

How Much Can Urban Green Infrastructure Reduce CO_2 levels? A Case Study of the Metropolitan Area of Barcelona

Qing Luo

Autonomous University of Barcelona

October 28th, 2026

sostenipra URBAG ICTA-UAB Institute of Environmental Science and Technology UAB Universitat Autònoma de Barcelona AGAUR Agència de Gestió d'Ajuts Universitaris i de Recerca Generalitat de Catalunya Departament de Recerca i Universitats Cofinançat per la Unió Europea

1.Background

Green infrastructure(GI): a network of (semi-)natural are
which are protected and enhanced to deliver ecosystem
while also benefiting biodiversity and society more widely.

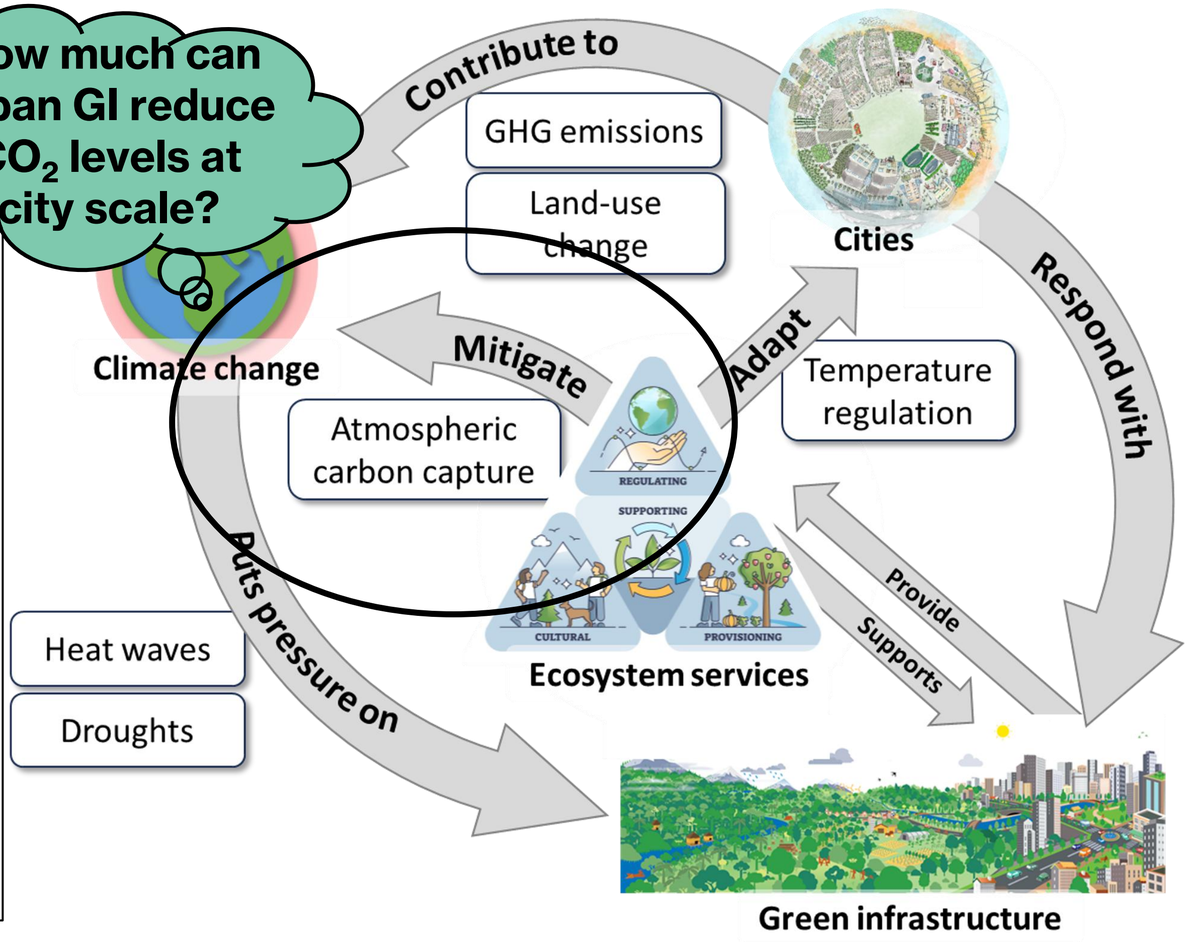




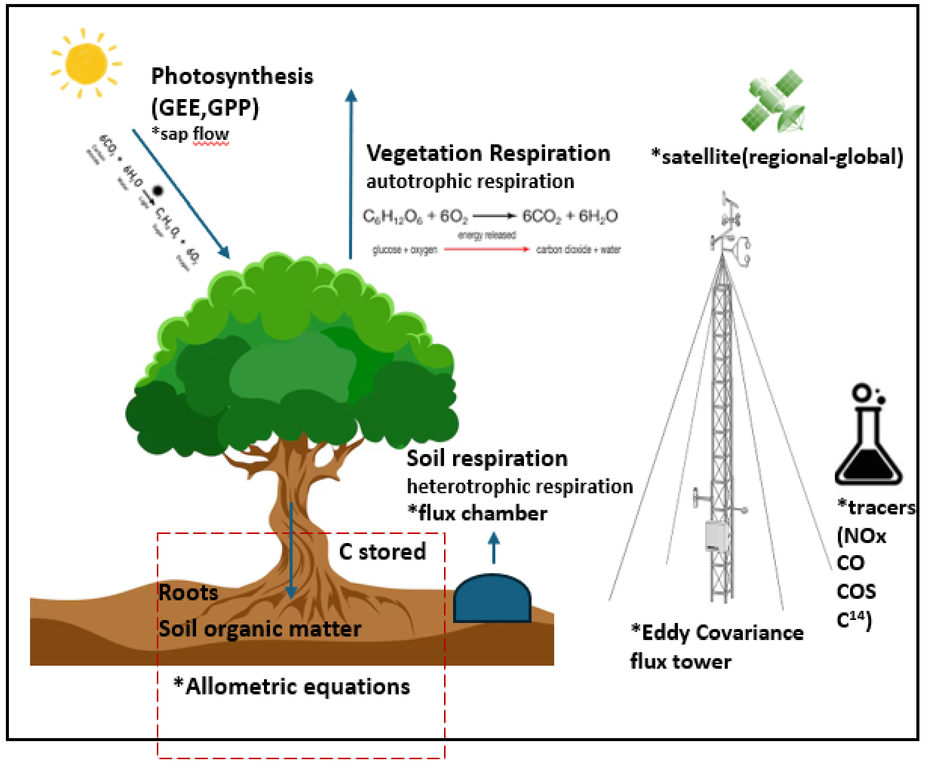




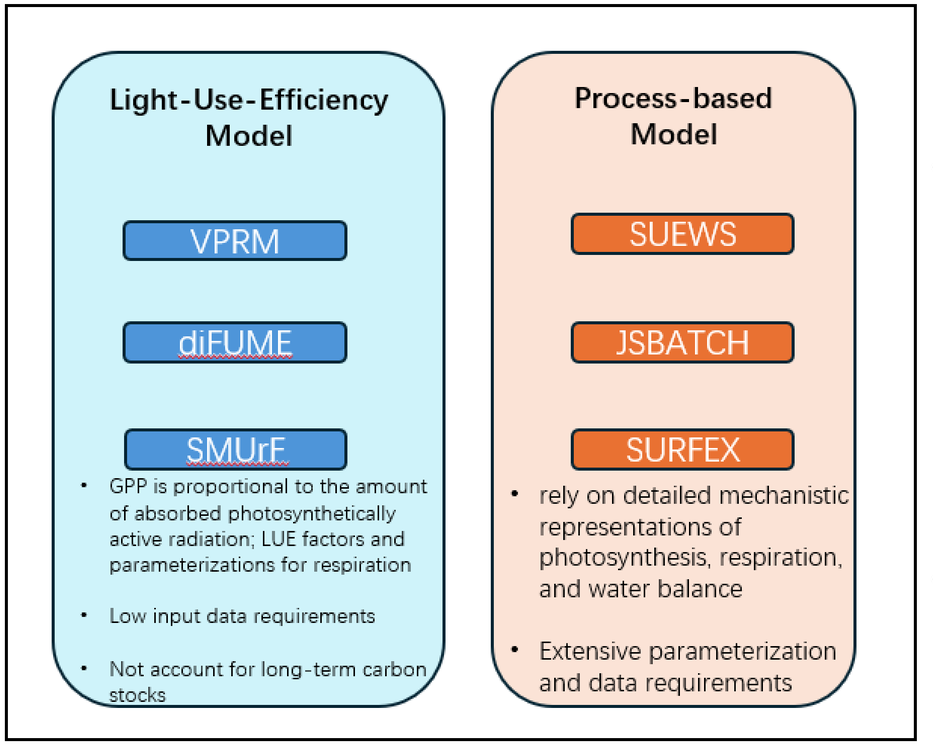




How to quantify the CO_2 exchange from GI of a city?



Measurements



Modelling Approaches

- Quantify the CO_2 exchange between urban ecosystem and atmosphere (i.e. biogenic CO_2 fluxes) at the urban scale is critical and challenging
- Urban heterogeneous landscape complicates the quantification

Research Questions

To assess the carbon-mitigation potential of urban GI (sink or source?), we need a high-resolution estimate of biogenic CO_2 fluxes

1) How to provide an accessible framework for producing initial and robust high-resolution estimates of urban biogenic CO_2 fluxes across metropolitan area?

- Default Vegetation Photosynthesis and Respiration model (VPRM) normally combined with MODIS satellite data (500m)

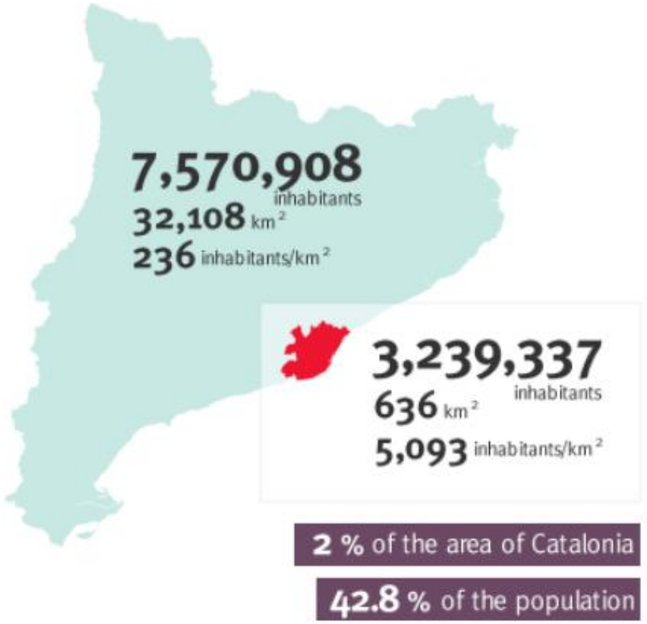
->A modified VPRM framework incorporating an explicit soil-moisture constraint to estimate biogenic CO_2 fluxes at 10m

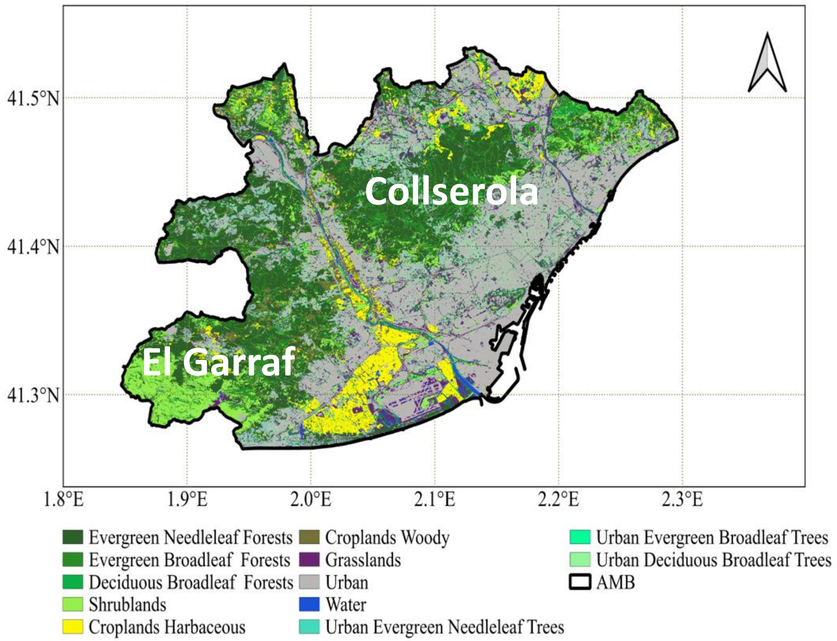
2) How does GI coverage relate to biogenic CO_2 uptake effect?

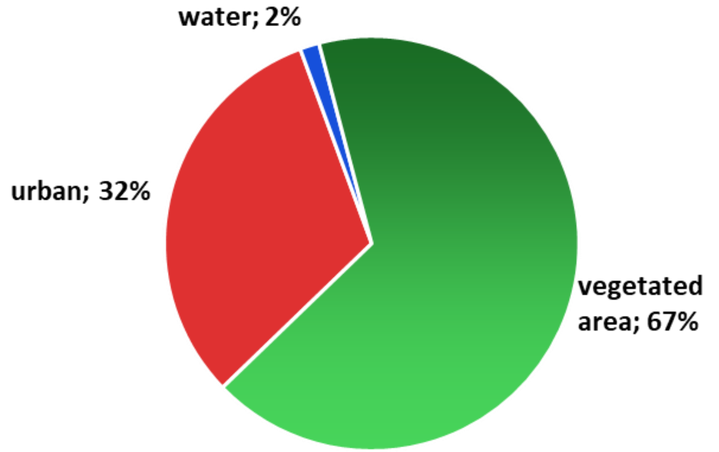
- Compare our results with published estimates from 12 other cities.

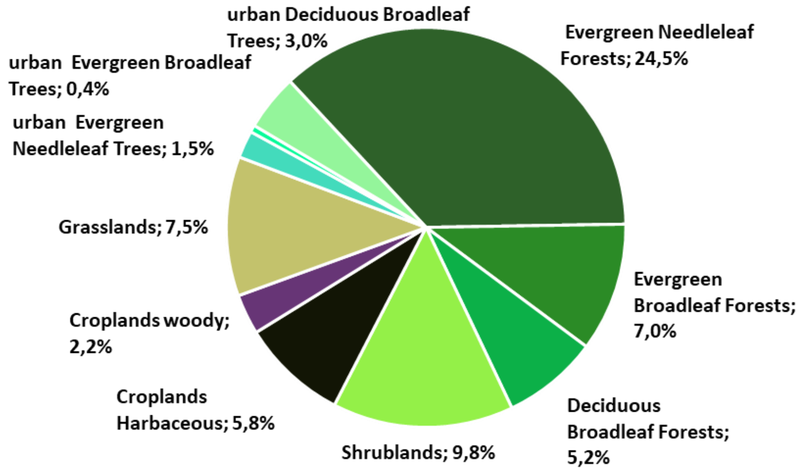
->Explore how GI coverage relates to carbon-offset efficiency

Metropolitan Area of Barcelona(AMB)





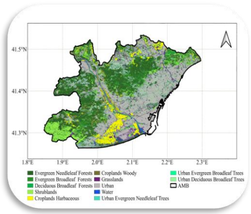




AMB; Metropolitan Urban Master Plan

2.Case Study_Methodology for estimating biogenic CO_2 fluxes

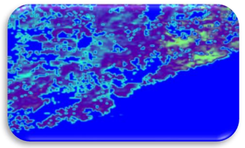
INPUT



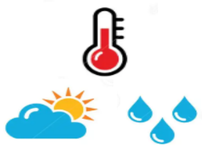
Land Cover



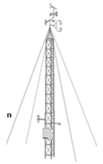
sentinel2(S2)



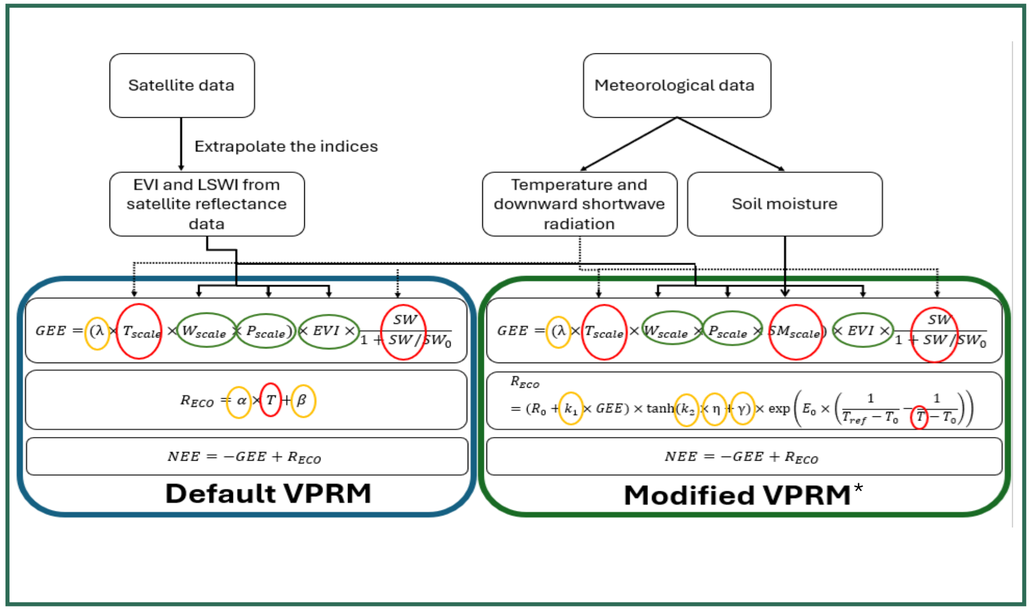
Vegetation indexes (10m)



Meteorological data



Eddy Covariance Tower*

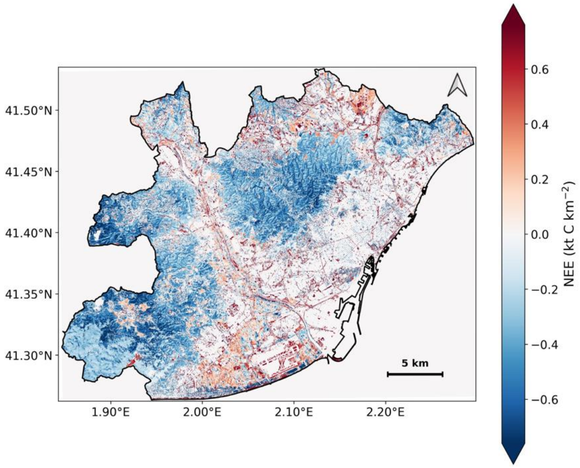


Output

Gross ecosystem exchange (GEE)

Ecosystem respiration (RES)

Net ecosystem exchange (NEE)

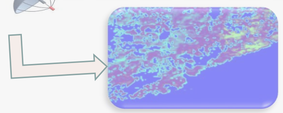


Segura-Barrero et al., 2025: Heat and Drought Events Alter Biogenic Capacity to Balance CO2 Budget in South-Western Europe. Glob. Biogeochem. Cycles, 39, e2024GB008163, https://doi.org/10.1029/2024GB008163

2. Case Study_Methodology for quantifying biogenic CO_2 offset

INPUT

EMISSION



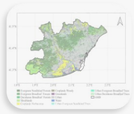
Vegetation indexes

Biogenic CO_2 fluxes



Meteorological data (WRF)

Vegetation Photosynthesis and Respiration Model (VPRM)



Land Cover

calculate biosphere's gross primary production and respiration



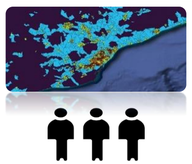
Anthropogenic emission inventory datasets

Local Inventory from BSC

Anthropogenic CO_2 emission

High-Elective Resolution Modelling Emission System(HERMES)

Python-based and multi-scale modelling tool for the processing and computation of atmospheric emissions for air quality and greenhouse modelling



Population density map

Emission factor

Human Respiration

Biogenic Offset

$$= \frac{Biogenic\ CO_2\ \text{fluxes}}{Anthropogenic\ CO_2\ emissions} \times 100\%$$

2. Case Study_Methodology for cross-city comparison

1. Literature review

Studies from the past 20 years

2. Select cities

12 cities with available reported data

3. Classify methods

Three main modelling approaches

- Allometric equations, growth rates and soil respiration models
- Process-based models
- LUE models

4. Harmonize spatial scale

Three hierarchical urban-domain scales

- Neighborhood: 0.1-10km^2
- City:10–300 km^2
- Metropolitan: >300 km^2

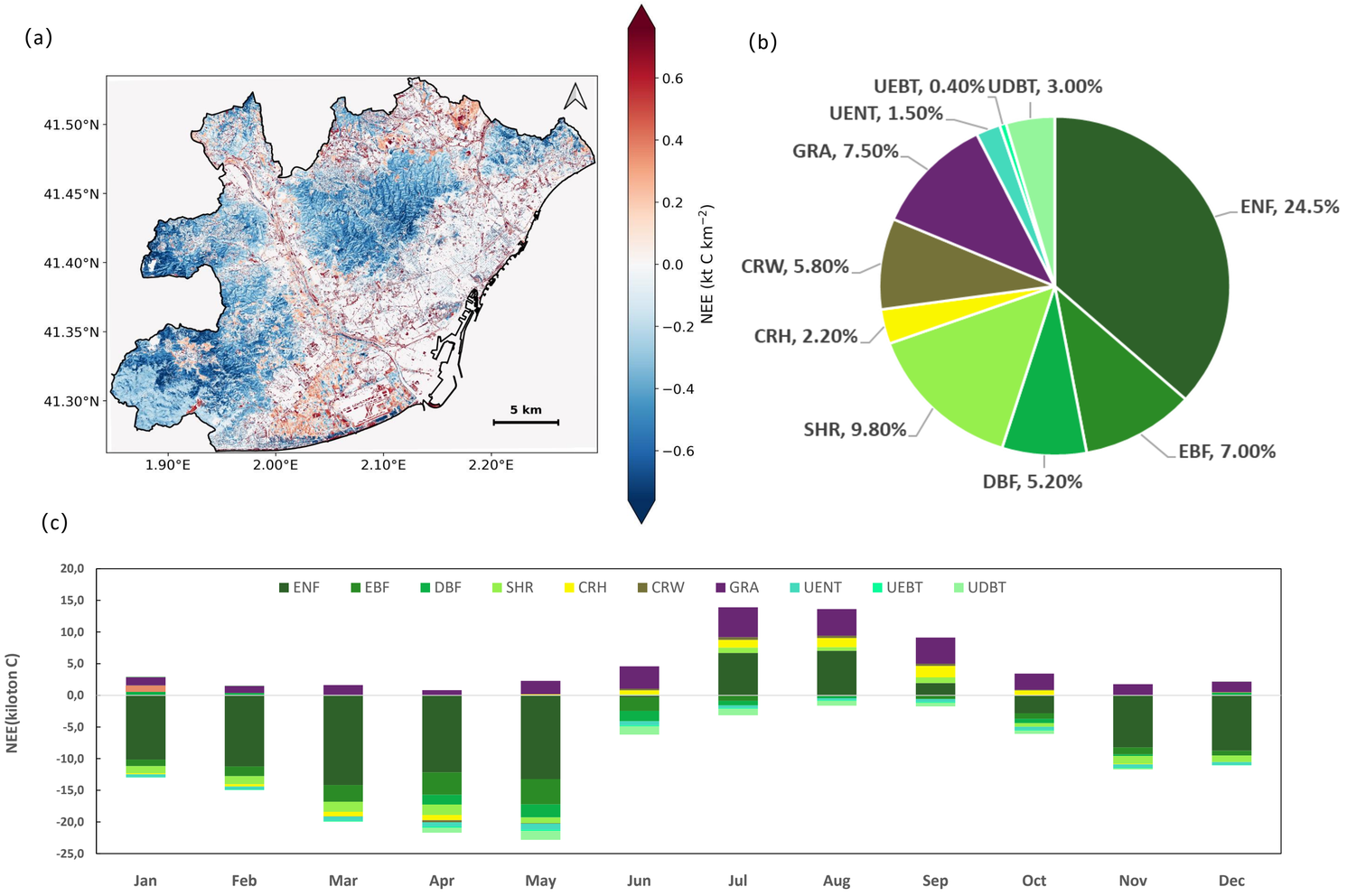
5. Characterize urban greenery

Use each study's reported greenery coverage

6. Compare across cities

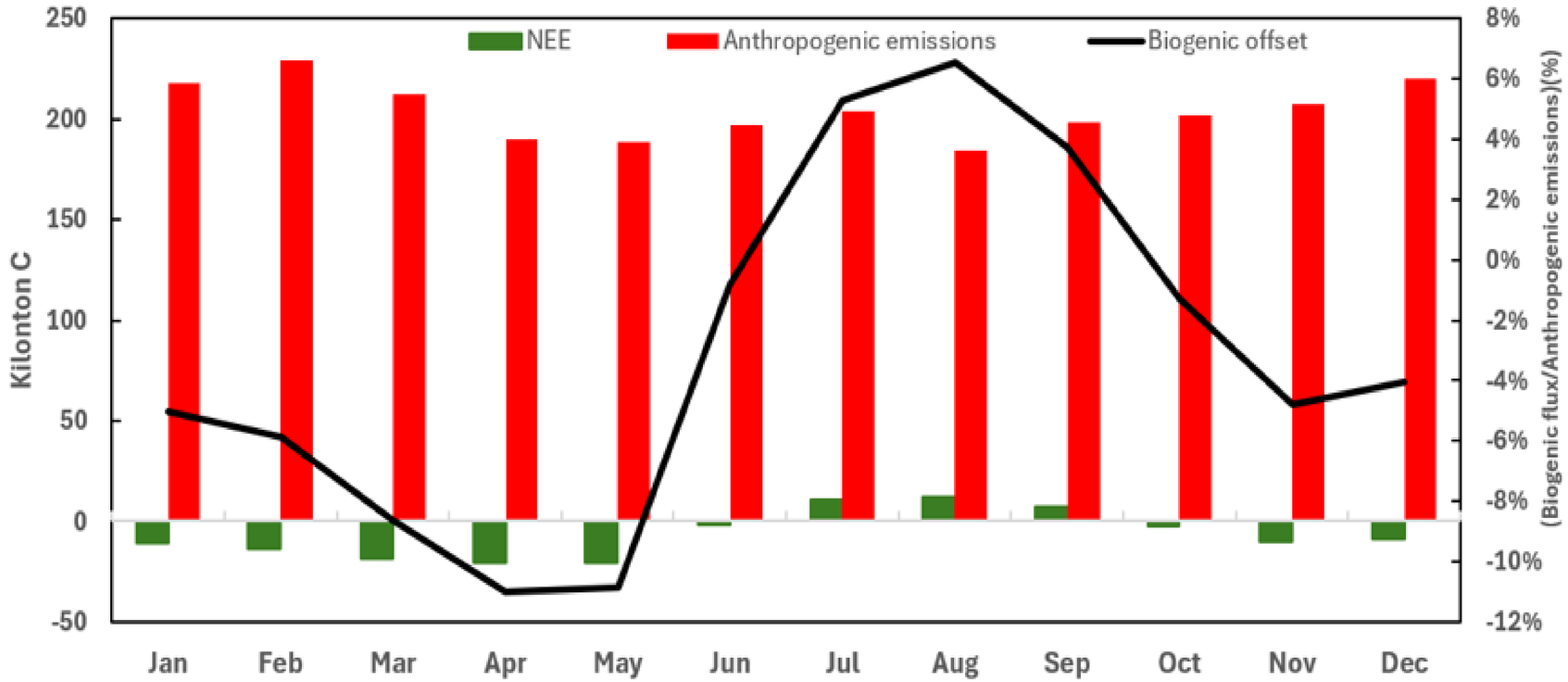
Greenery coverage vs. biogenic CO_2 offset

3.Results_biogenic CO_2 fluxes of AMB



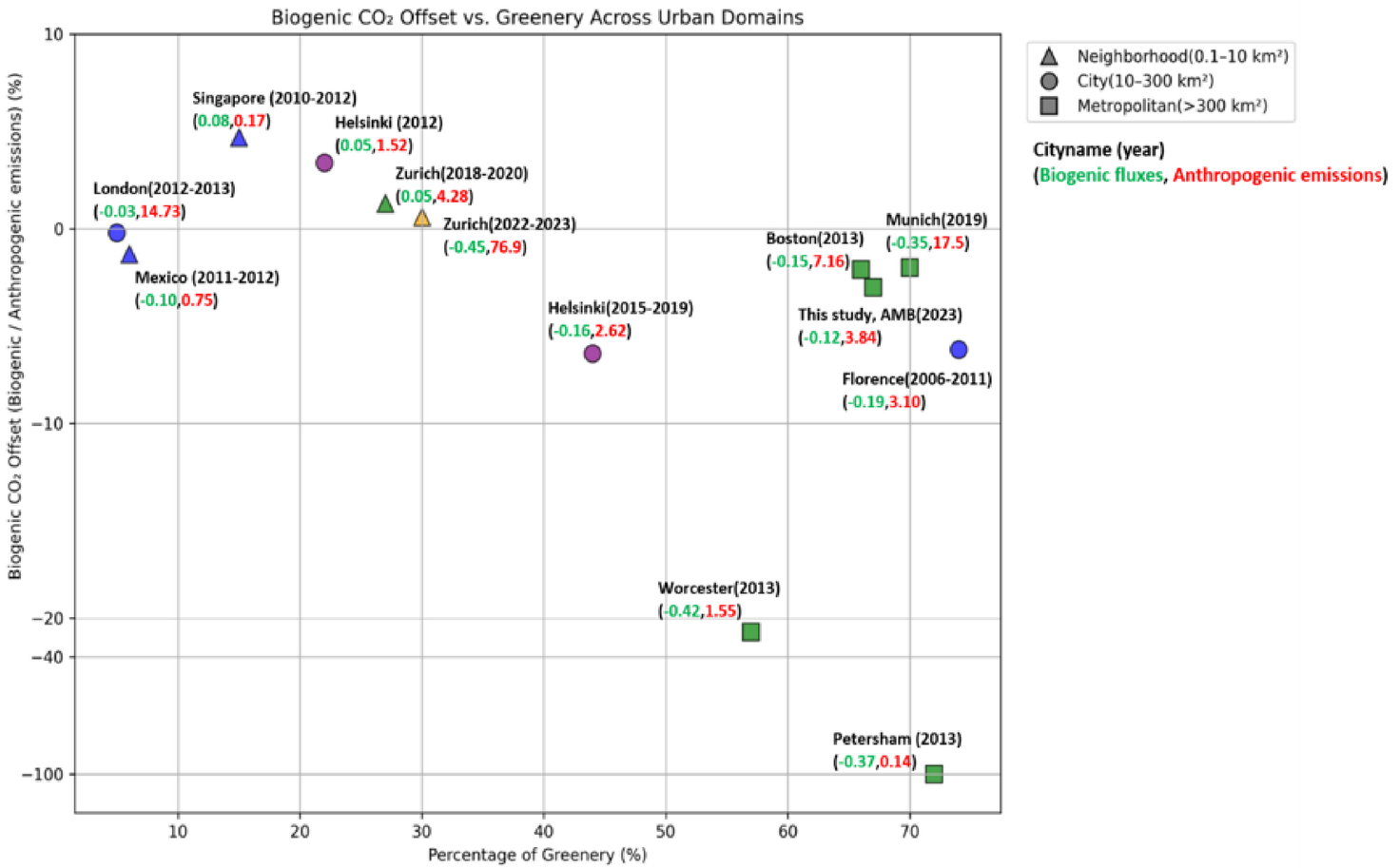
- Year: 2023
- GI (67% of the AMB) produced an annual biogenic CO_2 fluxes of −77 kt C.
- Evergreen needleleaf forests (ENF), covering 24.5% of the study area, are the largest carbon sink with annual NEE of −65 kt C
- Grasslands are a net carbon source year-round (29 kt C), while croplands act as a net source in summer and a moderate sink the rest of the year, for a net annual source of 5 kt C

3.Results_biogenic CO_2 offset of AMB



- During the peak growing season (April–May), biogenic CO_2 offset approximately 11% of anthropogenic emissions; in August, by contrast, biogenic fluxes added a further 7%.
- In AMB, biogenic component offset around 3% of anthropogenic emissions annually.
- The offset effect of urban GI is strongly seasonal, and vegetation can act as either a carbon sink or a carbon source depending on the time of year.

3.Results_cross city comparison



- Biogenic offset does not increase linearly with vegetation coverage.
- The need for strategic, standardized spatial planning to maximize urban climate mitigation.

4.Takeaways

To assess the carbon-mitigation potential of urban GI:

1) We provide an accessible framework for producing initial and robust high-resolution estimates of urban biogenic CO_2 fluxes across metropolitan area.

- In AMB, biogenic component offset around 3% of anthropogenic emissions in 2023.
- Evergreen needleleaf forests are the dominant regional carbon sink, while grasslands and summer croplands are CO_2 sources. Protecting existing high-performance ecosystems is likely more effective than implementing new, low-density green spaces like grasslands.

2) We assessed how GI coverage relates to biogenic CO_2 uptake effect.

- Increased vegetation cover alone does not necessarily yield a proportionally stronger urban carbon sink; ecosystem functioning, vegetation health, and site-specific conditions are critical determinants of biogenic CO_2 uptake.
- Cities should adopt standardized frameworks for accounting for biogenic CO_2 fluxes and uptake

Luo et al., 2026: High-resolution accounting of CO_2 fluxes and uptake by green infrastructure to support metropolitan planning. Urban Forestry and Urban Greening. Under review

5.Limitations

- Uncertainties arise from both model parameterization and input data. Its application to other cities should carefully consider differences in land-use composition and ecosystem characteristics.

- In this study only 13 cities are compared given the limited availability of comparable data, which is insufficient to support a statistical conclusion. Future research should try to adopt standardized framework for accounting for biogenic CO_2 fluxes and uptake.

Thank you!

Qing.Luo@uab.cat

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World Green Infrastructure Congress