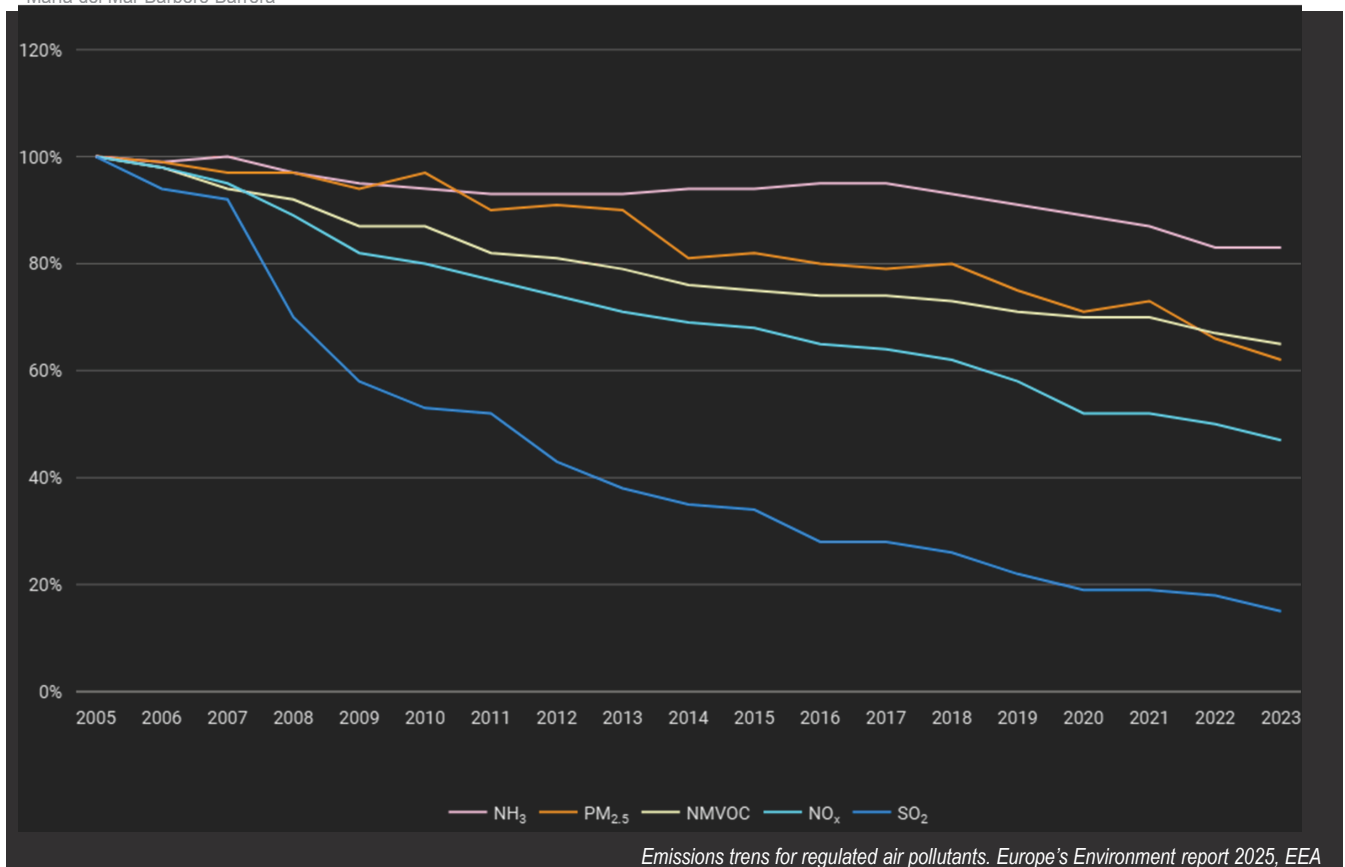


Consequences of the **climate change** on **indoor air quality** at **primary schools** in **Madrid**

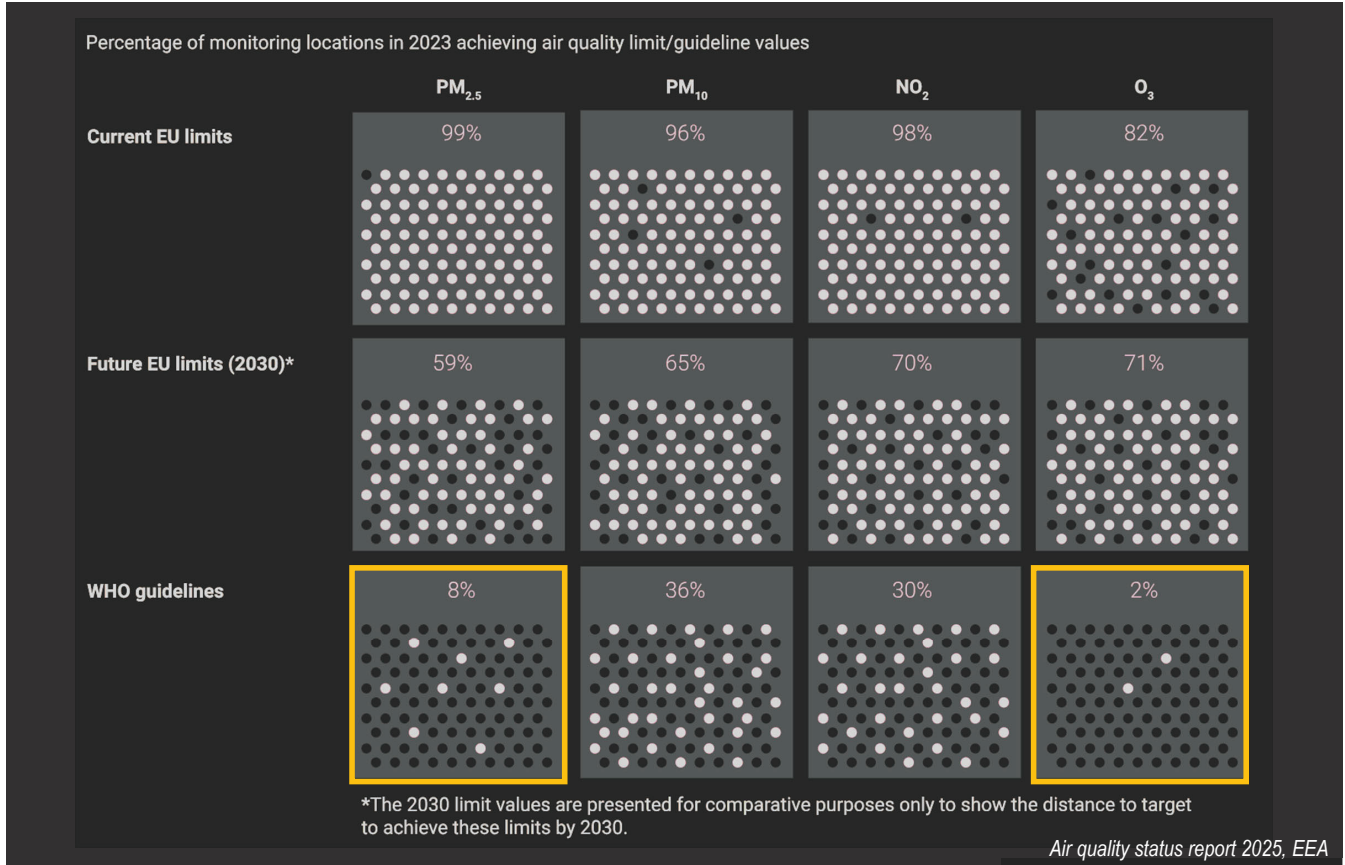
María del Mar Barbero Barrera
mar.barbero@upm.es



Consequences of climate change on IAQ at primary schools in Madrid
María del Mar Barbero Barrera



Emissions trends for regulated air pollutants. Europe's Environment report 2025, EEA

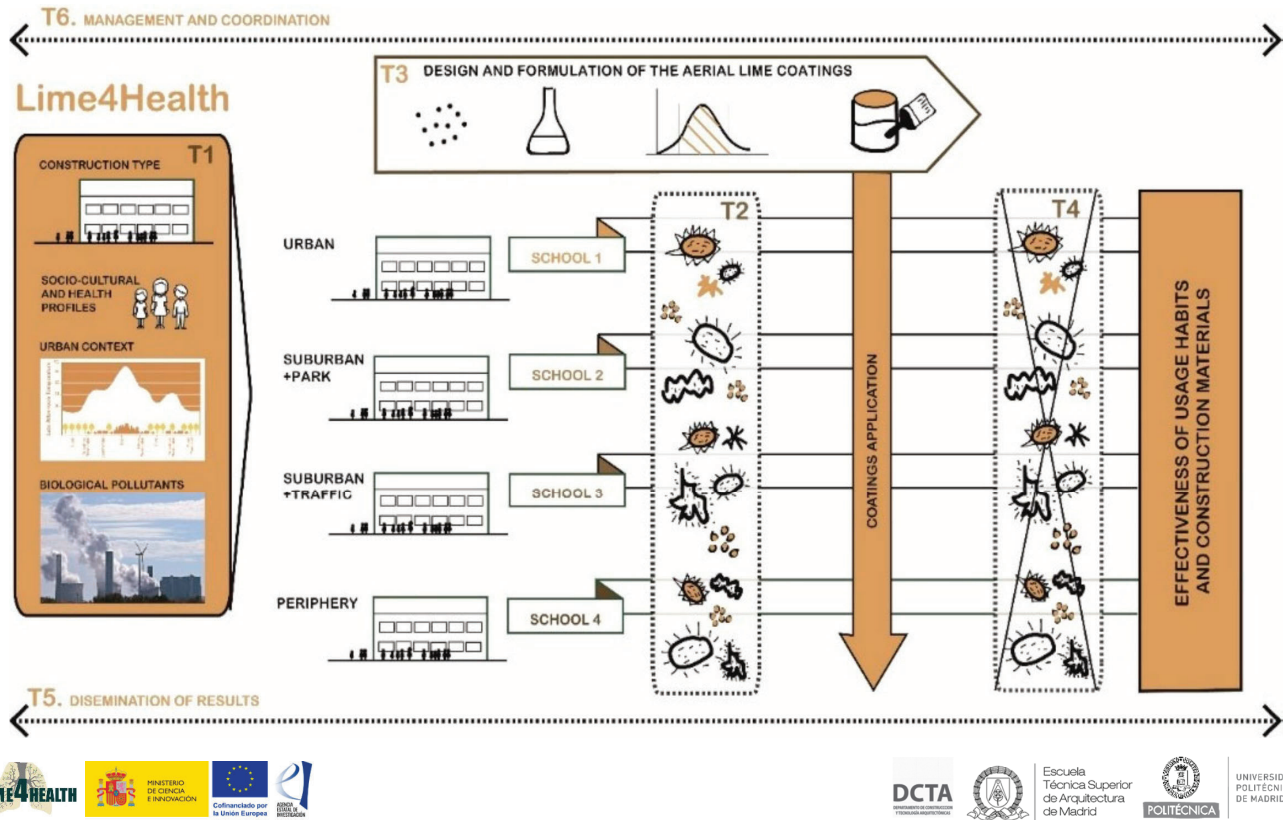


Children as one of the most vulnerable group of population:

- Lungs are not completely developed (under 12 years old)
- Higher breathing rate than adults
- Short stature



Lime4Health (PID2021-123023OA-I00) : Analysis of the contribution of aerial lime renders for the achievement of healthy indoor spaces



Urban context

Risk factors:

- altitude
- urban density and structure
- wind patterns
- green areas
- vegetation density
- high traffic stress
- industrial areas

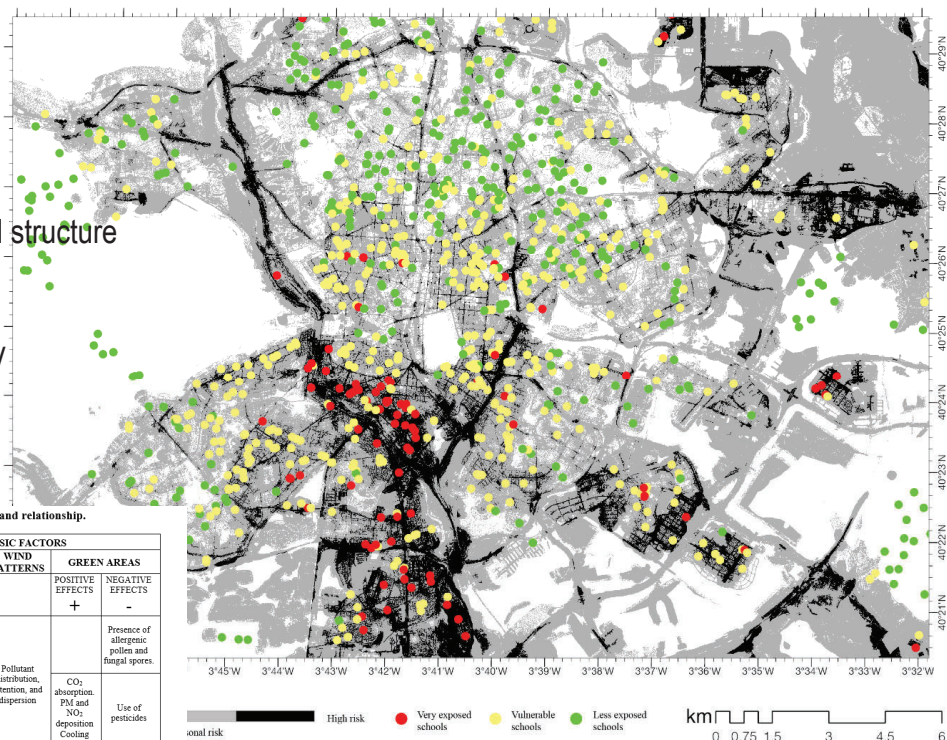


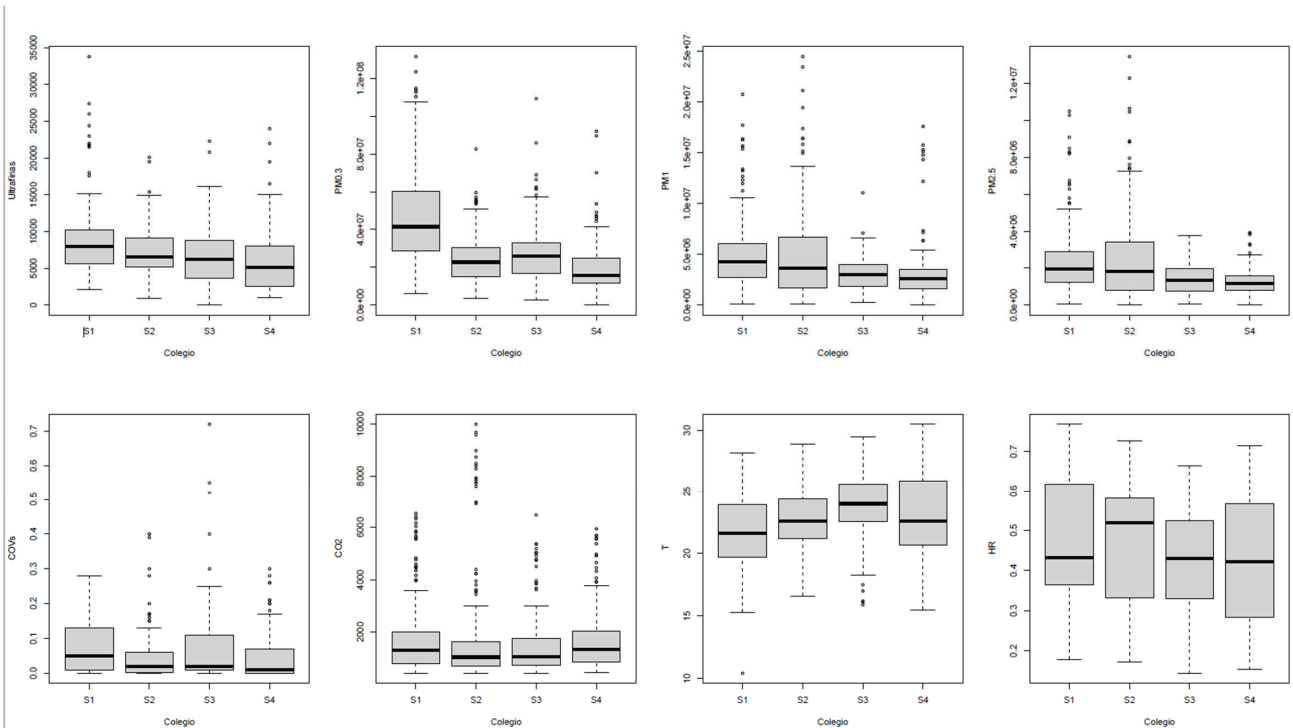
Table 2. Urban air quality extrinsic factors and relationship.

POLLUTANT	OUTDOOR AIR QUALITY EXTRINSIC FACTORS					
	SITE ALTITUDE		URBAN DENSITY		WIND PATTERNS	GREEN AREAS
	POSITIVE EFFECTS	NEGATIVE EFFECTS	POSITIVE EFFECTS	NEGATIVE EFFECTS	POSITIVE EFFECTS	NEGATIVE EFFECTS
BIOTIC	+	-	+	-	+	-
ABIOTIC	Better pollutant dispersion in high altitudes.	Higher exposure to pollution in high altitudes.	Less car dependence and less emissions in denser cities.	Higher concentration and worse pollutant dispersion in denser areas.	Pollutant distribution, retention, and dispersion.	Presence of allergenic pollen and fungal spores.
	Strong solar radiation can form secondary pollutants through photochemical reactions.				CO ₂ absorption, PM and NO ₂ deposition	Use of pesticides
					Global effect	

Waidler-Heiseke, M.; Galindo Ortiz, S.; Sánchez-Reyes, E.; Barbero-Barrera, M.M. (2025). Urban Air Quality Factors that Affect Children's Health. Springer Nature. In: Socio-Ecological Resilience and Sustainable Quality of Life: 187-214.

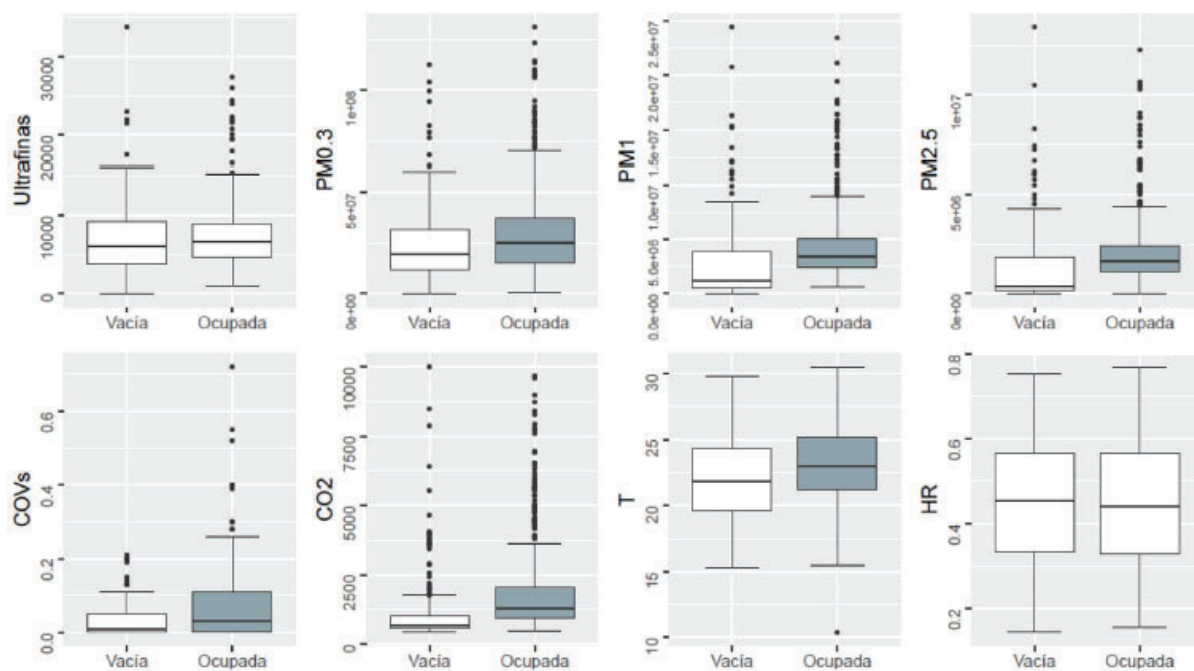


Holgate et al 2016



Pérez-Moneo, B.; Aparicio-Rodrigo, M.; Redondas Marrero, M.D.; Sabariego Moreno, K.; Barbero-Barrera, M.M. (2025). Description of the air quality and environmental characteristics at classrooms of primary schools in the Community of Madrid. *Anales de Pediatría*: 503792





Differences in the level of pollutants between **empty and occupied rooms**, grouped for all campaigns, measurements and schools. PM in part/m³ and COV (VOC) in ppm. When box is coloured, the result is significant

Pérez-Moneo et al 2025



Percentage of measures in each campaign (2023) in which the values are over the threshold

Parameter (threshold)	Room occupied	feb-23	abr-23	may-23	oct-23	dic-23
PM 2,5 (µg/m ³) (15 µg/m ³)	Empty	*	*	*	40.32	55.00
	Occupied	*	*	*	62.07	72.22
CO ₂ (ppm) (1200ppm)	Empty	13,89	4,60	46,5	13,04	46,42
	Occupied	52,17	4,15	70,37	44,53	90,27
CO ₂ (ppm) (700ppm)#	Empty	30,55	18,60	51,16	36,96	67,86
	Occupied	84,06	75,42	80,56	86,55	97,22
COV (ppb) (120 ppb)	Empty	^	13,95	9,30	^	0,29
	Occupied	^	41,52	19,44	^	0,47

PM: particulate matter; ppm; COV: volatile organic compound; ppb
 * Missing data due to measurement in units without described reference values.
 ^ Missing data for technical failure in the device.
 # Recommended by the Environmental Health Committee at AEP (Paediatrics Spanish Association)

Pérez-Moneo et al 2025




Variable	VOC	Ultrafine	PM0.3	PM2.5	CO ₂
Temperature	0.04	0.02	0.07	0.17	0.09
Relative humidity	-	0.83	2.14	2.44	2.63
Door	-0.47	0.13	-	-	-0.13
Window	-0.20	0.17	-	-	-0.17
VOC activity	0.37	-	-	-	0.08
PM activity	-	-	-	-	0.09
Occupation	0.25	-	0.09	0.58	0.29
R ² (%)	46	28	49	43	66

Calama-González, C.M.; Redondas Marrero, M.D.; Sabariego Moreno, K.; Barbero-Barrera, M.M. (2025). Statistical correlation analysis on indoor air high priority pollutants in Spanish public primary schools. Journal of Building Engineering 101: 111810



Additional number of days per year with high to extreme fire danger for three global warming scenarios

Spain's sees worst wildfire season since 1994 with 382,000 hectares burned so far in 2025



Date Published: 29/01/2026

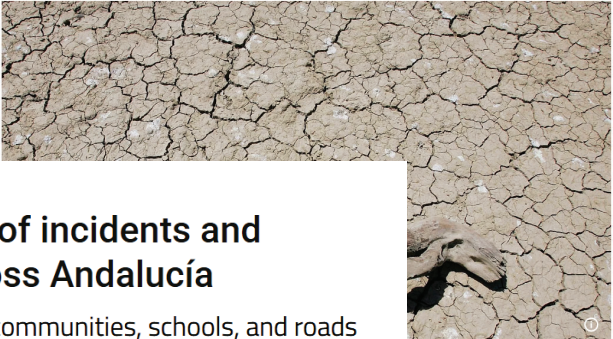
Storms cause thousands of incidents and ongoing evacuations across Andalucía

Strong winds and heavy rain disrupt communities, schools, and roads across the region

By Javier Iniguez De Onzono & Euronews en español
 Published on 21/08/2025 - 9:50 GMT+2

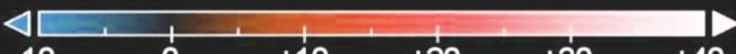
[Comments](#)

How flash droughts driven by climate change sparked record wildfires in Spain



These sudden, intense droughts accelerate vegetation drying, increasing wildfire risks across vulnerable regions.

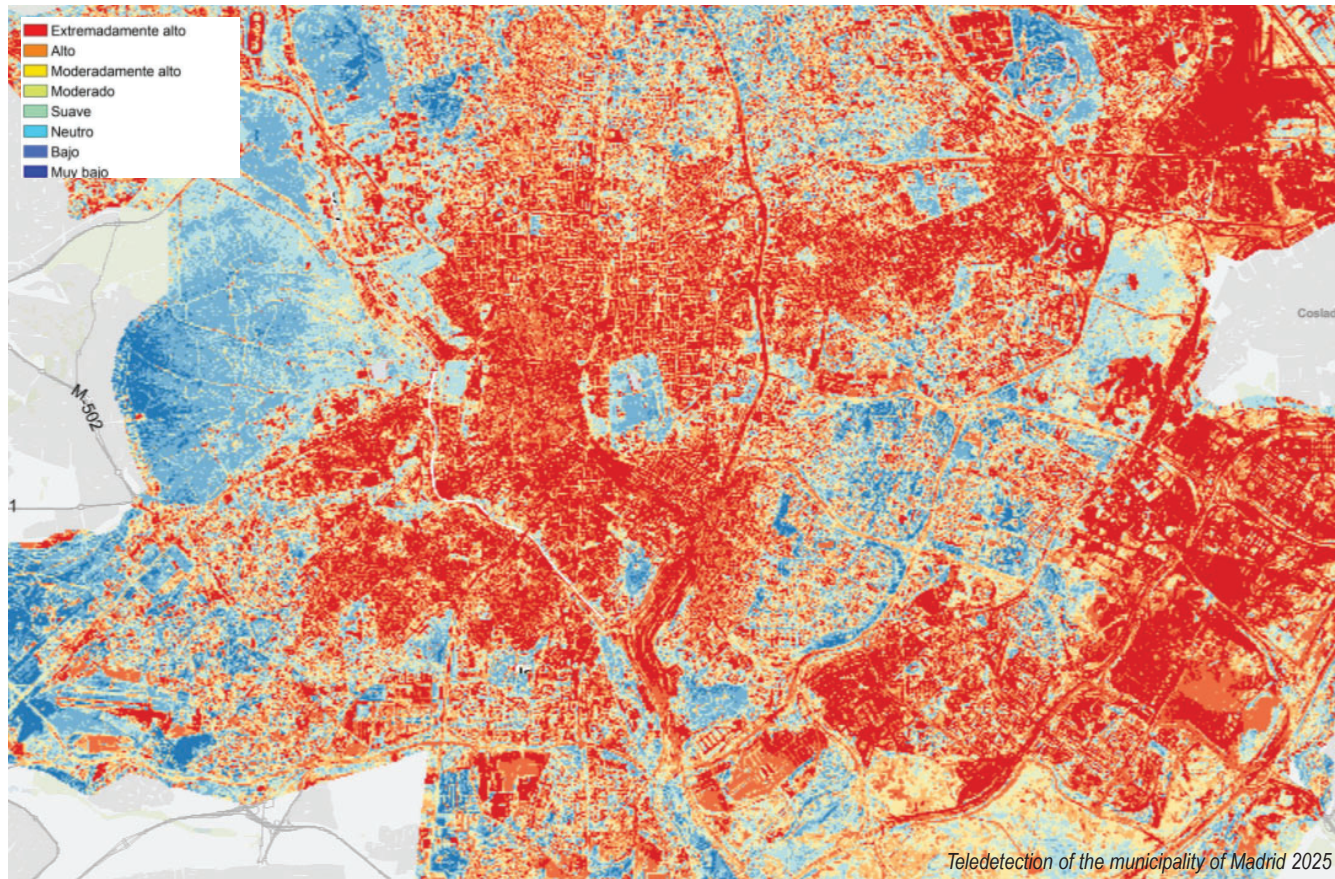
[Comments](#)



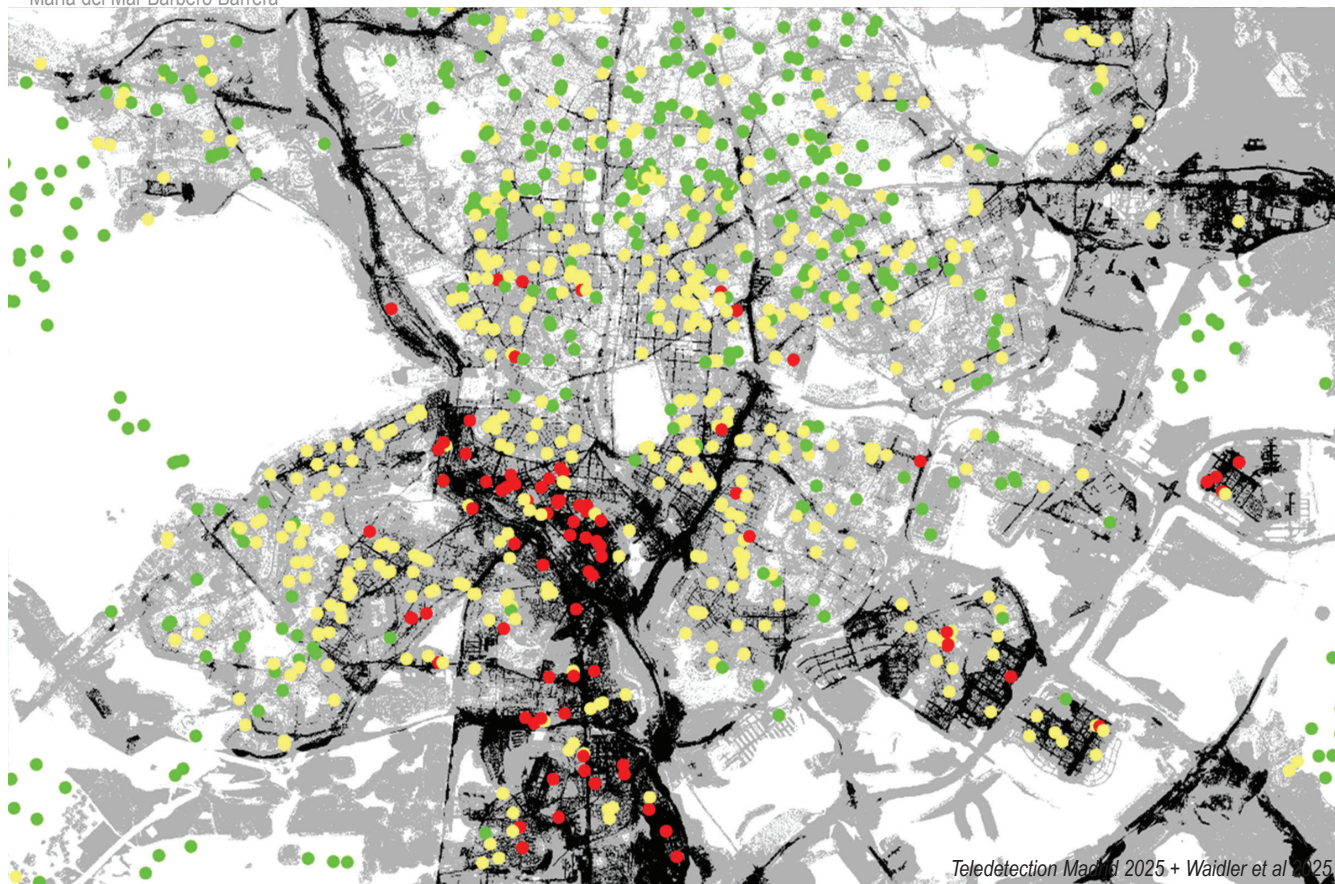
Days per year: -10 0 +10 +20 +30 +40 days and more

Climate.copernicus.eu/spain. Joint Research Centre (EC)





Teledetection of the municipality of Madrid 2025



Teledetection Madrid 2025 + Waidler et al 2025



Building simulation under 2050 climatic context

Tools:

- CCCWeatherGen tool from University of Southampton
- TeKton3D
- Four scenarios:
 - Current situation
 - Improvement of the thermal envelope of the buildings by ETICS
 - Solar control and reduction of the solar factor of glazings
 - Mechanical ventilation with heat recovery

Results:

- Heating demand reductions +60%
- Cooling demands increases +80% and out-of-setpoint hours increase +40%

Balanced year-round comfort approach

Passive solar control and ventilation are essential for mitigating overheating

Rodríguez-González, V.; Barbero-Barrera, M.M. (2025). Energy performance and thermal comfort in Madrid school buildings under climate change scenarios. Applied Science 15: 9980



Conclusions

- Placement of schools must be selected attending to risk factors
 - IAQ schools must be substantially improved
 - Climate change:
 - Increase cooling demand +80% and out-of-setpoint hours +40%
 - Increase of VOCs by higher temperatures
 - Increase of PM by wildfires or droughts
 - Change or increase the type of outdoor airborne (pollen)
 - Increase PM2.5 concentration indoors
- Changes in the user's habits adapting them to the new circumstances.
→ Need of continuous monitoring



M.Mar Barbero-Barrera (coord.) Luis Alou-Cervera; Isabella Anessi-Maesano; José Ramón Aira-Zunzunegui; María Aparicio-Rodrigo; Carmen M. Calama González; Elena Cerro-Prada; Elena Cuerda-Barcaiztegui; Gloria M. Gómez-Muñoz; Ester Higuera-García; F. Javier Neila-González; M. Esther Moreno-Fernández; Begoña Pérez-Moneo Agapito; M. Dolores Redondas-Marrero; Javier M. Rey-Hernández; Violeta Rodríguez-González; Kevin Sabariego-Moreno; Estefanía Sánchez-Reyes; David Sevillano-Fernández + degree students

Coord.



Health services:



Universities:



Collaboration:



UNIVERSIDAD DE MÁLAGA



in-SiEqES 2026

June 11th & 12th

International Symposium of
Environmental Quality in Educational Spaces

<https://eventos.upm.es/go/insieques>

