Development Sprawl Impacts on Terrestrial Carbon Dynamics

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Research Question

What is the sign and magnitude of development impacts on carbon cycling?

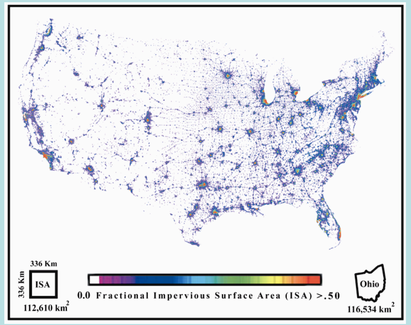
Goals

- To reduce the uncertainty in the terrestrial carbon accounting
- To develop methods that could be applied globally for multiple time periods

Approach

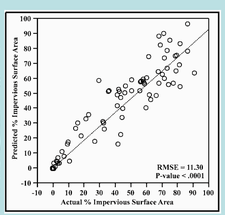
Develop a calibrated model of the spatial distribution of constructed materials. Use this with other data sources as input into a carbon model. Make model runs with and without current development and compare the results.

U.S. Constructed area approaches the size of Ohio



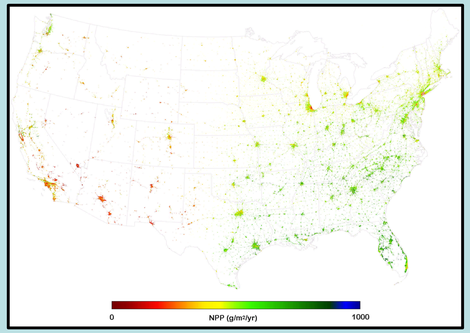
Percent cover of ISA was modeled on a 1-km grid for the continental US using DMSP/OLS nighttime lights, three classes of Landsat derived urban land cover and U.S. Census Bureau road vectors (*Elvidge et al., 2004*).

Ground truth calibration data were derived from 80 high-resolution aerial photographs selected along urban-to-rural development gradients from 13 major urban centers. Square-km tiles were extracted from the aerial photography, matching the coverage of specific cells in the reference grid. Gridded point counts were made on each photo tile to estimate the percentage of ISA.



The nighttime lights radiance, road density, and Landsat-derived urban land cover values were paired to the percentage of ISA values from the aerial photography. Linear regression was used to develop an empirical model for estimating percentage of ISA from the lights, roads, and the three National Land Coverage Data urban classes.

Annual NPP of urban vegetation potentially accounts for 4% of U.S. NPP

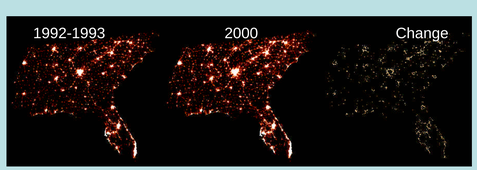


NPP of continental US urban vegetation was modeled using 2002-2004 1-km MODIS NDVI, 1-km gridded climate data from the Daymet dataset (*Thornton et al., 1997*), and the NASA-CASA model. Urban NPP was estimated for grid cells with a percent cover of ISA of at least 10%. The vegetation was assumed to be well irrigated.

Total urban NPP for the conterminous U.S. from this analysis amounts to 0.13 Pg C/yr (compared to a total estimated U.S. NPP of ~3.1 Pg C/yr)

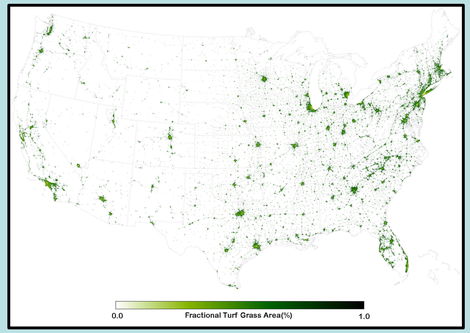
Although the U.S. is undergoing rapid urbanization, the intensive management of urban vegetation (fertilization and irrigation) stimulates NPP, partially counterbalancing the loss in vegetated surface due to construction.

An analysis of the impact of the 1990's urban development in the S.E. U.SA.. by comparing pre-urban NPP with urban NPP using MODIS NDVI data and the MOD17 NPP logic indicates a loss in 0.3% for an increase in developed area of 2% (*Milesi et al., 2003*).

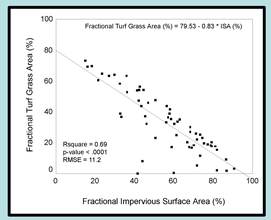


DMSP/OLS nighttime data

U.S. lawns and turf grasses alone can contribute to 60% of the annual urban NPP



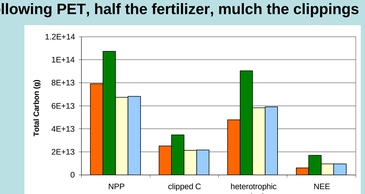
Percent cover of turf grasses (residential lawns and commercial lawns, parks, golf courses) was modeled on a 1-km grid based on the percent cover of ISA and ground truth calibration data from high-resolution aerial photography.



Occupying an estimated surface of 165,000 km^2 (±31,500 km^2, equivalent to 41 million acres ± 8 million acres) turf grasses rank as the single largest irrigated crop in the U.S. (compared to 11 million acres of irrigated corn) (Milesi et al., 2005).

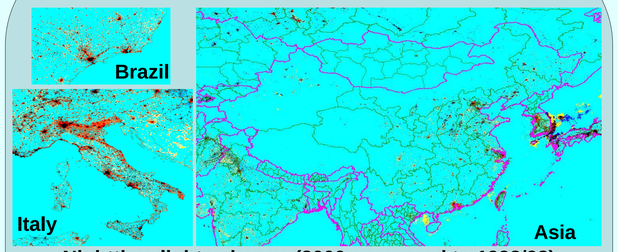
The carbon balance of the total surface potentially under lawn was modeled adapting the ecosystem process model BIOME-BGC.

Modeling Scenario	NEE
water 1"/week, fertilize with 146 kg N/ha/yr, bag the clippings	6 Tg C / yr
water 1"/week, fertilize with 146 kg N/ha/yr, mulch the clippings	17 Tg C / yr
water 1"/week, half the fertilizer, mulch the clippings	9 Tg C / yr
water following PET, half the fertilizer, mulch the clippings	9 Tg C / yr



Total US NEE
0.30-0.58 Pg C/yr
Pacala et al. 2001

Global impacts of urban development



Nighttime lights change (2000 compared to 1992/93)
Black = Bright lights (saturated) in both time periods
Red = Lights much brighter in 2000
Yellow = New lights in 2000
Blue = Lights missing or substantially dimmer in 2000
Grays = Dim light detected in both time periods with little change

Today almost half of the world's population lives in urban areas, with the most rapid changes occurring in developing countries in Latin America, Asia, and Africa.

As urbanization rapidly proceeds, more surface will become covered by impervious materials and withdrawn from the photosynthetic activity.

Making use of satellite derived nighttime lights and vegetation index data we are generating a global one km grid depicting the percent cover of impervious surface areas (ISA) for two time periods (1992-93 and 2000). The ISA product is being calibrated using a sub-sample of high spatial resolution aerial photography and commercial satellite imagery (IKONOS).

The global ISA grids for the two time periods will be used as input into terrestrial carbon model runs. The results from the two time periods will then be compared, providing the first global assessment of the impacts of urban development on carbon cycling.

Impacts of urban development on carbon dynamics for other countries are expected to significantly differ from the patterns observed in the U.S.

References

- Elvidge CD, Milesi C, Dietz JB, Tuttle BJ, Sutton PC, Nemani R, Vogelmann JE: U.S. Constructed Area Approaches the Size of Ohio. *Eos, Transactions, American Geophysical Union* 85: 233 (2004)
- Milesi C, Elvidge CD, Nemani RR, Running SW: Assessing the impact of urban land development on net primary productivity in the southeastern United States. *Remote Sensing of Environment* 86: 273-432 (2003)
- Milesi C, Elvidge CD, Dietz JB, Tuttle BJ, Nemani RR, Running SW: Mapping and modeling the biogeochemical cycling of turf grasses in the United States. *Environmental Management* (In review)
- Pacala SW et al.: Consistent Land- and Atmosphere-Based U.S. Carbon Sink Estimates. *Science* 292: 2316-2320 (2001)
- Thornton PE, Running SW, White MA: Generating surfaces of daily meteorological variables over large regions of complex terrain. *Journal of Hydrology* 190: 214-251 (1997)