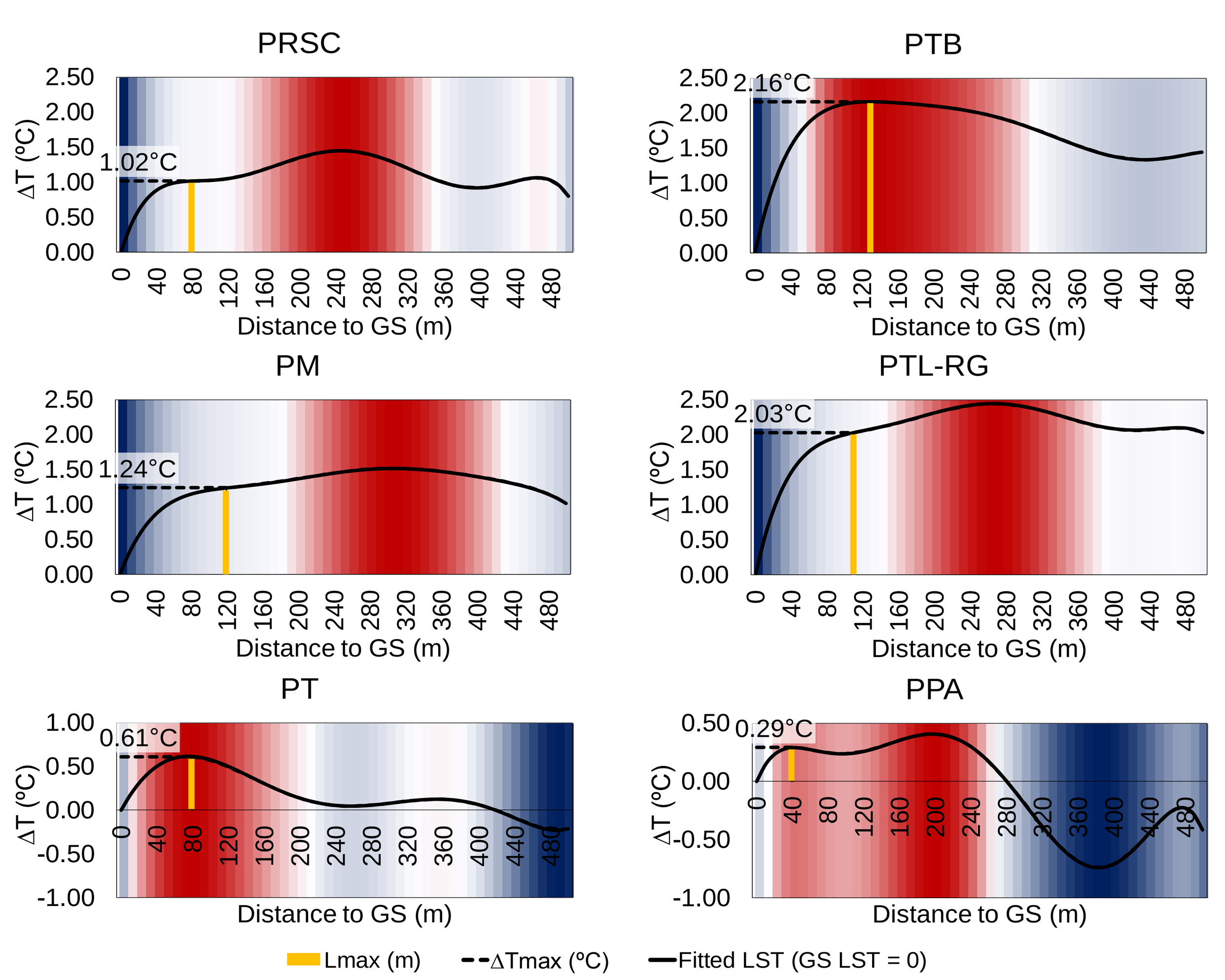
Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	37.577	0.009		4368.92	0.00
	Distance_to_UGS	0.018	0.000	0.352	201.79	0.00
	NDVI_10m	-7.293	0.029	-0.440	-252.50	0.00

a. Dependent variable: LST_urban

↑ **Table 4. Urban area model results.** Predictors of the urban model resulted in *p<0.01* significance. This model also pointed that the distance to UGS has less influence on LST than the NDVI. Particularly, it points that each 100m farther from a UGS, LST increase 1.81°C and a tenth higher of NDVI reduces 0.73°C.

6. Quantifying the cooling effect of the UGS

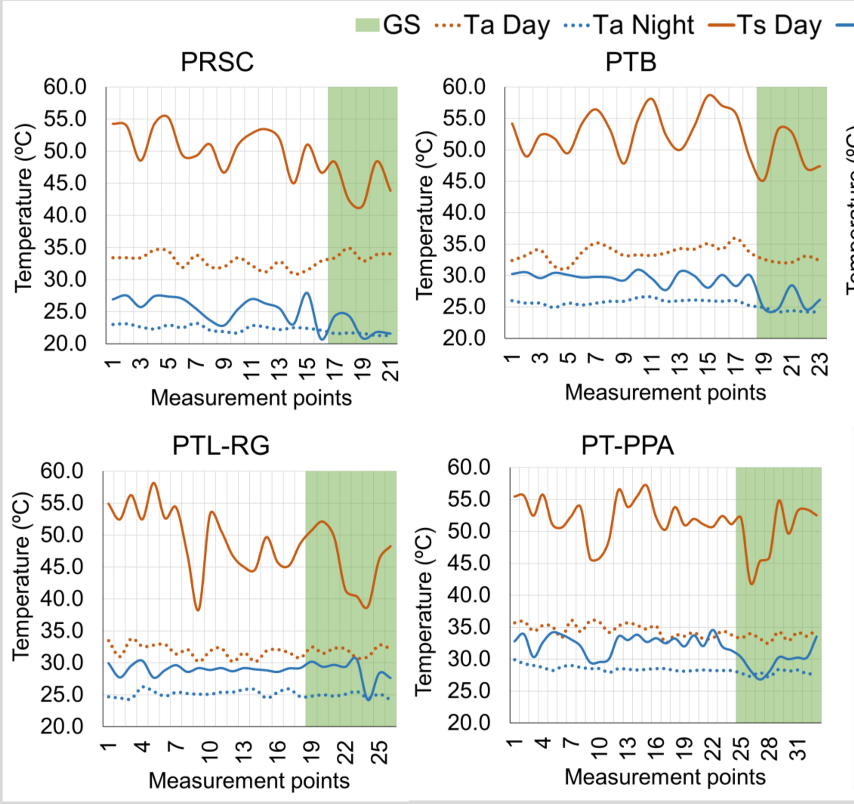


↑ **Fig. 9. Cooling effect calculation.** Figure shows six fitted LST series of the 50 concentric rings of each GS selected. PTL and RG cases are joined due to proximity. The seven cases resulted in positive cooling effect, which imply that the inner temperature of the GS is lower than their urban surroundings. Likewise, LST series behavior of the surroundings , pointed higher Lmax and ΔTmax in Viladecans and Gavà. It seems that higher LST in the urban context, promotes a stronger GSC.

	GS LST (ºC)	Lmax LST (ºC)	300m LST (ºC)	ΔT 300m (ºC)	Lmax (m)	ΔTmax (ºC)
PRSC	36.17	37.19	37.55	1.38	80	1.02
PTB	36.26	38.42	38.24	1.98	130	2.16
PTL - RG	36.79	38.81	39.1	2.31	110	2.03
PM	34.85	36.08	39.19	4.34	120	1.24
PT	35.15	35.76	35.35	0.20	80	0.61
PPA	34.71	35.00	35.35	0.64	40	0.29

← **Table 5. GSC indicators.** Mean LST of: the green space (GS LST), the extent limit ring (Lmax LST); and the 300m surrounding area (300m LST). The ΔT 300m = 300m LST – GS LST; Lmax is the extent limit shown in Fig.9; and ΔTmax = Lmax LST – GS LST.

7. GSC by field measurements



Urban - GS points	ΔT field measurements			
	Ta day	Ta night	Ts day	Ts night
PRSC	-1.08	0.99	6.01	3.01
PTB	1.23	1.43	4.07	3.97
PTL-RG	-0.08	0.34	3.82	0.33
PM	-0.13	0.63	1.04	3.14
PT	1.18	0.69	-0.73	1.25
PPA	0.90	0.74	6.24	4.52

↑ **Fig. 10. Field measurements of air and surface temperature during day and night, and table of cooling intensity between average value of points in the urban areas and GS.** Measurements in the microscale registered inconsistent behavior in relation to distance to the GS, as well as some average values of the urban surroundings resulted in lower values than the average temperatures inside the GS.

8. Summary of results

Results present a first look on the influence of the GS on the climate of urban and rural areas of this context and the interaction with their surroundings:

VGC area:

- Increasing 0.10 of NDVI reduces LST by 1.15°C in the VGC area and 0.73°C in the urban areas.
- For each 100m farther from GS, LST increase 0.61°C in the VGC area and 1.81°C in urban areas.

Cases of study:

- All cases of study resulted in positive GSC, Lmax between 40 to 130m and ΔTmax 0.29 to 2.15°C.
- Field data pointed positive cooling at all cases only in nocturnal Ta (max=1.43°C) and Ts (max=4.52°C).

9. Acknowledgements

This study is part of the project "Urban-CLIMPLAN. The urban heat island: effects on climate change and modeling for territorial and urban planning strategies. Application to the metropolitan region of Barcelona". Financed by the Ministry of Economy and Competitiveness of Spain (MINECO) and the European Regional Development Fund (ERDF).

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10. References

[1] U.S. Geological Survey (USGS). (2018). Image of Metropolitan Area of Barcelona, Spain at July 26 of 2018. Landsat-8 OLI/TIRS imagery.

[2] Copernicus Land Monitoring Service. (2016). Corine Land Cover 2012 Version 18.

[3] Artis, D. A., & Carnahan, W. H. (1982). Survey of emissivity variability in thermography of urban areas. Remote Sens. of Env., 12(4), 313-329.

[4] Sobrino, J., Jiménez-Muñoz, J., & Paolini, L.(2004). Land surface temperature retrieval from LANDSAT TM 5. Remote Sens. of Env., 90(4), 434-440.

[5] Stathopoulou, M., & Cartalis, C. (2007). Daytime urban heat islands from Landsat ETM+ and Corine land cover data: An application to major cities in Greece. Solar Energy, 358-368.

[6] Weier, J., & Herring, D. (2000). Measuring Vegetación (NDVI & EVI). NASA Earth Obs.

[7] Institut Cartogràfic i Geològic de Catalunya (ICGC). (2018). NDVI Àrea Metropolitana de Barcelona.

[8] Copernicus Open Access Hub. (2018). Image of Metropolitan Area of Barcelona, Spain at July 27 of 2018. Sentinel-2 Level-1C imagery.

[9] Du, H., Cai, W., Xu, Y., Wang, Z., Wang, Y., & Cai, Y. (2017). Quantifying the cool island effects of urban green spaces using remote sensing data. Urban Forestry & Urban Greening (27), 24-31.