Carbon stocks and fluxes in urban and suburban residential landscapes

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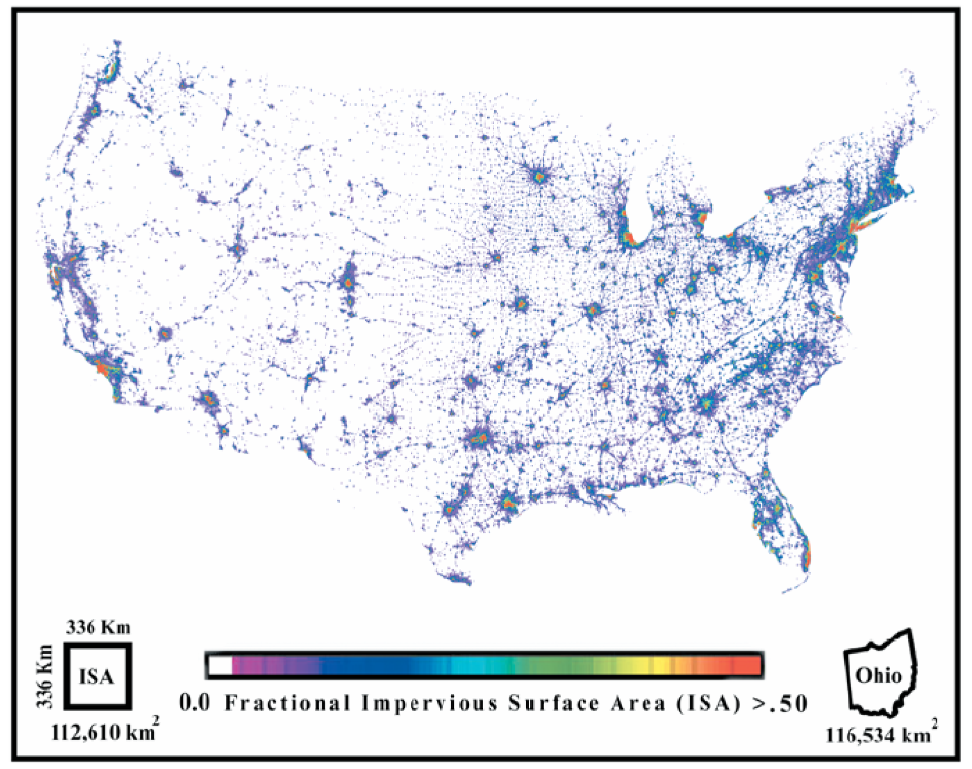
ABSTRACT

Substantial carbon (C) sequestration occurs in residential systems, though the residential land base is largely excluded from national greenhouse gas inventories. In fact, EPA's 2002 inventory of US Greenhouse Gas Emissions and Sinks reports that, of the 188 Tg C sequestered in the US, 87% (164 Tg C) was sequestered in forests (including wood products and soils), while 3% (6 Tg C) was sequestered in agricultural soils. Fully 8% of the C sequestered nationwide in 2002 (16 Tg C) was stored in urban trees (both above- and below-ground) and the remaining 1% (3 Tg C) was stored in landfills as yard trimmings and food scraps. Despite the large land area occupied by residential systems, the importance of these areas for the human population, the aesthetic similarity of residential land all across the country, and the rapid conversion of land to these residential uses, very little is currently known about the biogeochemical processes occurring in urban and suburban residential areas. Our work will begin to fill this knowledge gap by **quantifying C stocks and fluxes, and the factors that drive them, in residential neighborhoods of metropolitan Baltimore, Maryland**. We are in the early stages of a project funded by the National Science Foundation (NSF) which is designed to: a) quantify key C stocks and fluxes in the vegetated component of the residential landscape; and b) identify the relative importance of urban ecosystem structure, soil functional properties, historical land use, and land management practices as drivers of C stocks and fluxes in residential systems. Though this work is taking place as part of the Baltimore Ecosystem Study (BES), an NSF-supported Long Term Ecological Research (LTER) site, it will test methods that can be used in assessments of C cycling in residential areas in other regions, laying the groundwork for future cross-city analyses. In addition, this study will contribute to the ongoing effort to characterize the Northern Hemisphere C budget by providing data on components of the C budget that have largely been ignored.

What is the national extent of urban/ suburban land?



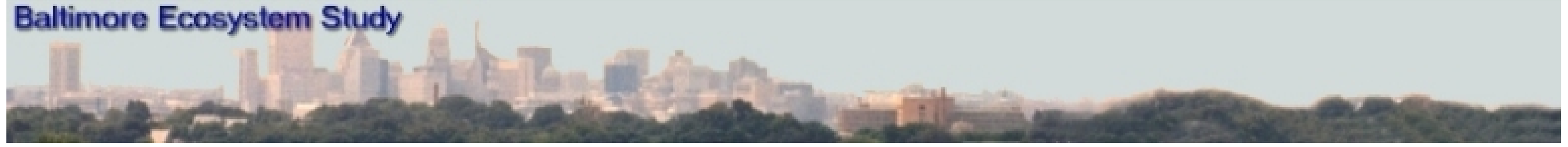
Impervious surface area is one indicator of the extent of "developed," "settled," or "urban/ suburban" land (left).

The total area of uninventoried land is not currently known with certainty, due in large part to difficulties with defining terms such as "urban," "exurban," and "suburban."

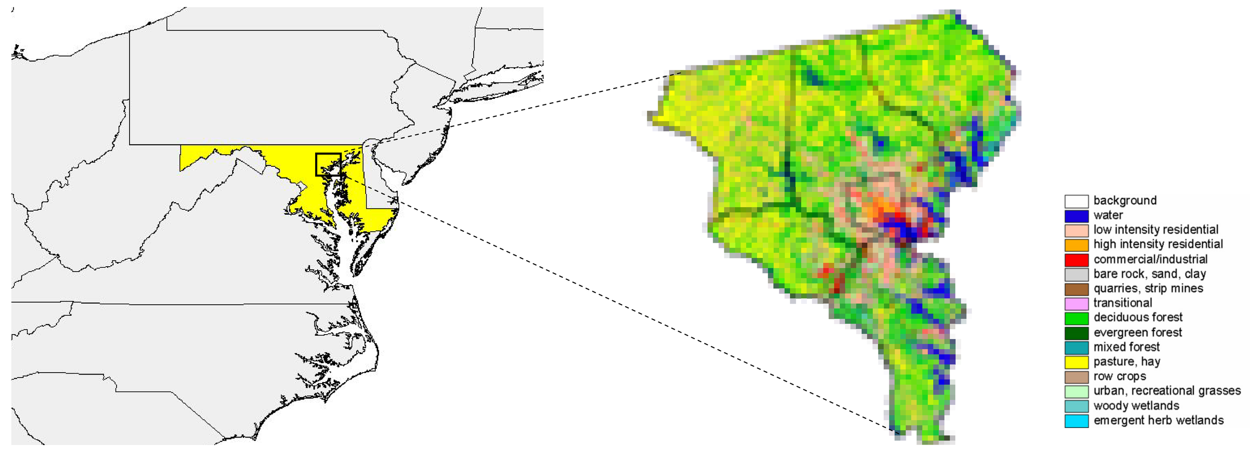
From Elvidge et al. (2004): "The spatial distribution and density of ISA for the conterminous United States. The aggregated area of ISA is nearly the size of the state of Ohio."

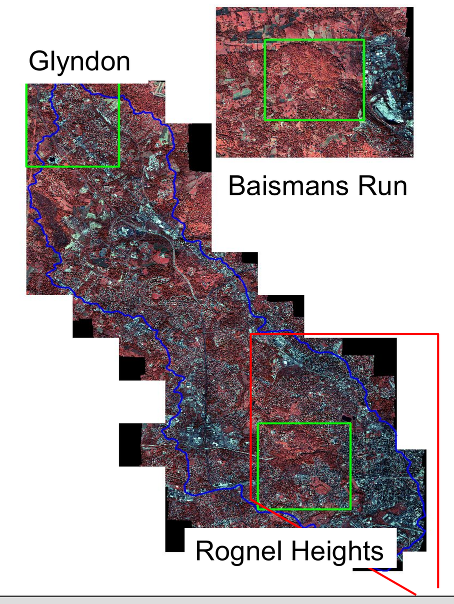
Further reading

- **Cadenasso, M. L., and S. T. A. Pickett. 2002. A new urban land cover classification system: exploring patch dynamics in metropolitan Baltimore. Ecological Society of America Annual Meeting, August 3-9, 2002. Tucson, AZ. Abstract available at: http://abstracts.co.allenpress.com/pweb/esa2002/document/?ID=17494.**
- **Elvidge, C. D., C. Milesi, J. B. Dietz, B. T. Tuttle, P. C. Sutton, R. Nemani, and J. E. Vogelmann. 2004. U.S. Constructed Area Approaches the Size of Ohio. EOS - Trans. American Geophysical Union 85:233-234.**
- **Grove, J., M. Cadenasso, W. Burch, S. Pickett, C. Boone, M. Wilson, and Schwarz. 2004. An Ecology of Prestige: Association of Group Identity and Social Status with Ecological Structure in the Baltimore Metropolitan Region, Maryland. Society and Natural Resources in review.**
- **Jenkins, J., and R. Riemann. 2003. What does nonforest land contribute to the global C balance? Pages 173-179 *in* R. McRoberts and G. A. Reams, Van Deusen, P.A., Moser, J.W., editors. Third Annual FIA Science Symposium, October 14-16, 2001. St. Paul, MN: USDA Forest Service North Central Research Station General Technical Report NC-230, Traverse City, MI.**
- **Pouyat, R., P. Groffman, I. Yesilonis, and L. Hernandez. 2002. Soil carbon pools and fluxes in urban ecosystems. Environmental Pollution 116:S107-S118.**



Study sites





The three study neighborhoods (each 18 km²) fall along a continuum of development intensity within the Gwynns Falls watershed.

What is the potential impact of nonforest/ residential land on current national-scale C cycling estimates?

	forest	nonforest
land area (thousand ac)	2701	3594
average biomass (Mg C ha^{-1})	72.25	17.80
wood-biomass increment (Mg C ha^{-1} yr^{-1})	1.90	0.42
total C storage (x 10^6 Mg C)	78.96	25.92
annual C storage (x 10^6 Mg C yr^{-1})	2.08	0.61

Forest and nonforest biomass and wood biomass increment statistics for Maryland (from Jenkins and Riemann 2003)

Nonforest: forest comparisons	*Maryland*	*Northeast*
forest land (thousand ac)	2701	85484
nonforest land (thousand ac)	3594	41333
nonforest: forest land area	1.33	0.48
per-unit-area ratios		
nonforest: forest biomass	0.25	*assume 25%*
nonforest: forest WNPP	0.22	*assume 22%*
aggregate state & region-level		
nonforest: forest biomass	0.33	0.13
nonforest: forest WNPP	0.29	0.24

Ratios of nonforest: forest statistics for Maryland and the Northeast (from Jenkins and Riemann 2003)

Study design

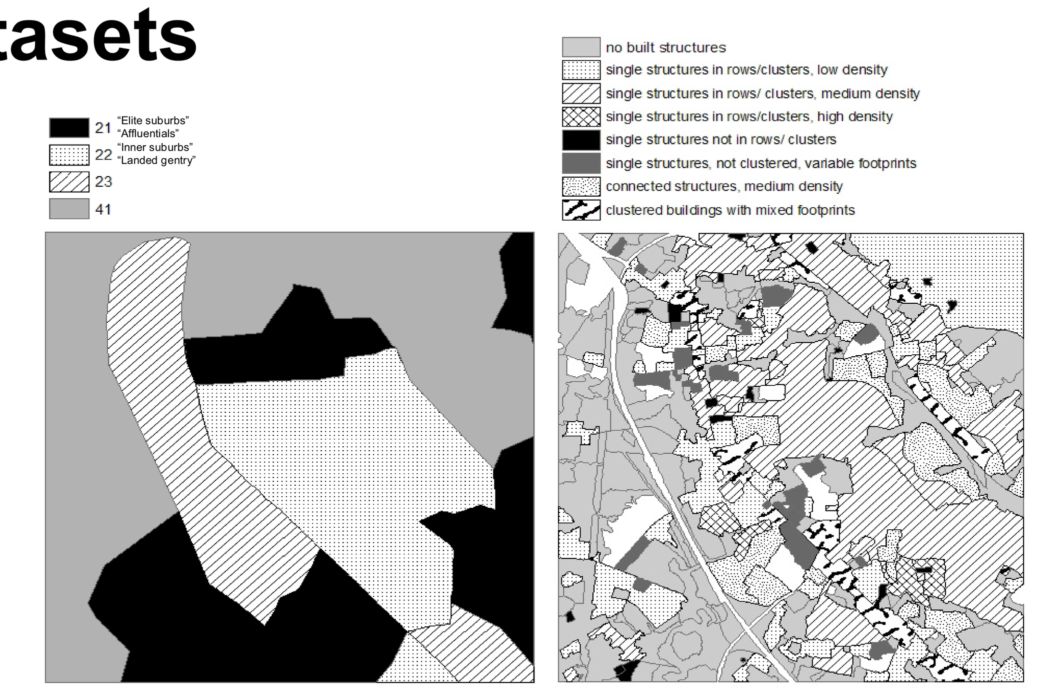
The study is designed to test the relative strengths of:

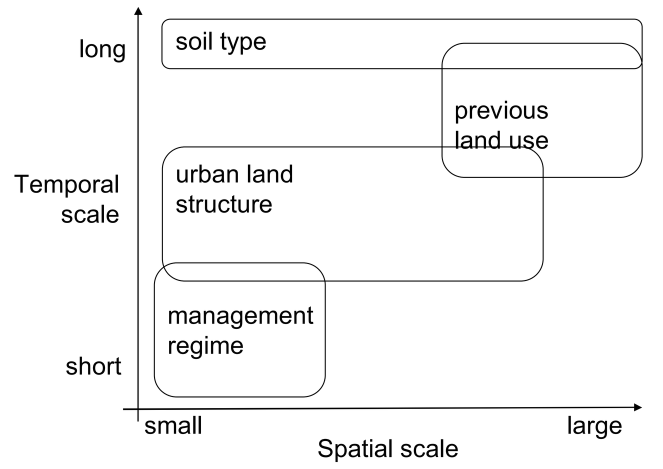
- Urban ecosystem structure (HERCULES classification system)
- Historical land use (former forest or agriculture)
- Soil functional properties
- Land management practices (PRIZM household cluster analysis); and
- Housing age

as drivers of above- and below-ground C stocks and fluxes in residential systems.

Major datasets

PRIZM lifestyle classification (left) and HERCULES urban ecosystem structure classification (right) for Glyndon neighborhood.





Theoretical framework describing the temporal and spatial scales of variation in the factors driving C stocks and fluxes in the natural components of residential ecosystems.

Key hypotheses

At the longest temporal and largest spatial scales, we expect that soil and vegetation C stocks will be driven primarily by structural factors such as soil type and previous land use, and that this variation will be modulated by the age of the residential development. Conversely, we expect that short-term C fluxes will be determined primarily by the extent of nutrient and water input.

Specifically, we hypothesize that:

1. Soil C stocks are controlled by natural factors (parent material, texture, topography) rather than sociodemographic characteristics such as management practices or current land use type, but:
   In newly-established residential parcels, soils established on former forestland have higher C stocks than soils established on former agricultural land.
   Controlling for previous land use, newly-established residential parcels have lower soil and tree C stocks than older residential parcels.
2. Turfgrass production (expressed on a per-unit-area basis) is directly proportional to inputs of nitrogen-based fertilizer and water, and follows a Kuznets curve with respect to household income, housing value, or both.
3. Per unit of vegetation area and regardless of management practices, annual aboveground production of grasses is at least equal to annual aboveground production of trees.
4. Per unit of land area, aboveground C stocks on residential parcels are a) directly proportional to the density of woody vegetation and b) inversely proportional to the density of built structures.