# 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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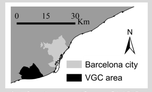
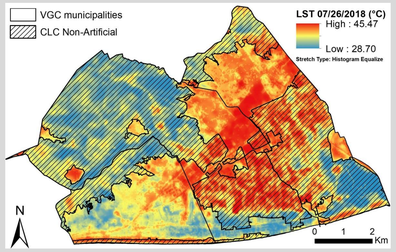
## 1. Introduction



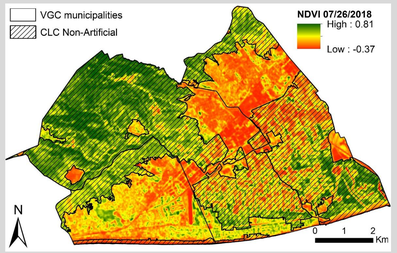

↑ Fig. 1. Location of VGC.

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.

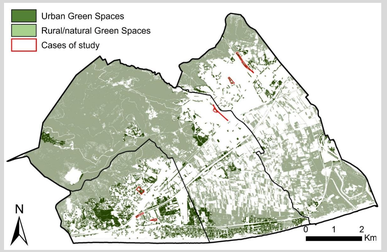
## 2. Data



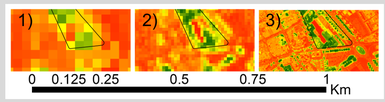

↑ Fig. 2. Land Surface Temperature (LST) from Landsat-8 of 07-26-2018 [1] **and Corine Land Cover (CLC) artificial surfaces** [2] **as urban areas**. LST retrieved from thermal-infrared 1 band (10) with the emissivity corrected LST equation [3] and surface emissivity derived from the NDVI threshold method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



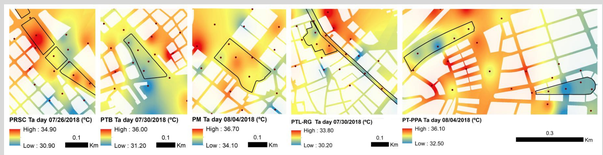

↑ Fig. 3. Normalized Difference Vegetation Index (NDVI) from Landsat-8 of 07-26-2018. The NDVI goes from -1 to +1, the lower the value the less the vegetation. It is calculated with the Top of Atmosphere (TOA) reflectance of near-infrared (NIR) and red bands [6] of Landsat-8 and Sentinel-2 imagery.



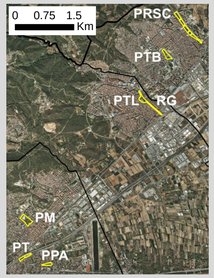

↑ Fig. 4. Green spaces (GS). Areas with more than 1,000m² of continuous 1m-cell NDVI ≥ 0.30. Value defined as the lower limit of vegetated areas by the regional administration [7].




↑ Fig. 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. 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.




↑ 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

## 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 ($\Delta T_{max}$) = $L_{max\ LST}$ – 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] | | | | | |
|---|---|---|---|---|---|
| | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| Model | | B | Std. Error | Beta | | |
| 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 |

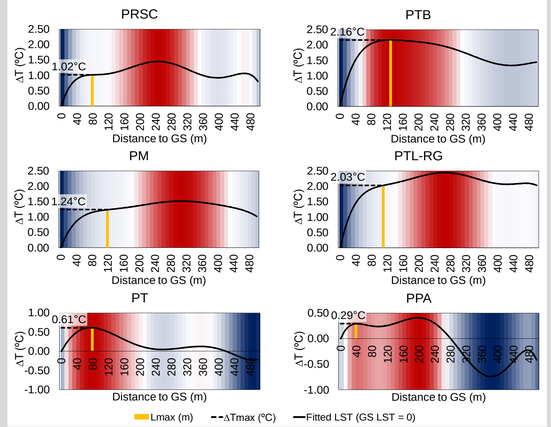
a. Predictors: (Constant), Distance_to_UGS, NDVI_10m

| Coefficients[a] | | | | | |
|---|---|---|---|---|---|
| | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
| Model | | B | Std. Error | Beta | | |
| 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

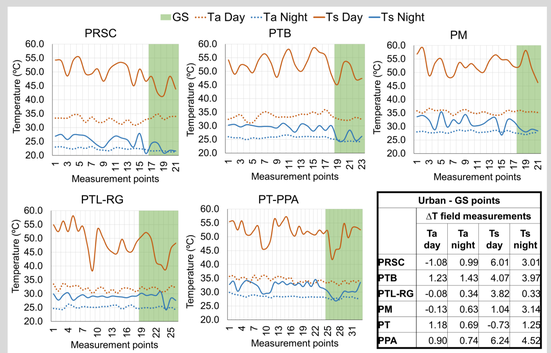



↑ **Fig. 9. Cooling effect calculation.** Figure shows six fitted LST series of the 50 concentric rings of each GS selected. PTL and RG cases are joined due to proximity. The seven cases resulted in positive cooling effect, which imply that the inner temperature of the GS is lower than their urban surroundings. 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 (°C) | Lmax LST (°C) | 300m LST (°C) | ΔT 300m (°C) | Lmax (m) | ΔTmax (°C) |
|---|---|---|---|---|---|---|
| **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).

European Union
European Regional Development Fund

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## 10. References

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