Quantifying the role of urban ecosystems on terrestrial carbon cycling

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Land transformed by urbanization is often the most fertile and the transformation tends to be permanent.
Why measure the terrestrial carbon budget of urban ecosystems?

• In the next decades, after deforestation, urbanization may be the most common form of land cover change.
• A measure of the carbon budget of urban ecosystems allows to monitor the desertification or greening of cities and helps detecting other components of urban biogeochemistry.
• As urban areas grow, their vegetation will have an increasingly important role in:
  • human quality of life
  • the impact of urbanization on the carbon budget
  • the functioning of an urban area: two cities with same emissions function differently depending on greenness
Relevant question to understand the C cycling of urban ecosystems

- Where are the urban areas?
- How much area do they occupy?
- How much do they contribute to the C budget?
Chicago
Digital camera image from the International Space Station.
How much Area?

MODIS Land Cover (1km)
Urban: 0.3%
How much Area? (cont.)

MODIS Land Cover (1km)
- N America: 0.7%
- US (48 states): 1.5% (including Alaska: 1.3%)
- CA: 0.1%
- MX: 0.4%

NLCD 1992 (30m from Landsat)
- US (48 states): 2.1%

Impervious Area from DMSP/OLS: 1.3%
How much C?

Global Impact:

- Long-term AVHRR records of NDVI (photosynthetic capacity) at 8 km from 1982

Change in NDVI during data record (late 1990s vs. early 80’s)

- Significantly lower
- Significantly higher
Continental impact of urbanization on C

Ecosystem Process Models:

• Satellite-driven top-down approach: relates satellite estimates of photosynthetic active radiation absorbed by vegetation (APAR) to the net (NPP) or gross (GPP) amount of carbon absorbed by vegetation
  CASA, MODIS NPP: \( NPP, GPP = f(\text{APAR}) \times T \times W \)

• Bottom-up approach: plant growth model is calibrated with site-specific physiological, soil and climate parameters; i.e. Biome-BGC
Impact of urbanization in SE-US on Net Primary Production

1992-1993

4.5% is urban

2000

6.4% is urban

+ 1.9%

Based on MODIS NPP algorithm (MOD17), the total decrease in NPP due to expansion of urban areas: 3 Tg C/yr, or 0.4% of the total NPP of southeastern US.
Total US surface potentially under turf
164,000 km² (±35,850 km²)
*compare with 220,000 km² of total irrigated cropland
Bottom-up modeling approach to estimate role of US turf on C cycle

- don’t water, don’t fertilize
- water 1”/week, fertilize, bag the clippings
- water 1”/week, fertilize, mulch the clippings
- water 1”/week, half the fertilizer, mulch the clippings

![Graph showing carbon sequestration and costs](image)

Gross C sequestration

- 1 Tg C / yr
- 10 Tg C /yr
- 25 Tg C /yr
- 15 Tg C /yr

Total US C seq

300-580 Tg C/yr

Pacala et al. 2001

C-cost: 25-45% of soil C sequestration
**NPP of urban ecosystems in the US**

<table>
<thead>
<tr>
<th>Method</th>
<th>Calculation</th>
<th>Continental US</th>
<th>SE-US</th>
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<tbody>
<tr>
<td><strong>NASA-CASA</strong></td>
<td>$\text{NPP}=\text{PAR} \times \text{FPAR} \times \epsilon_{\text{max}} \times T \times W$</td>
<td>0.117 Pg C/yr</td>
<td>0.032 Pg C/yr</td>
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<td>$\text{NPP}=\text{PAR} \times \text{FPAR} \times \epsilon_{\text{max}} \times T$</td>
<td>0.126 Pg C/yr</td>
<td>0.033 Pg C/yr</td>
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<tr>
<td><strong>MODIS NPP</strong></td>
<td>$\text{GPP}=\text{PAR} \times \text{FPAR} \times \epsilon_{\text{max}} \times T \times W$</td>
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<td>0.030 Pg C/yr</td>
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<td>$\text{NPP}=\text{GPP} – \text{Rm} - \text{Rg}$</td>
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<tr>
<td><strong>BIOME-BGC</strong></td>
<td>Turf grasses only</td>
<td>0.007–0.110 Pg C/yr</td>
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**Total US NPP:** ~3.1 Pg C/yr  
**Total US NEP:** 0.30-0.58 Pg C/yr
Summary

- There is an increasing need to develop tools and approaches to quantify and validate the impact of urbanization on the terrestrial C cycle.
- Globally, urbanization is associated with an overall decline in photosynthetic capacity.
- The amount of carbon stored in urban ecosystems and its changes over time differ significantly among developed and undeveloped nations.
- Beyond their role in C cycling, urban ecosystems are important for their ecological services.