The changing landscape: ecosystem responses to urbanization and pollution across continental and regional gradients

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Forthcoming:
Frontiers in Ecology and the Environment

...and CAP LTER collaborators
World urbanization

UN Population Division 2005
Cities today

- 20 mega-cities with >10 million
- 30 cities with 5-10 million
- 364 cities with 1-5 million
- 455 cities with 0.5-1 million
- > 1 million with <0.5 million

Cities concentrate:
- Production & consumption
- Pollution & waste generation
- Innovation (and solutions?)

UN Population Division 2005
Urbanization in context

- Assertion: understanding the dynamics of urban social-ecological systems will require comparative work across gradients
- Gradients of biologic, climatic, geologic, hydrologic, demographic, economic, political, and cultural variables exist at multiple scales
- A connectivity framework applies to urban ecosystems and their effects at local, regional, and global scales
- Existing networks, such as LTER, are well placed to advance our knowledge of these important hot spots of environmental challenges
Hypothesis: Human socio-demographic changes are the primary drivers of change at continental/regional scales.
Mission of the US LTER Network:

- Understanding ecological phenomena over long temporal and large spatial scales
- Creating a legacy of well-designed and documented long-term experiments and observations for future generations
- Providing information for the identification and solution of ecological problems
- Conducting major synthetic and theoretical efforts

In 1997 NSF added two urban ecosystems: Phoenix & Baltimore
Key research questions

What are the ecological and socio-ecological consequences of local land-use changes at local, regional, and continental scales?
Local-to-regional land change
A changing landscape
CAP’s Overall Conceptual Theme - Socio-Ecological Interaction

How do the patterns and processes of urbanization alter ecological conditions of the city and its surrounding environment, and how do ecological consequences of development feed back to the social system to generate future changes?
Urban ecosystem structure and function

- Regular spatial pattern
- Many small patches
- Built structure
- Hydrologic modifications
- Imported floras
- Altered trophic dynamics
- Metabolism dominated by fossil-fuel-derived activities (urban fire)
- Elevated material inputs
- Elevated exports (air, water)
- Intentional and unintentional
- Managed and hidden ecosystem services
Urban Fringe Study: SE Zone of Residential Completions, 1990-98

Houses built, SE metro area

Number of completions

Distance from the center (miles)

1990
1993
1996
1998

Gober 1998
Effects of urban activity extend regionally
Continental gradients

What are the ecological and socio-ecological consequences of local land-use changes at continental scales?
Exurbanization gradient

From Brown et al. 2005
Ecological Applications
Key research questions

- How will varying patterns of urbanization interact with climate change across continental gradients in climate and land cover to affect ecosystem processes and services?
Conceptual Framework for CAP2

**External drivers**
- Climate change
- Globalization

**Press or pulse events**
- Land-use change & urbanization
- Housing development
- Landscape creation and management
- Heat island dynamics
- Atmospheric deposition
- Hydrologic/geomorphic alteration
- Natural events
  - Flood
  - Drought

**Ecosystem structure**
- Built structure
- Habitat structure & diversity
- Species abundance & diversity
- Geomorphic structure
- Food-web structure

**Ecosystem function**
- Primary production
- Organism interactions & behavior
- Nutrient cycling & retention
- Fluvial processes
- Groundwater recharge

**Ecosystem services**
- Regulating: Air quality, pest control, water quality, temperature control
- Supporting: soil fertility, nutrient cycling
- Cultural: recreation, aesthetics

**Human outcomes**
- Exposure risk
- Quality of life
- Human health
- Perception & value

**Human behavior**
- Institutional and Individual levels
  - Planning & design
  - Regulation
  - Migration

**Socio-cultural-economic template**
Megapolitan regions - continental US
Regional growth-rate gradient?
Basis for LTER urban

After R. Lang, A Nelson
Key research questions

☐ Does urbanization increase or decrease social, physical and biological connectivity at local, regional, and continental scales?

Hypothesis: Urbanization will generally increase connectivity via wind and animal vectors, but will disrupt connectivity via water vectors, especially at local to regional scales
Connectivity framework

Connectivity across scales results from broad-scale drivers interacting with finer-scale vectors that redistribute materials within and among linked terrestrial and aquatic systems. Feedbacks occur throughout the system. Because the scale of responses interact, one needs to study a hierarchy of scales in order to understand and predict continental-scale dynamics.
Humans can directly alter connectivity

Water-use ecological footprints of 20 largest U.S. cities

Luck et al. 2001 Ecosystems
Key research questions

- How are pollutant source and deposition regions (connected through air and water vectors) related to patterns of land use, and how do ecosystem structure, function and services respond to changes in pollutant loadings resulting from changing land use?

Emission, transport, deposition - air vectors
Loading, transport, retention, export - water vectors
Hot spots of N delivery to the Mississippi River

Vector: water
Source: diffuse land-use related
Recipient: Gulf of Mexico dead zone

Goolsby et al.
Spatial variation in total N deposition

Inorganic nitrogen wet deposition from nitrate and ammonium, 2005

Vector: air
Source: industrial and agricultural pollution
Recipient: Northeast forests and aquatic ecosystems

National Atmospheric Deposition Program National Trends Network
http://nadp.sws.uiuc.edu
Components of a research program on urbanization and pollution up to the continental scale

- Wall-to-wall coverage of land change associated with urbanization (and sub-ex- ...)
- Historical and demographic analyses
- Monitoring of ecosystem response along multiple gradients at multiple scales
- Infrastructure to track changes in source, transport, fate of materials
- Regional scenarios
- Robust simulation models to forecast change
- Hypothesis testing