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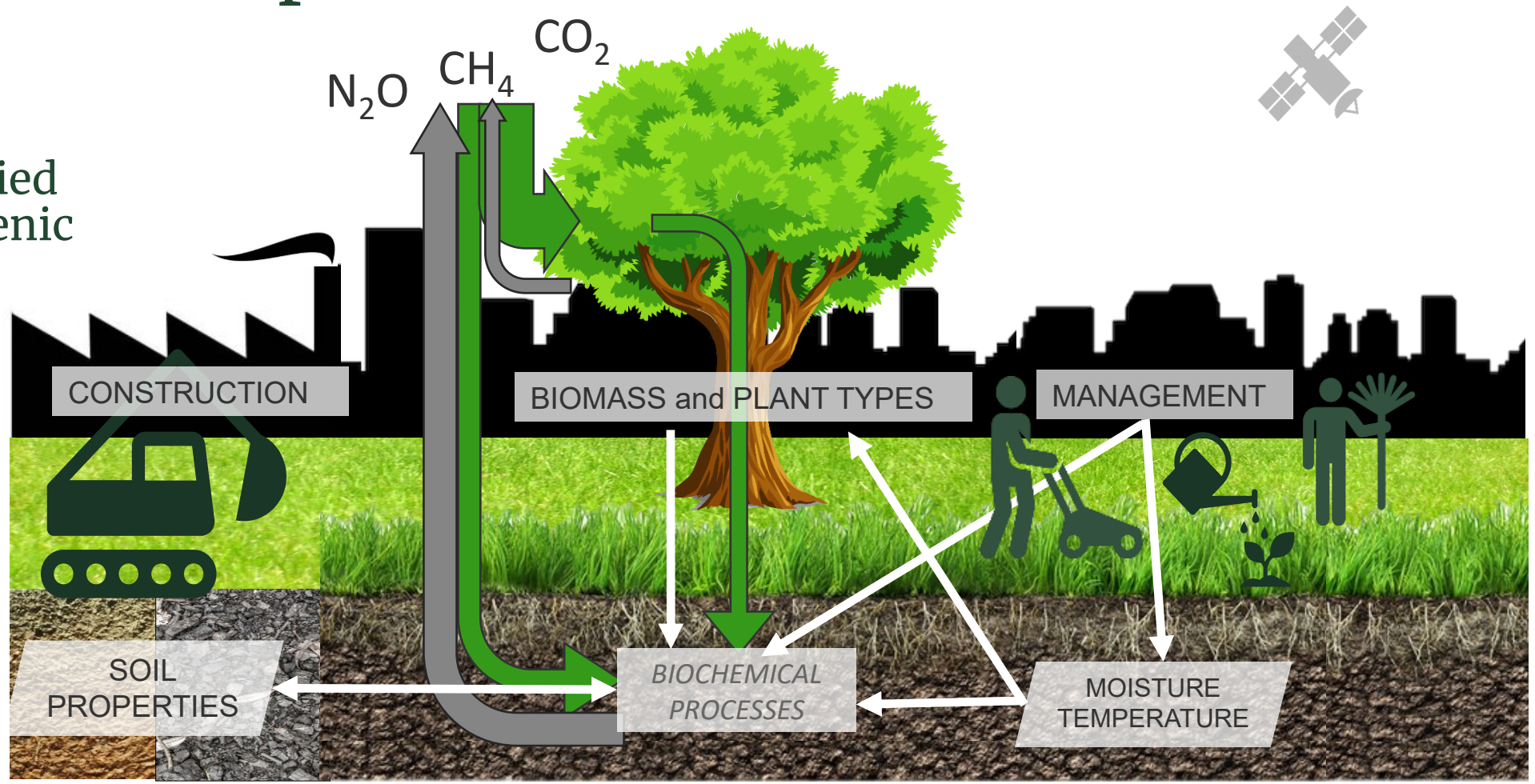
Quantification of carbon storage, fluxes, and sequestration in urban nature

Esko Karvinen, Finnish Meteorological Institute

Background:
Urban nature is special

...and understudied in terms of biogenic carbon cycle



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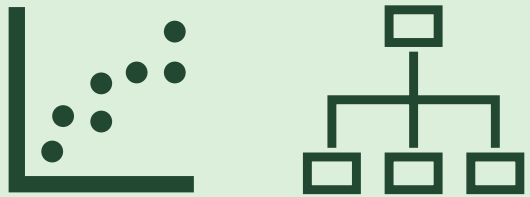
Outline:
From measurements to practical tools

1.

Collecting observational data; field measurements, satellites

2.

Model performance assessment; validation with observations



3.

Model utilisation; upscaling the results, building tools for practice

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1. Observational data

- Carbon cycle is a complex network of interconnect processes that transport carbon from one carbon stock to another
- Ecosystem carbon balance
  = changes in ecosystem carbon stock over a certain time
- Carbon balance determines whether a system is a carbon sink or a source of carbon

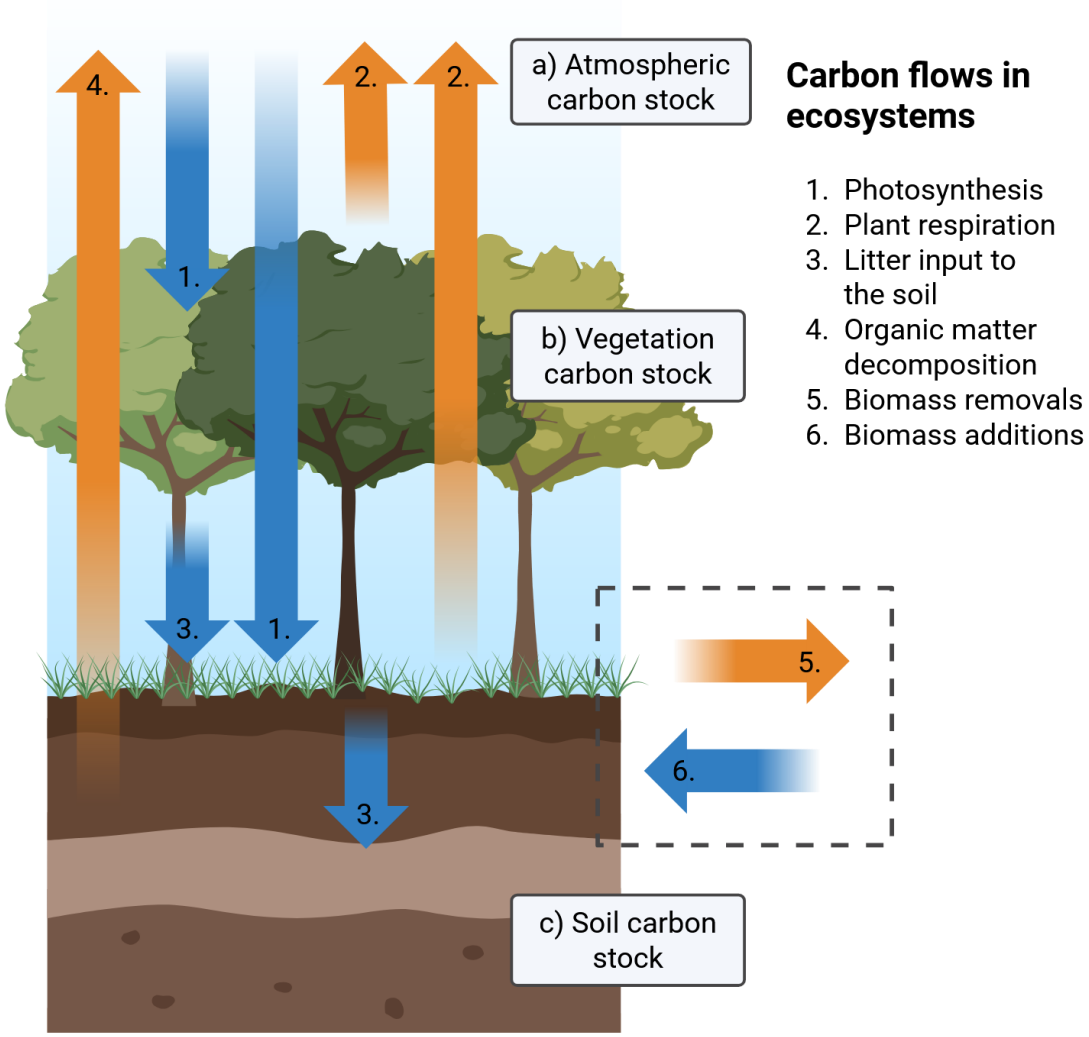

Figure: Esko Karvinen

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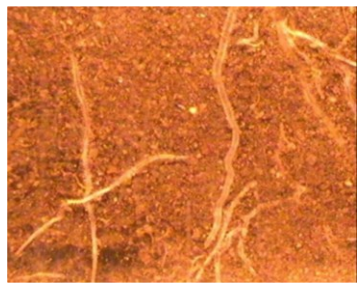
1. Observational data

- Intensive measurement campaigns around Helsinki Metropolitan Area during 2020-2026
- Automatic and manual measurements of
  - C stocks
  - CO_2 exchange
  - Chl. fluorescence
  - Transpiration
  - Growth dynamics
  - Root longevity
  - Meteorology
  - Soil conditions







Photos: Yasmin Frühauf, Liisa Kulmala, Esko Karvinen

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2. Model validation

- We cannot measure everything, so process-based ecosystem models provide a way to leverage the measurement data – after careful validation!

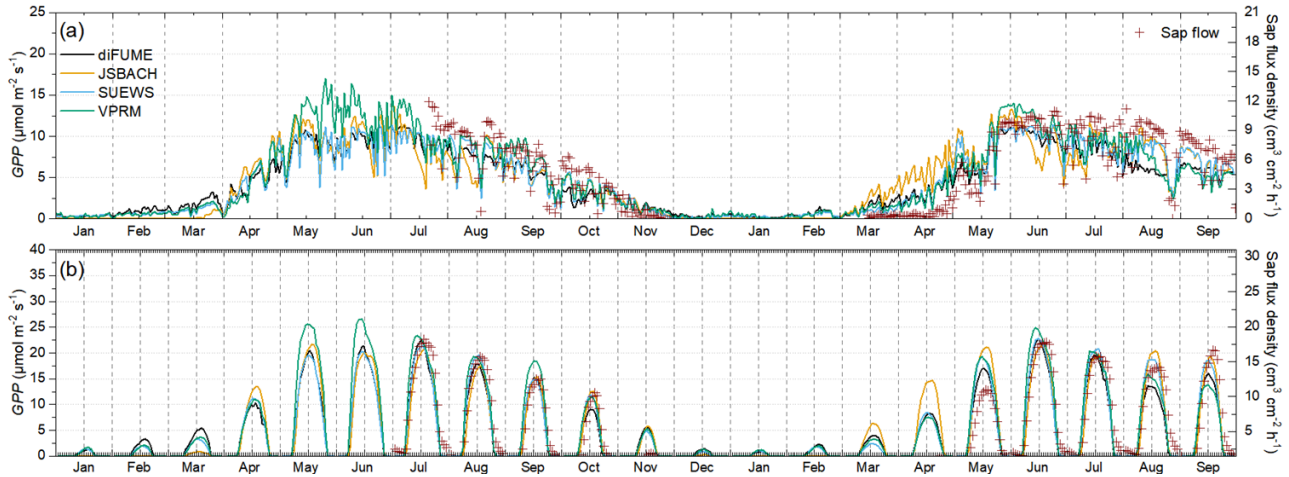
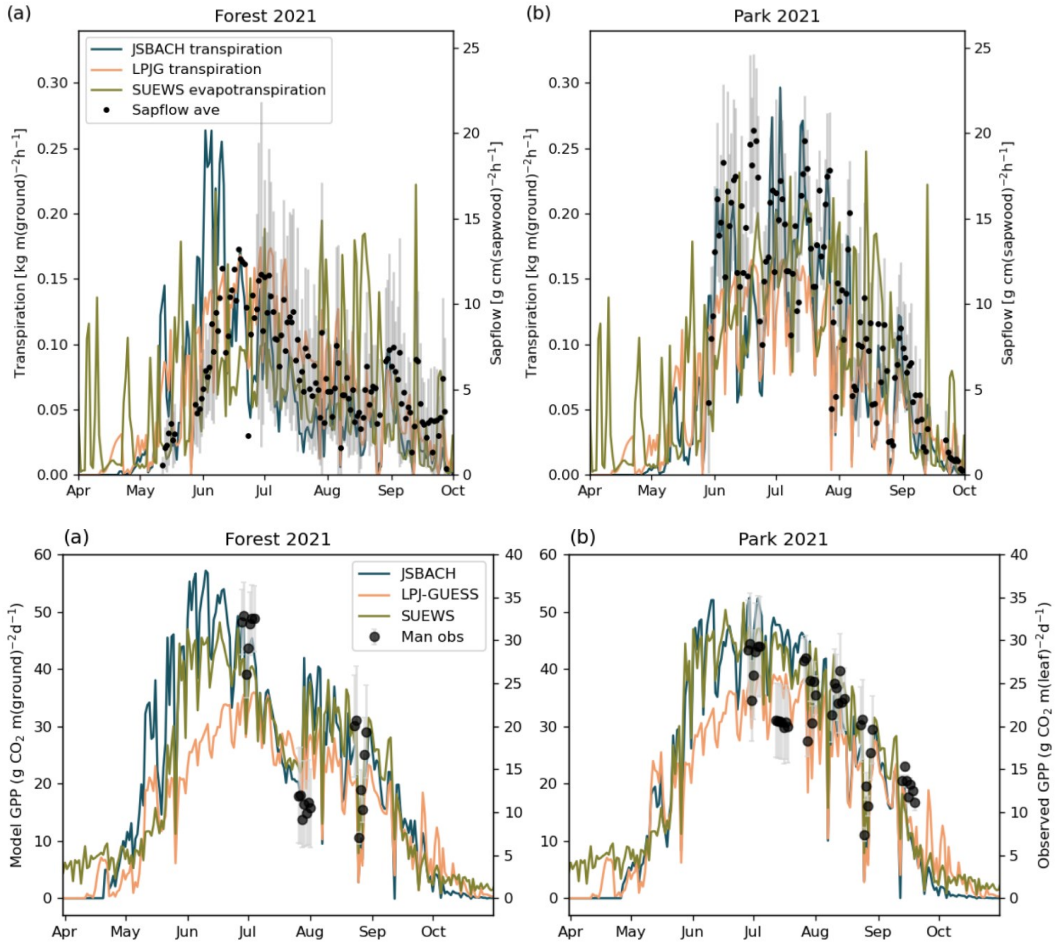


Figure: Stagakis et al. (2025)

Figures: Thölix et al. (2025)



Publications

- Stagakis et al. (2025): Intercomparison of biogenic CO_2 flux models in four urban parks in the city of Zurich, Biogeosciences, 22, 2133–2161, https://doi.org/10.5194/bg-22-2133-2025
- Thölix et al. (2025): Carbon sequestration in different urban vegetation types in Southern Finland, Biogeosciences 22, 725–749, https://doi.org/10.5194/bg-22-725-2025
- Karvinen et al. (2024) Soil respiration across a variety of tree-covered urban green spaces in Helsinki, Finland. Soil, 10, 381–406 https://doi.org/10.5194/soil-10-381-2024
- Havu et al. (2024) CO_2 uptake of urban vegetation in a warming Nordic city. Urban Forestry & Urban Greening. Article ID 128261. https://doi.org/10.1016/j.ufug.2024.128261
- Trémeau et al. (2024) Lawns and meadows in urban green space – a comparison from perspectives of greenhouse gases, drought resilience and plant functional types, Biogeosciences, 21, 949–972, https://doi.org/10.5194/bg-21-949-2024

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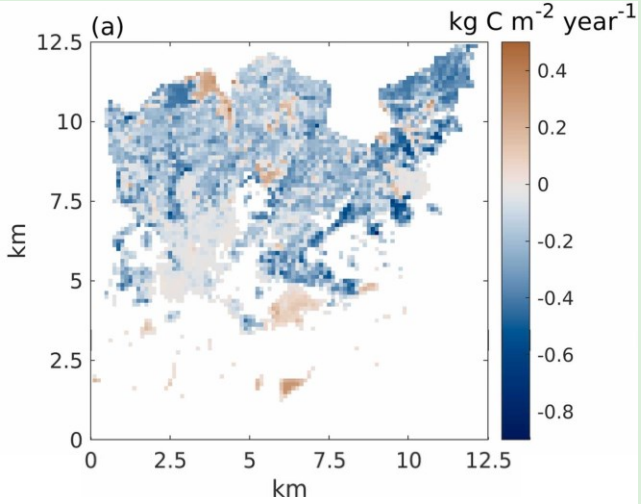
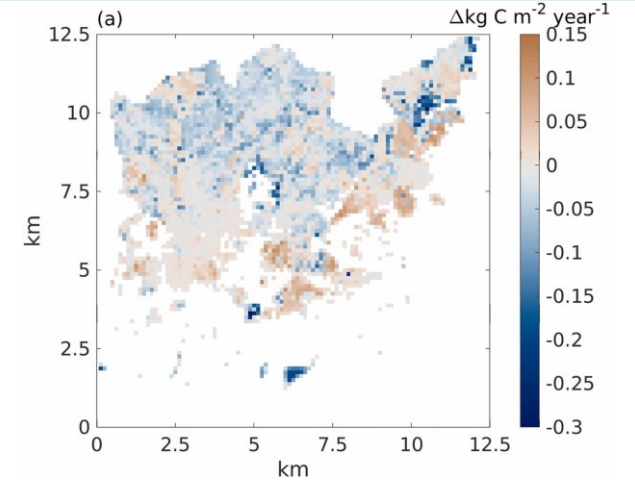
3. Model utilisation

- Upscaling the results…



…in space



…in time

Havu et al. (2024).
CO_2 uptake of urban vegetation in a warming Nordic city.
Urban Forestry & Urban Greening. Article ID 128261.

https://doi.org/10.1016/j.ufug.2024.128261

Figures: Havu et al. (2024)

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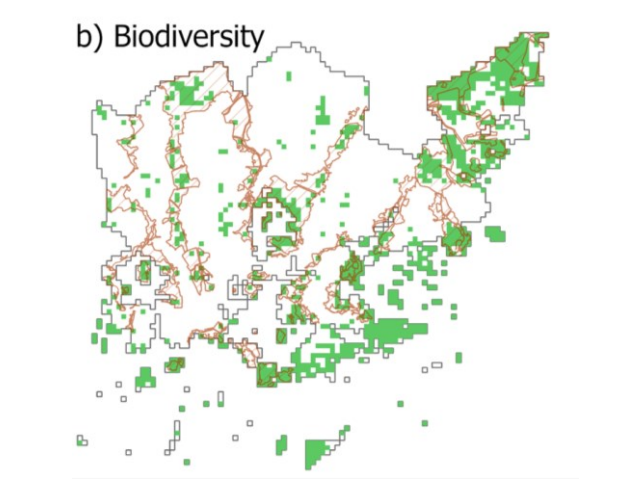
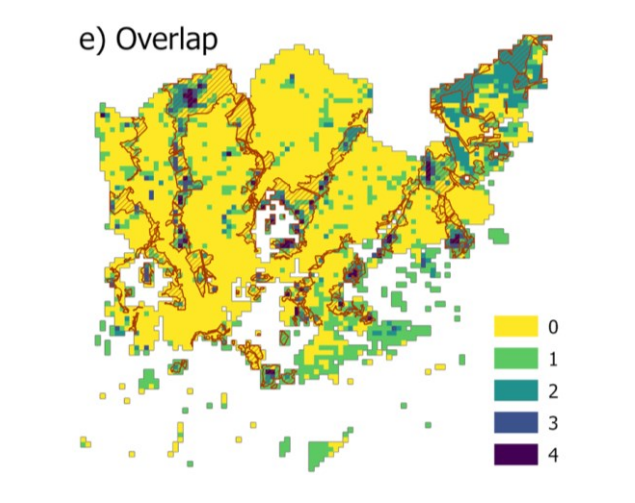
3. Model utilisation

- Combining carbon…



…with other data



…to locate overlaps

Raymond et al. (2023). Identifying where nature-based solutions can offer win-wins for carbon mitigation and biodiversity across knowledge systems. Npj Urban Sustainability. 3:27

https://doi.org/10.1038/s42949-023-00103-2

Figures: Raymond et al. (2023)

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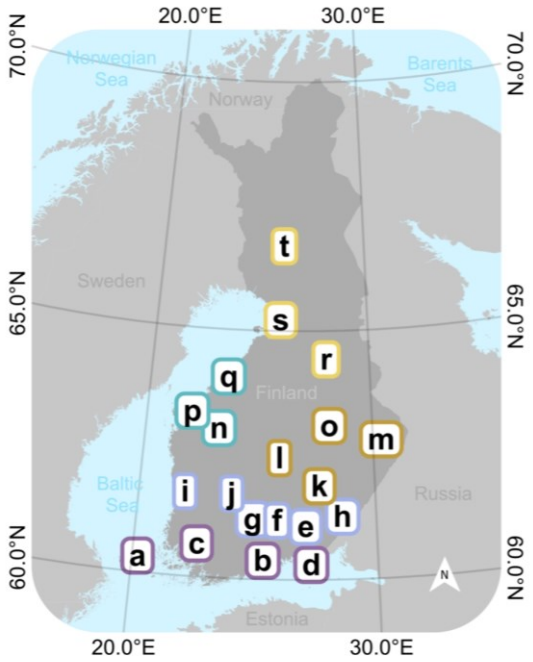
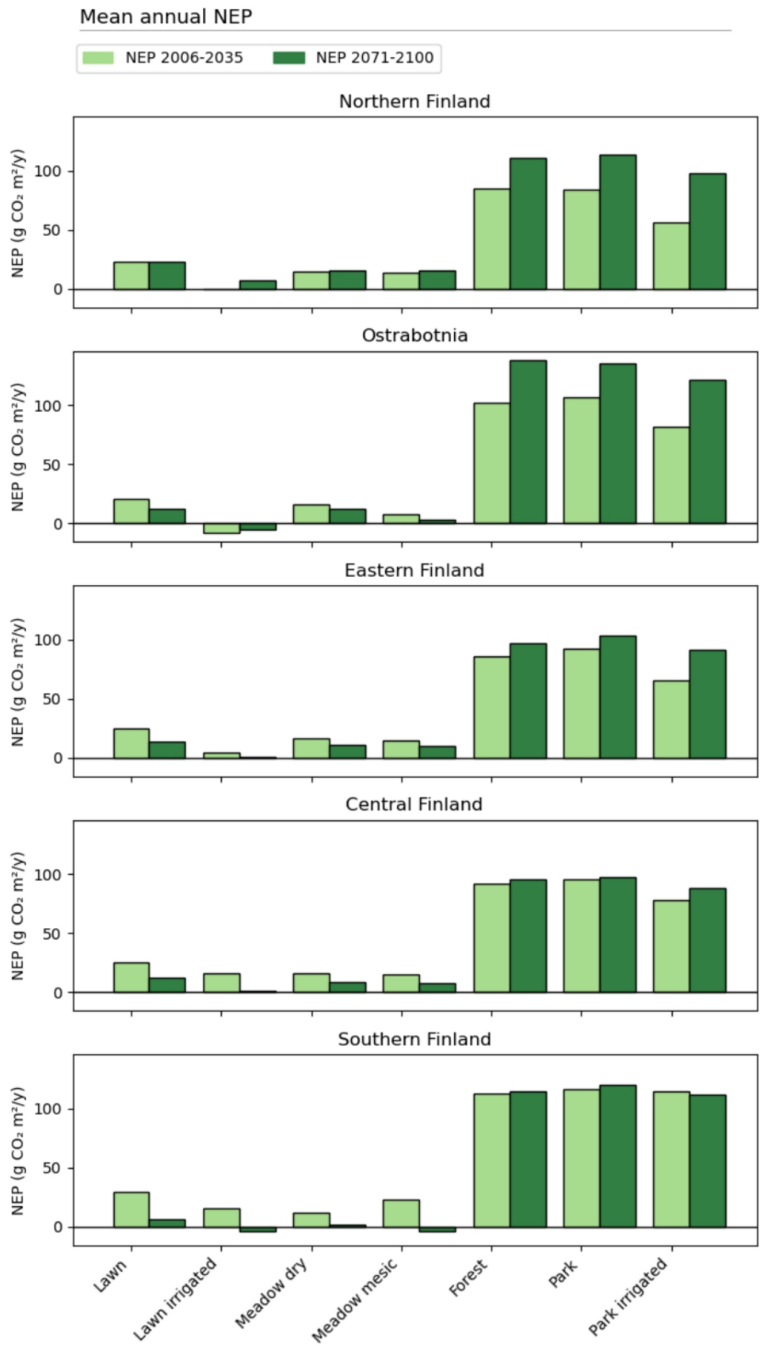
3. Model utilisation

- Studying the effects of regional climatic variation and projected future climate change





Koiso-Kanttila et al. (2026). Future climate impacts on carbon sequestration dynamics across urban ecosystem types in Finnish cities. Urban Ecosystems. 29:116.

https://doi.org/10.1038/s42949-023-00103-2

Figures: Koiso-Kanttila et al. (2026)

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Take home messages

- Measurement campaigns provided vital data on urban carbon cycling processes
- Process-based ecosystem models enable scaling up measurement data in space and time
- Machine learning based emulators allow incorporating the information into practical tools

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Thank you for your attention!

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