Developing Carbon Budgets for Cities: Phoenix as a Case Study

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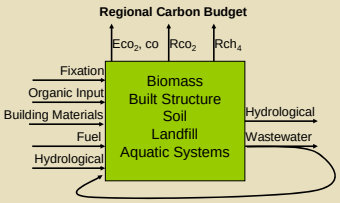
Introduction

Cities alter regional carbon dynamics through changing ecosystem productivity, overall carbon cycling rate, and total carbon storage in vegetation and soils. People in urban regions import a large amount of carbon in food and fuel and release an exceptional amount of CO2 into the atmosphere. A complete carbon budget for a city that accounts for total inputs, outputs, and storage within the ecosystem has yet to be fully constructed.

Goals

1. To understand the drivers of carbon dynamics in urban ecosystems

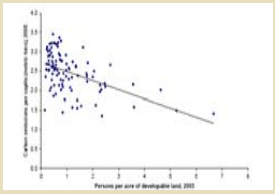


Potential Drivers:

- climate
- population size, density, growth rate, and demography
- affluence
- lifestyle choices of residents
- housing density and size
- residents per home
- energy sources
- energy efficiency
- commute times, traffic
- public transportation quality and availability
- technology

2. **To develop and standardize methods for estimating comparable carbon budgets among cities**

- Challenges: Data at appropriate scales are typically unavailable leading to potentially invalid conclusions and policy recommendations.



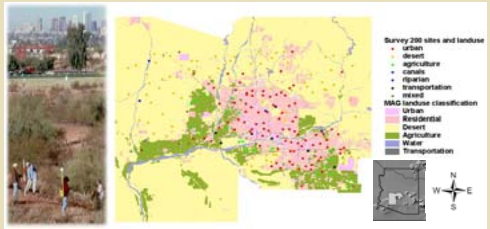
Conclusion: Population density is a main driver of CO_2 emissions.

Do these data really support this conclusion?

Can we make these conclusions only knowing broad scale estimates of residential energy and transportation emissions?

CO_2 emissions associated with residential energy and transportation vs. population density. Source: Brookings Institute 2008.

Methods

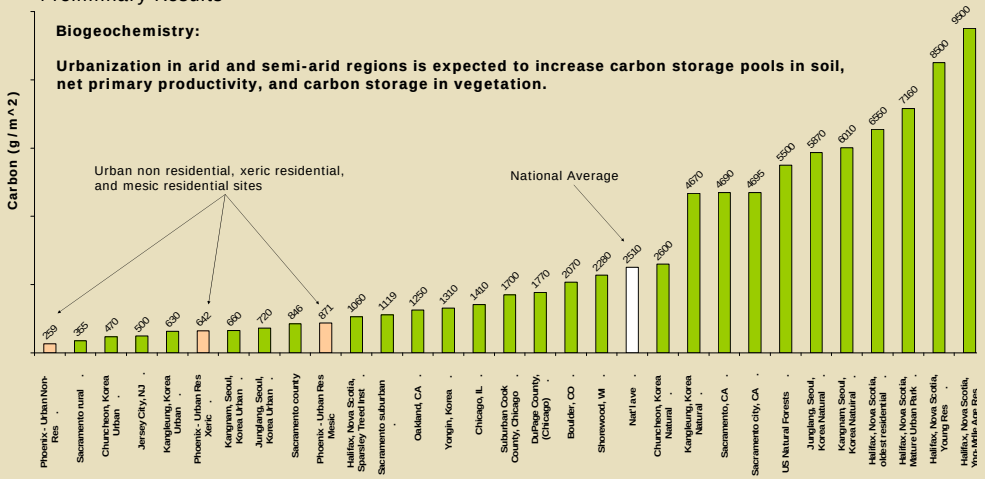


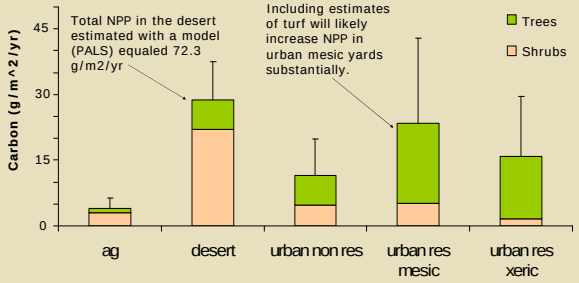
Central Arizona-Phoenix Long Term Ecological Research (CAP LTER) Boundaries. The points represent 204 30x30-m plots distributed across the region in a dual-density, tessilation-stratified design.

Preliminary Results

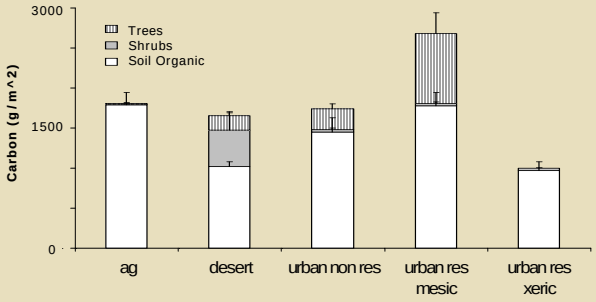
Biogeochemistry:

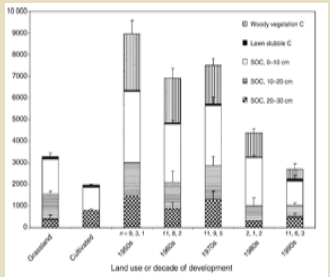
Urbanization in arid and semi-arid regions is expected to increase carbon storage pools in soil, net primary productivity, and carbon storage in vegetation.





Examples of Residential xeric (left) and Mesic (above) sites in Phoenix, AZ





Results for Boulder, CO (Golubiewski 2006)

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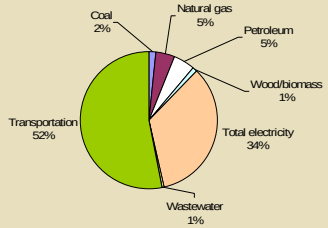
Outputs: Residential, commercial, and industrial energy related C emissions, transportation emissions: 13,585 Gg C / Yr (year 2000).

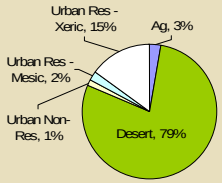


Different Methods Produce Varying Results:

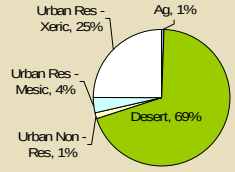
- The pie chart above represents state-level data (EIA, 2000) scaled down to the Phoenix Metropolitan Region implementing a per-capita emissions conversion (Phoenix Metro includes 60% of the state's total population).
- The transportation estimate (9130 Gg C/y) above includes jet fuel and other fuel sources that are unidentifiable.
- When emissions are calculated using fuel import data for the region (AZ Dept. of Weights and Measures) transportation emissions are estimated at 3720 Gg C/y.
- Using a Transportation model, however, estimates of transportation emissions are even lower, at 2753 Gg C/y.

Outputs vs. Vegetation (Trees and Shrubs) Storage and NPP

Tree and Shrub Total NPP: 172 Gg C / Year



Tree and Shrub Total C Storage: 4317 Gg C



Conclusions

- Trees and shrubs only offset 1.3% of the annual emissions we estimated for Phoenix
- Desert shrubs contribute most to the CAP LTER's regional productivity and C storage, because desert covers the largest area in central Arizona
- Urban residential mesic sites do store more C per unit area, mostly because of soil storage
- Urbanization has not yet changed total C storage in biomass on a per area basis, but there is more storage in trees and less in shrubs
- NPP in urban mesic plots will likely be higher than desert areas once lawn productivity is included in our estimates
- As the urban area continues to expand, we expect residential landscapes to account for an increasing fraction of C storage and uptake. However, this increase is unlikely to have a significant effect on the rate of CO_2 emission without large changes in transportation or lifestyle.