Carbon sinks of urban green in a warming Nordic city

Minttu Havu[1], Liisa Kulmala[2,3], and Leena Järvi[1,4]
[1]INAR /Physics, University of Helsinki, Helsinki, Finland
[2]FMI, Helsinki, Finland
[3]INAR /Forest, University of Helsinki, Helsinki, Finland
[4]HELSUS, University of Helsinki, Helsinki, Finland

Introduction

- Carbon sinks in urban green compensate part of cities anthropogenic emissions
- Cities climate action plans benefit from the aims to maintain or increase these carbon sinks
- Urban green infrastructure has other environmental benefits such as heat mitigation
- Currently, cities estimate their sinks based on tree biomass growth and largely ignore other vegetation and emissions from soils
  - Useful for estimating carbon stocks in urban vegetation, but lack the possibility to assess the effects of climate change on future sinks
- Aims of this study:
  - Estimate the magnitude and spatial variability of local temperatures and biogenic CO_2 exchange in the city of Helsinki, Finland
  - Study the effect of the warming climate on carbon sinks

Methods

- Surface Urban Energy and Water balance Scheme (SUEWS) simulates local 2 m air temperature[4] and CO_2 exchange that includes both biogenic components and local anthropogenic emissions[2]
- Two different simulations covering minimum of one year with hourly resolution conducted:
  1) current weather conditions in 2015-2019
  2) future climate according to temperatures in RCP8.5 for 2050s[3]
- Simulated grids classified into Local Climate Zones[1] (LCZ, Fig 1a)

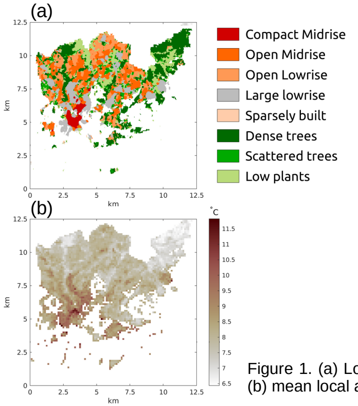

Figure 1. (a) Local Climate Zones in Helsinki[1] and (b) mean local air temperatures for 2015-2019

BIOGENIC CO_2 EXCHANGE

Respiration
depends exponentially on
Simulated local 2 m air temperature

The CO_2 uptake
modelled with canopy conductance model where uptake depends on
Leaf area index
Solar radiation
Air temperature
Specific humidity
Soil moisture

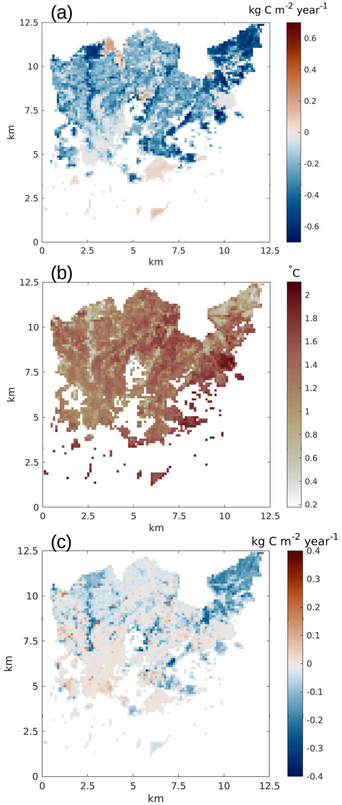

Figure 2. (a) Biogenic CO_2 exchange for 2015-2019, and change between the RCP8.5 scenario and current climate for (b) local air temperatures, and (c) biogenic CO_2 exchange

Urban forests uptake
0.4 kg C m^{-2} $year^{-1}$

Suburbs uptake
50% less per m^2 than urban forests

Urban neighbourhoods
contribute for 44% of Helsinki's carbon sinks

Local temperatures
higher in city centre than in urban forests by 5 °C

Expected increase
in temperatures 1.5 °C for urban neighbourhoods

Urban forest uptake
expected to get stronger by 0.1 kg C m^{-2} $year^{-1}$

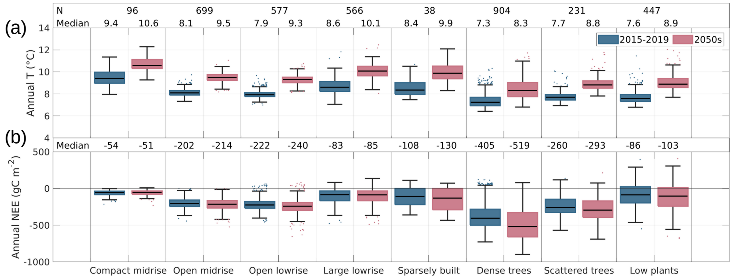

Figure 3. (a) Annual local air temperatures, and (b) biogenic CO_2 exchange (NEE) for each grid divided into LCZ separately for 2015-2019 and 2050s

Results

- Simulated local 2 m air temperature varies in Helsinki due to 1) anthropogenic heating and 2) evapotranspirative cooling by vegetative surfaces (Fig 1b). Streets are expected to heat the most due to paved areas and human activity. Parks can get colder, because irrigation increases the amount of evapotranspiration
- Local temperatures and biogenic CO_2 exchanges differ between LCZ classes
  - Temperatures are expected to rise by 1.5 °C in urban neighbourhoods and 1 °C in urban forests (Fig 2b, 3a)
  - Dense urban forests uptake 0.4 kg C m^{-2} $year^{-1}$ and the sinks are expected to increase 28% in 2050s (Fig 3b)
  - Low plants uptake on average 0.09 kg C m^{-2} $year^{-1}$, having also possibility to be a source of CO_2 to the atmosphere, as soil can respire more carbon to atmosphere than low plants can capture (Fig 3b)
- Suburbs are only 50% as efficient as urban forest (Fig 3b) but due to their high spatial coverage, their contribution is 44% of the sink of the whole city

Conclusions

- Local Climate Zone classes can be used to study the impact of urbanization to local temperatures and biogenic CO_2 exchange
- Although urban forests are strongest sinks, urban neighbourhoods contribute for 44% of Helsinki's carbon sinks
- Annual mean temperatures are expected to rise 1.3 °C and total CO_2 uptake increase 18% by 2050s

References
[1] Demuzere et al., (2019). Mapping Europe into local climate zones. PLOS ONE, 14(4), e0214474.
[2] Järvi, et al., (2019). Spatial modeling of local-scale biogenic and anthropogenic carbon dioxide emissions in Helsinki. J. Geophys. Res.: Atmos. 124.15: 8363-8384.
[3] Saranko, et al., (2020). Impacts of town characteristics on the changing urban climate in Vantaa. Sci. Total Environ. 727: 138471.
[4] Tang, et al., (2021). Urban meteorological forcing data for building energy simulations. Build Environ. 204: 108088.

Contact
Minttu Havu, University of Helsinki/INAR,
minttu.havu@helsinki.fi