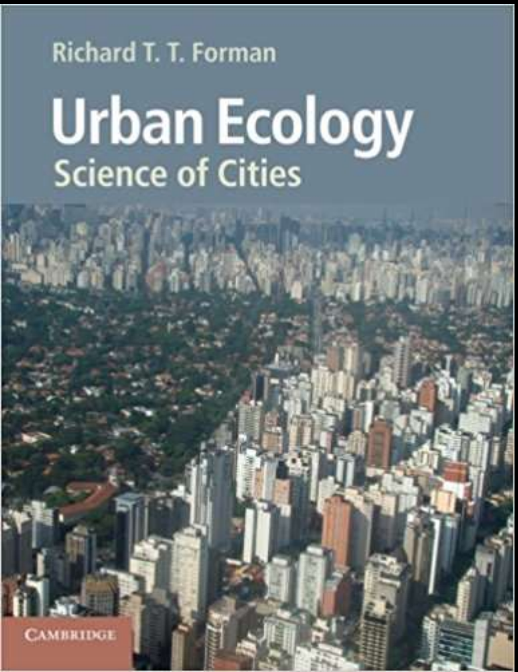
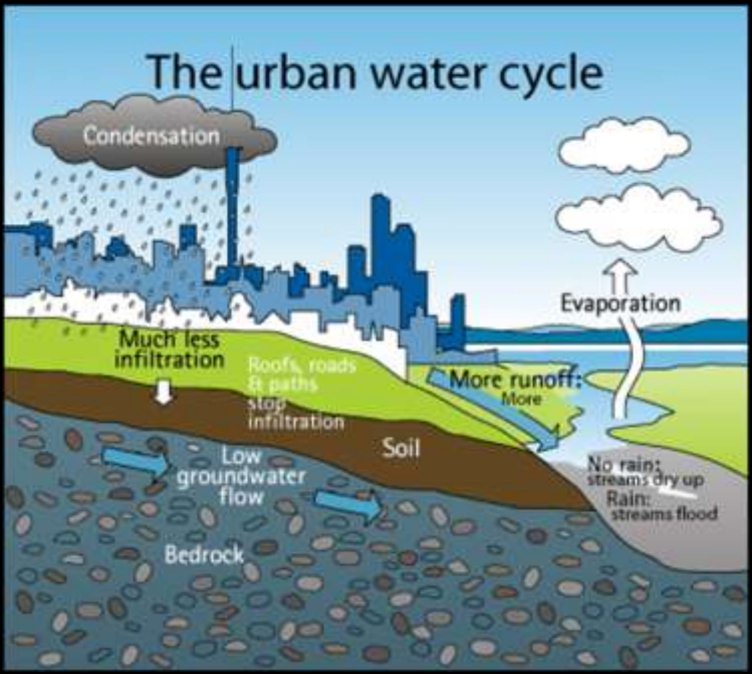
Center for Environmental Research at Hornsby Bend

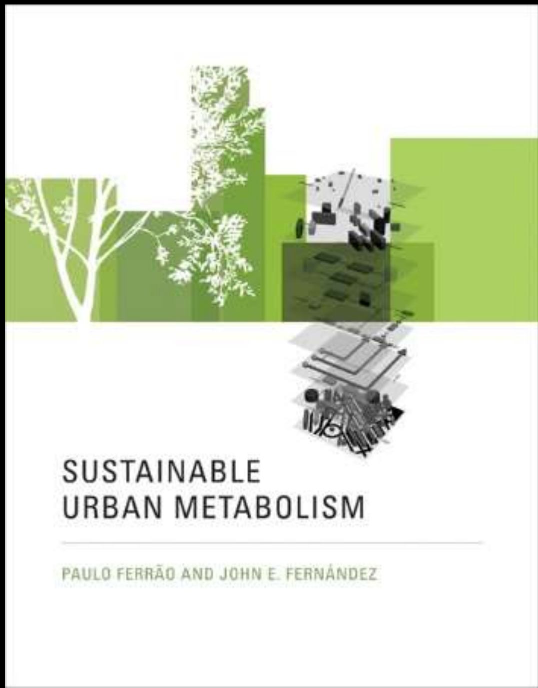
Austin WATER

The Elemental City: Cycles, Services, and Urban Ecology

Kevin Michael Anderson, Ph.D.
Austin Water – Center for Environmental Research



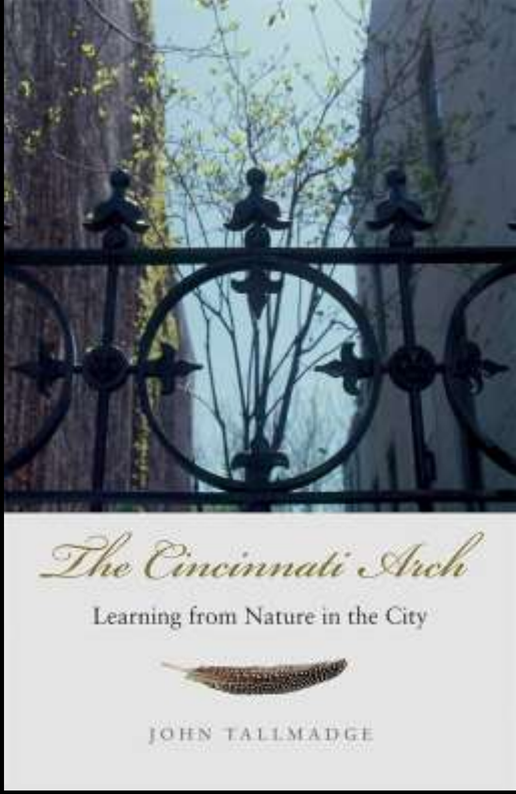




The Problem of Urban Nature

"Urban nature is not sublime…There's too much sterility in the form of roofs and pavement, and, oddly enough, there's also too much wildness, too many weeds and wooded borders and tangled banks, not to mention vacant lots going to brush.

Of course, "wilderness" won't do to describe such landscapes either. Despite the degree of wildness, there's too much human impact, too many alien species, too few large animals to meet the legal and cultural criteria.



The fact is that urban landscapes are just too mixed up, chaotic, and confused to fit our established notions of beauty and value in nature.

Maybe it's not really nature at all, not a real ecosystem, just a bunch of weeds and exotics mixed up with human junk."

John Tallmadge
The Cincinnati Arch: Learning from Nature in the City
(2004)

Perspectives on Nature and the City

Narratives of Urban Nature

Narrative of Redemptive Urban Nature – The Wild and The Pastoral

Narrative of Restorative Urban Nature

Version 1 - Architecture and Urban Design/Planning

Version 2 - Restoration Ecology and Conservation Biology

Narrative of Functional Urban Nature - Ecology and the City

- The ecology 'in' cities or The ecology 'of' cities
- Urban Ecology = Ecology of Cities

Urban Ecology

What is a City? An Ecosystem


Colonial Nesting Mammals
Congress Avenue Bridge 1.5 -2 Million
Mexican Free-tailed Bats

Colonial Nesting Mammals

Black-Tailed Prairie Dog



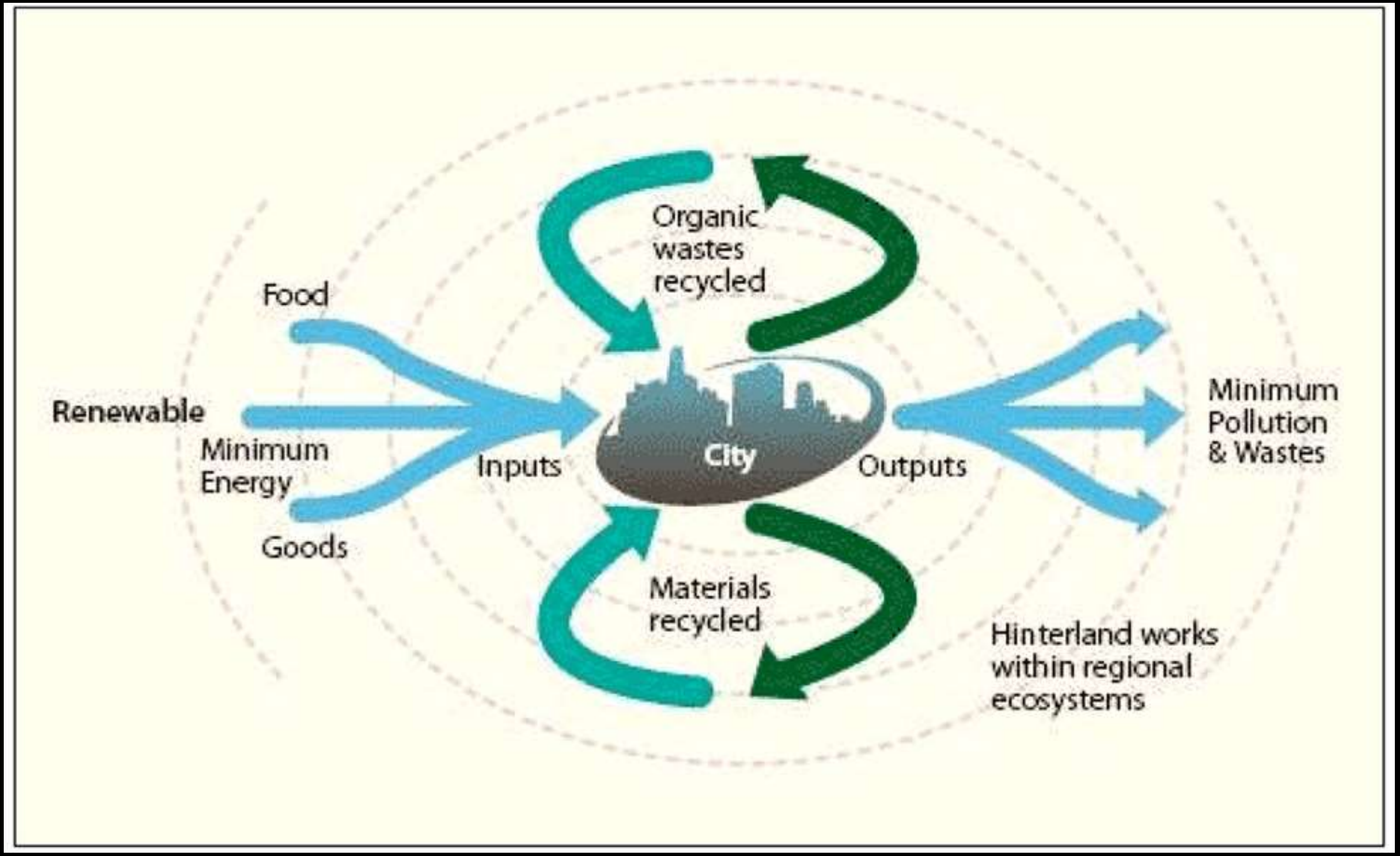
Colonial Nesting Mammals

The Socioecological City

The Socioecological Elemental City

The Problem of Urban Ecology

The ecology "in" cities
or
The ecology "of" cities



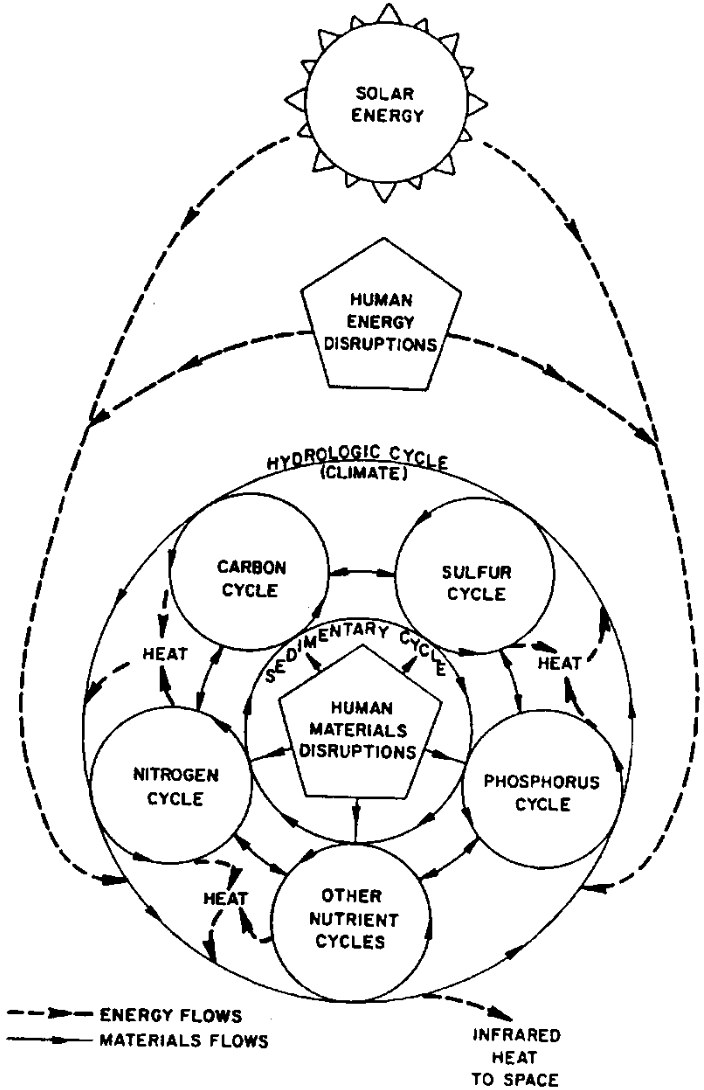


Figure 5.1. Climate and life are linked by a complex web of interconnected cycles. Life on earth depends on the cycling of nutrients through air, water, soil, and living things. The climate mediates the flow of materials through these global cycles. Solar energy degrades to heat at each stage of the cycling process and is eventually returned to space as infrared radiation. The composition of the earth's atmosphere regulates the radiative balance on earth between absorbed solar energy and emitted infrared energy, which, in turn, controls the climate.
Source: Schneider and Morton 1981.

Urban Ecology

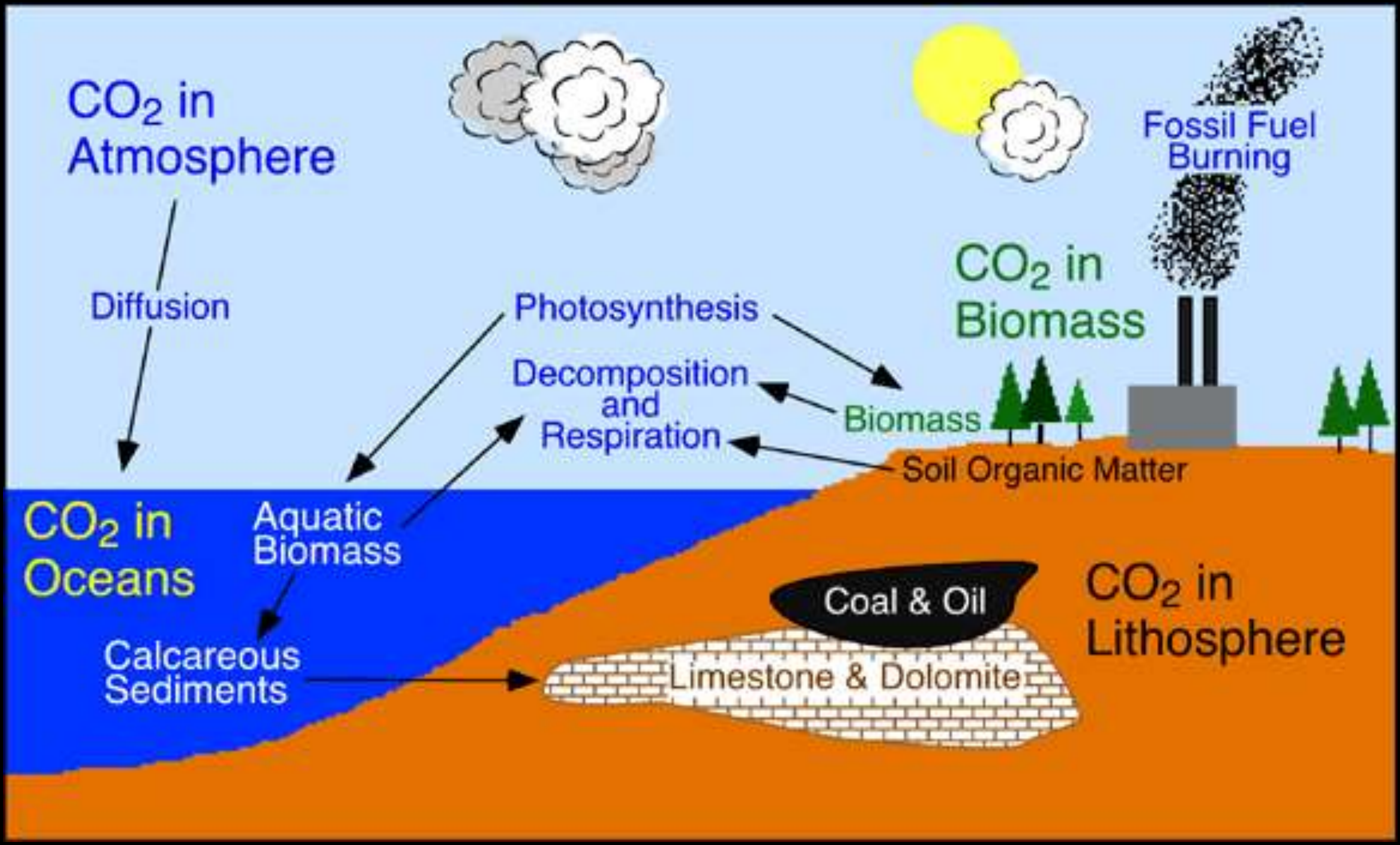
The Elemental City

Ecosystem Cycles

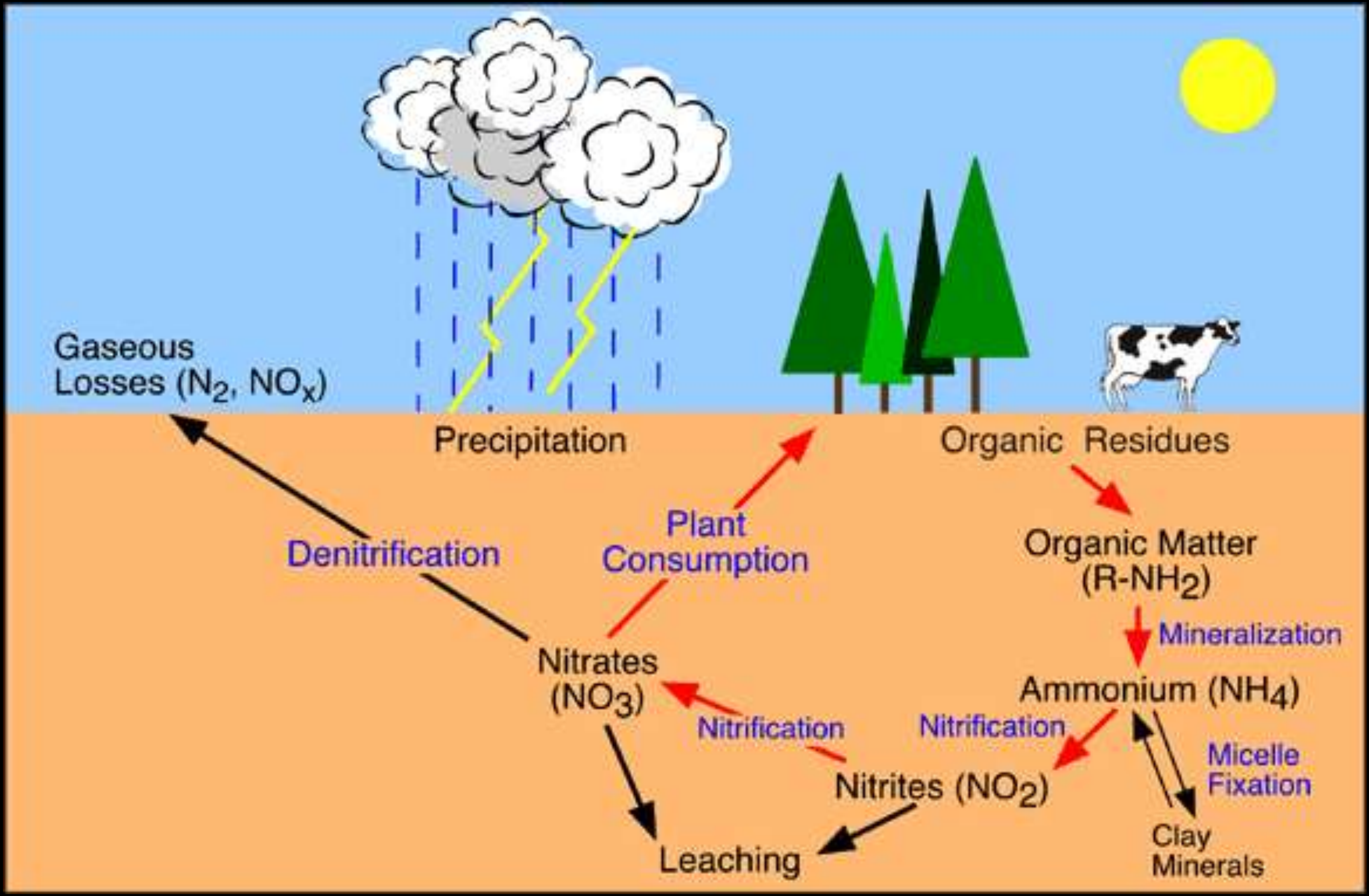
[Biogeochemical Cycles]

- Water cycle
- Carbon cycle
- Nitrogen cycle
- Phosphorus cycle
- Other trace minerals and metals

The Carbon Cycle



The Nitrogen Cycle

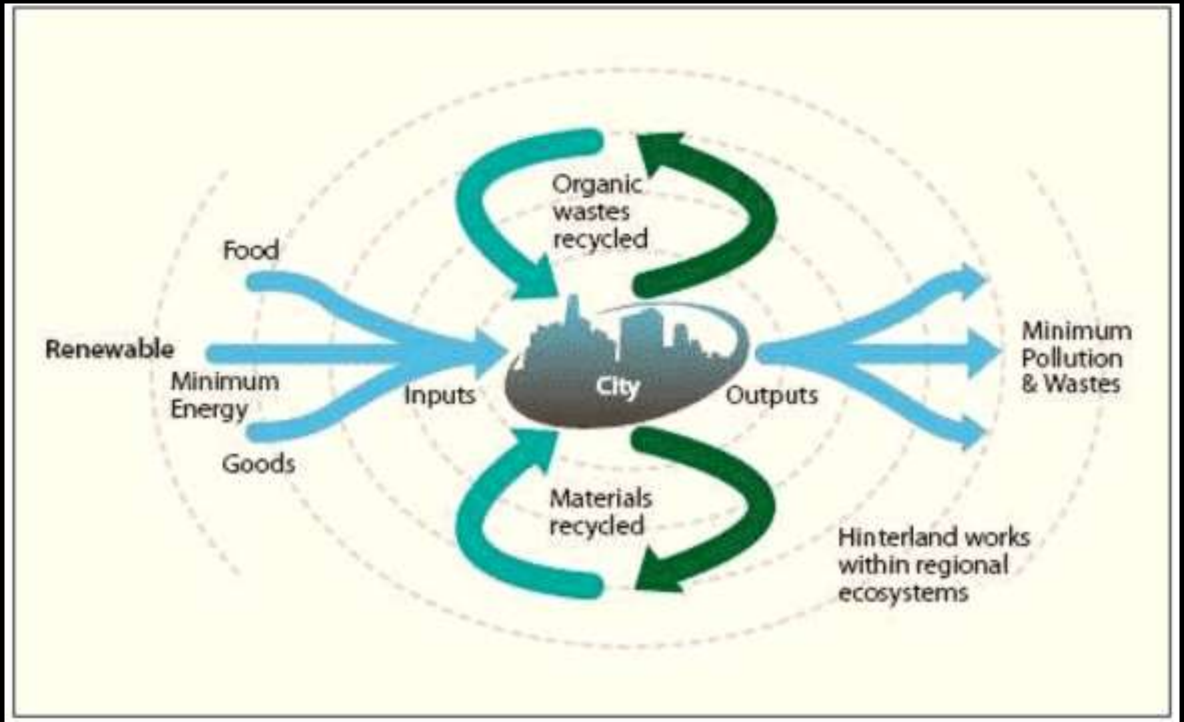


Urban Ecology and the Socioecological City

Narrative of Functional Nature

Version 1 – Engineering and "Resource" Management
Version 2 – Urban Environmental History
Version 3 – Urban Political Ecology

Version 4 – Science and Environmental Management - Urban Ecology



Narrative of Functional Urban Nature - ***The Idea of Urban Metabolism***

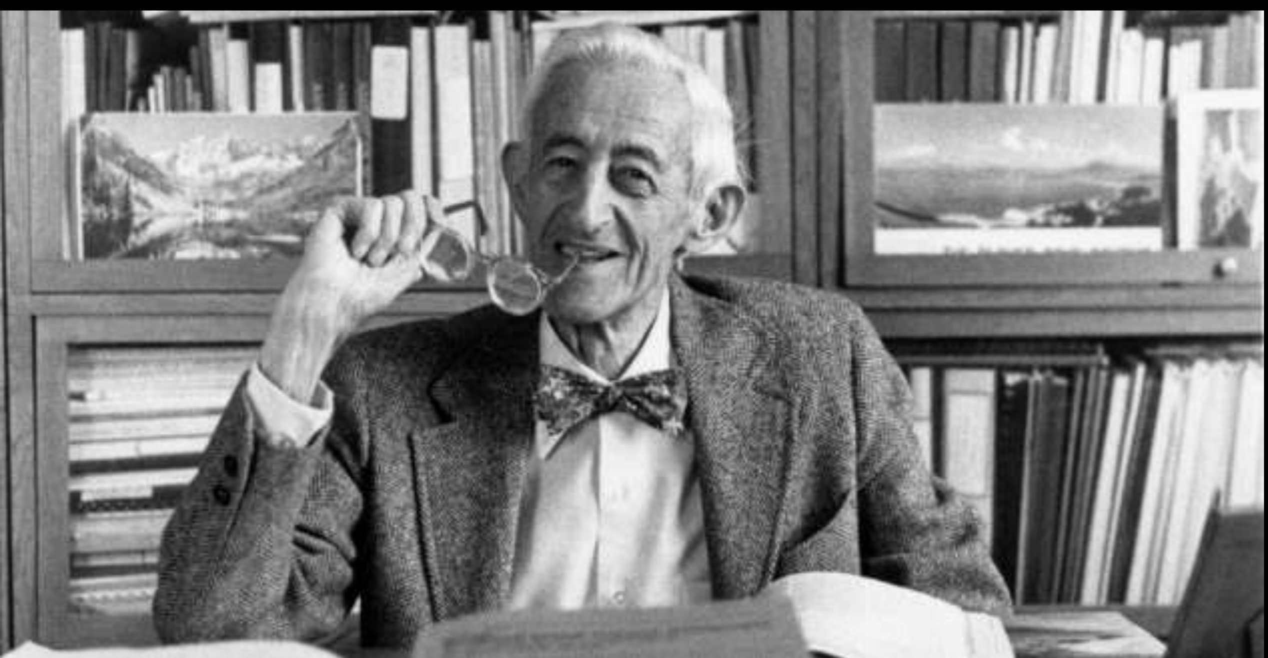
Version 1 - Engineering and Resource Management - Cities as Material Systems

Process and Functionality – Inputs and Outputs – Linearity

“The metabolic requirements of a city can be defined as the materials and commodities needed to sustain the city’s inhabitants at home, at work and at play…The ***metabolic cycle*** is not completed until wastes and residues of daily life have been removed and disposed of with a minimum of nuisance and hazard.”

- Abel Wolman (1892 – 1989) “The metabolism of cities” *Science* (1965)

Urban Sustainability = Equilibrium = Homeostasis



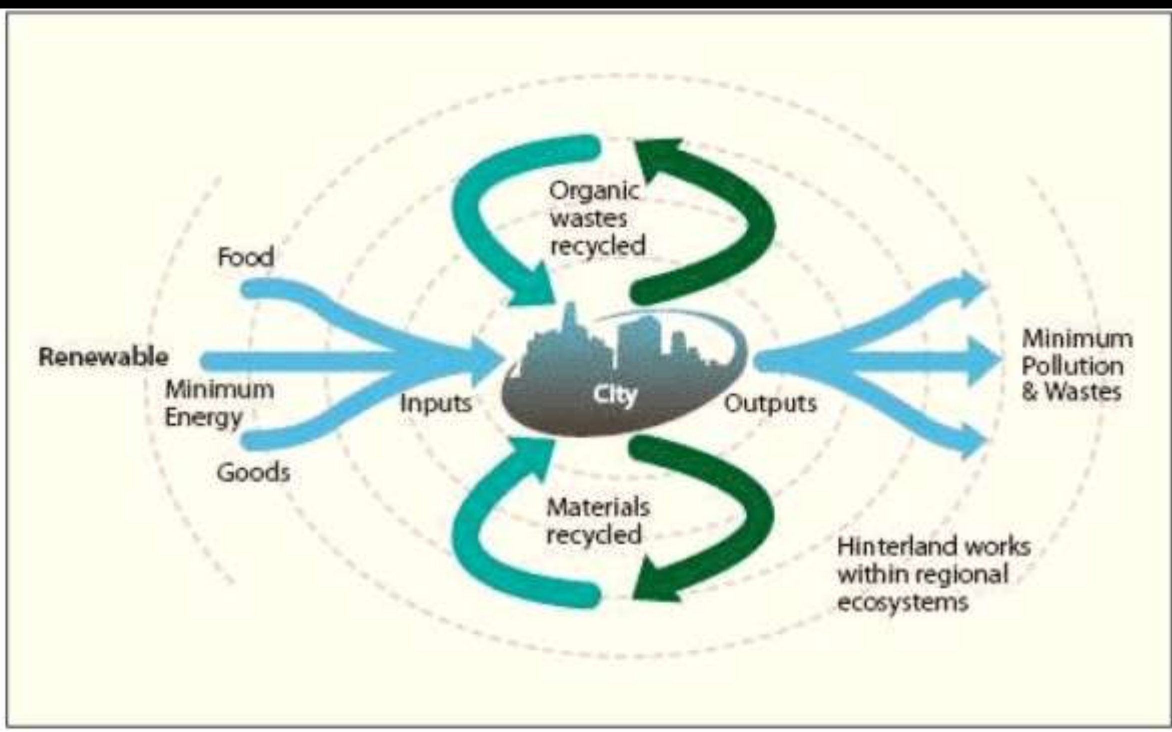
Urban Metabolism – The Earth as an "urban system"

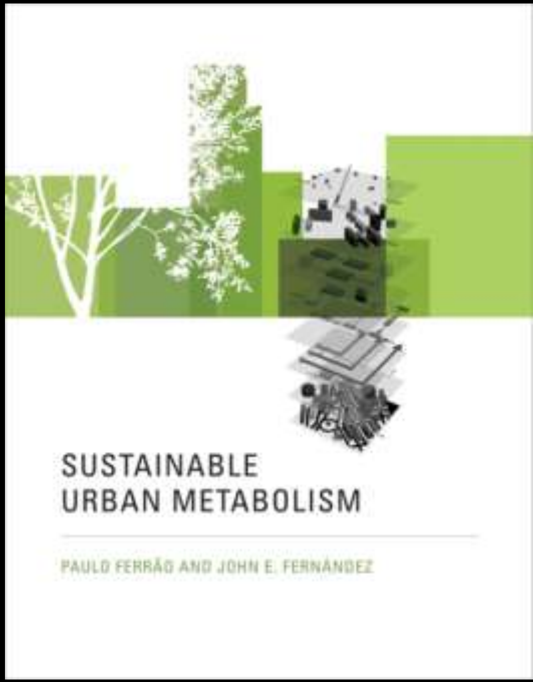
Environmental Engineering - Process and Functionality

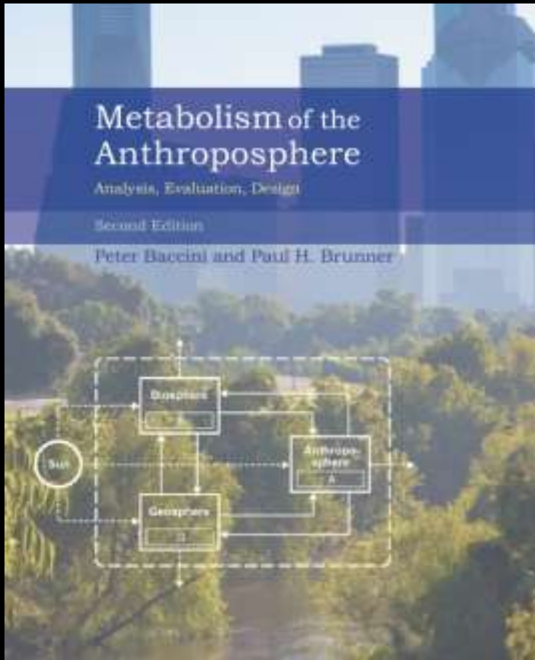
This global network of urban systems, including ecosystems, is the anthroposphere; the physical flows and stocks of matter and energy within it form its metabolism.

The characterization of these flows and the relationships between anthropogenic urban activities and natural processes and cycles defines the urban metabolism.

Urban Sustainability = Equilibrium = Homeostasis





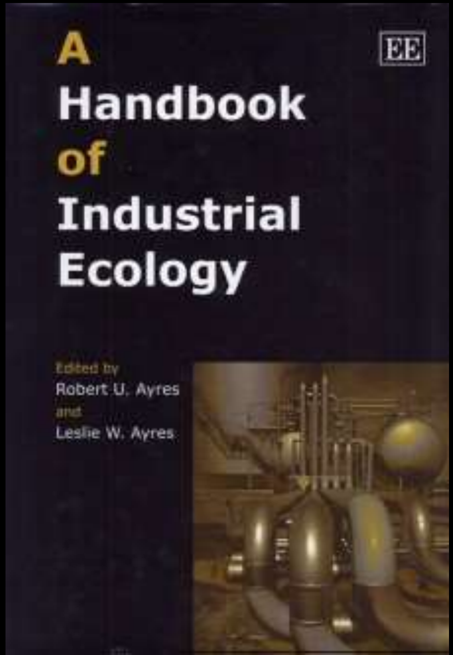


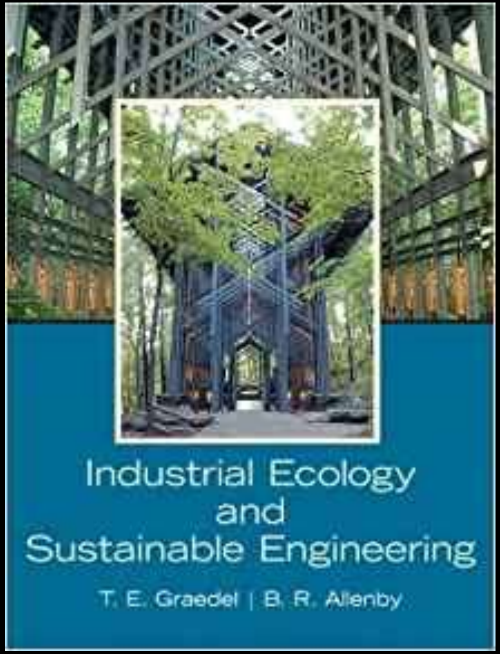
Narrative of Functional Nature

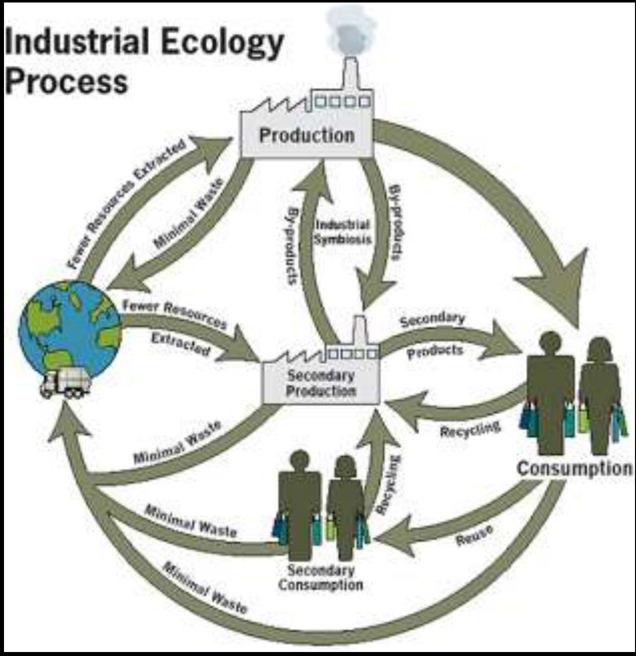
Industrial Ecology and the Earth as an “industrial ecosystem”

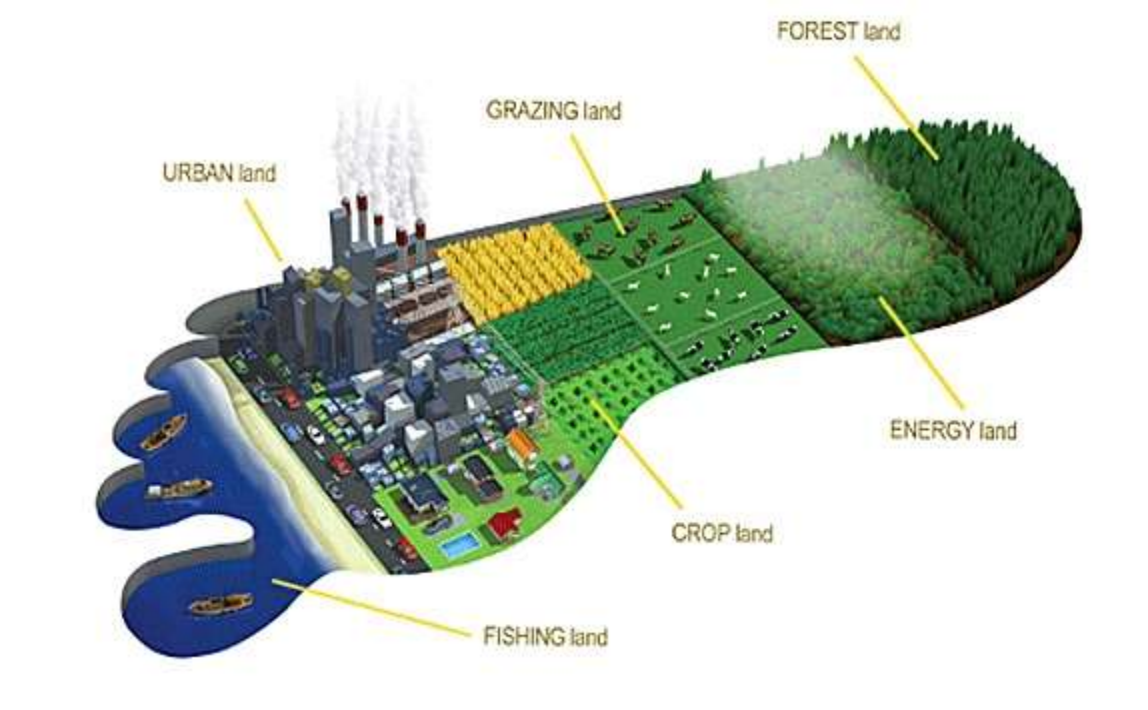
Industrial ecology (IE) is **the study of material and energy flows through industrial systems**. The global industrial economy can be **modelled as a network of industrial processes** that extract resources from the Earth and transform those resources into commodities which can be bought and sold to meet the needs of humanity.

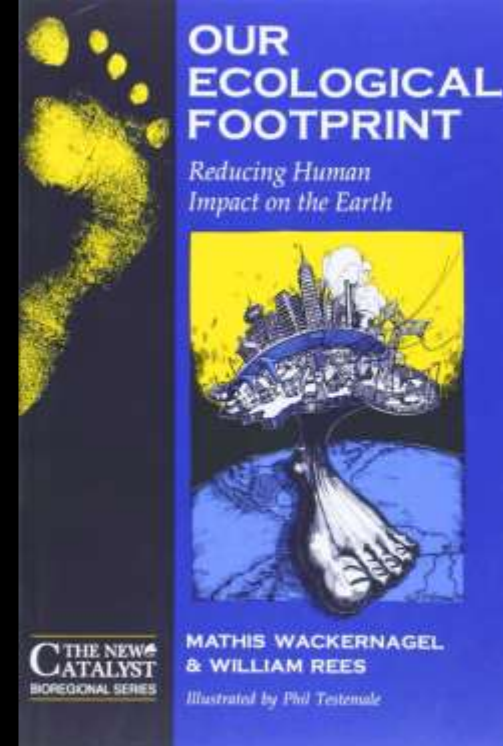
Industrial ecology seeks **to quantify the material flows and document the industrial processes** that make modern society function. Industrial ecologists are often concerned with the impacts that industrial activities have on the environment, with use of the planet's supply of natural resources, and with problems of waste disposal.



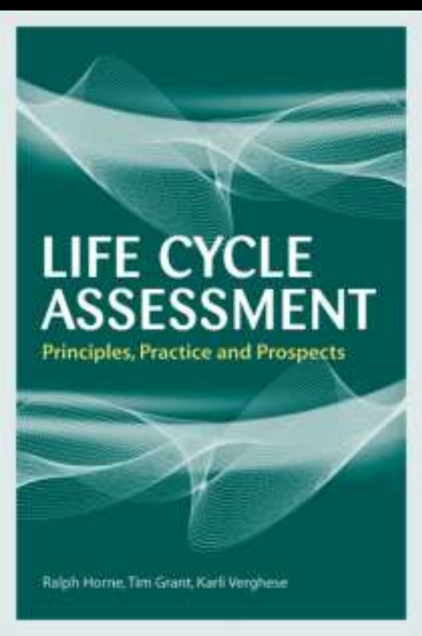


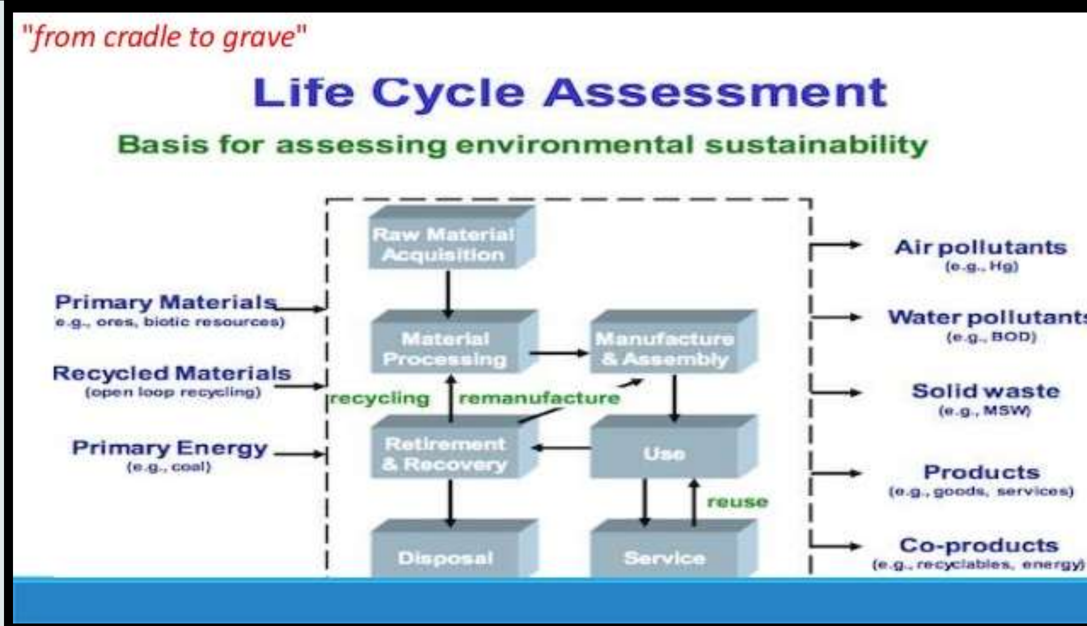


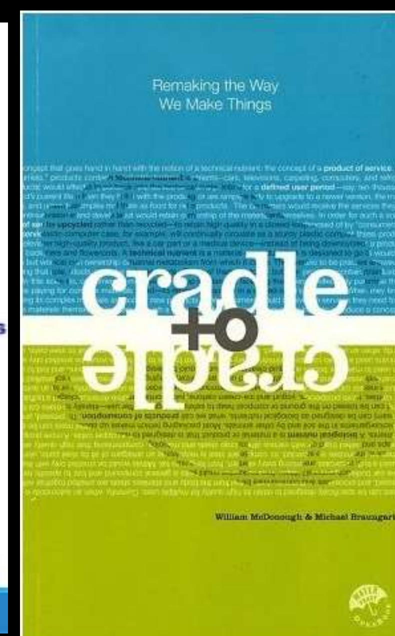




Quantify the Material Flows







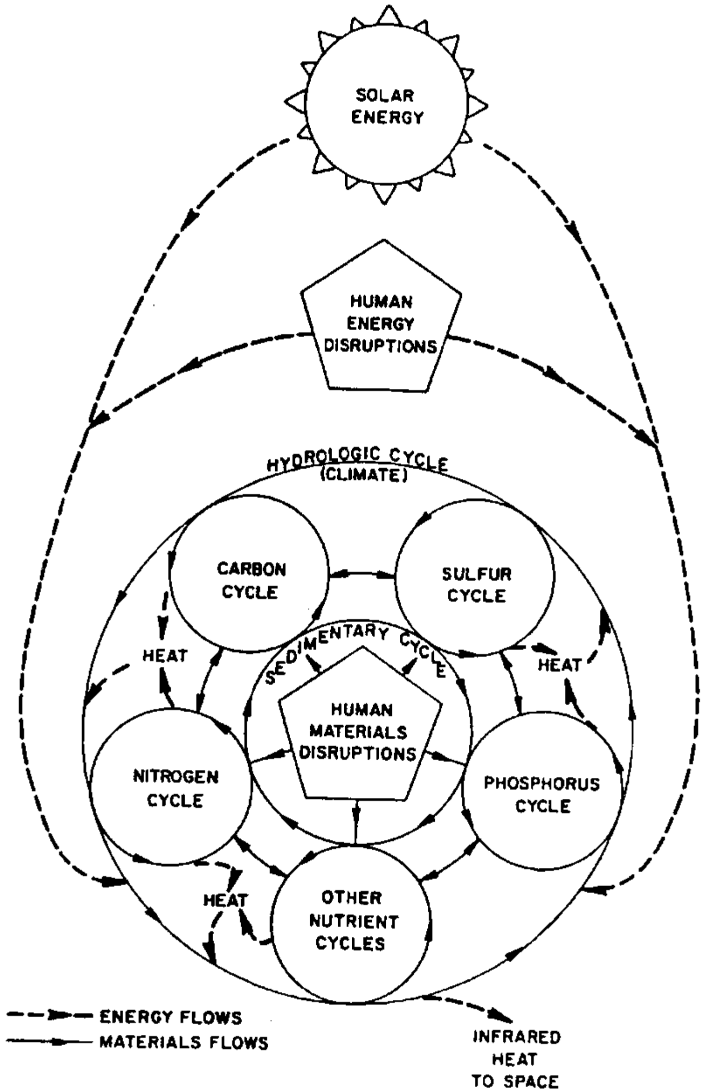


Figure 5.1. Climate and life are linked by a complex web of interconnected cycles. Life on earth depends on the cycling of nutrients through air, water, soil, and living things. The climate mediates the flow of materials through these global cycles. Solar energy degrades to heat at each stage of the cycling process and is eventually returned to space as infrared radiation. The composition of the earth's atmosphere regulates the radiative balance on earth between absorbed solar energy and emitted infrared energy, which, in turn, controls the climate.

Source: Schneider and Morton 1981.

Industrial Ecology

Urban Metabolism

Ecosystem Cycles

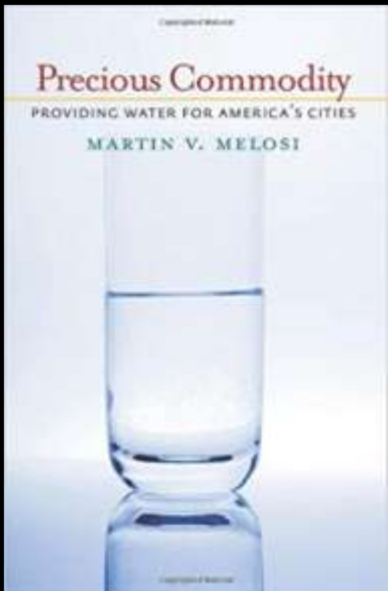
[Biogeochemical Cycles]

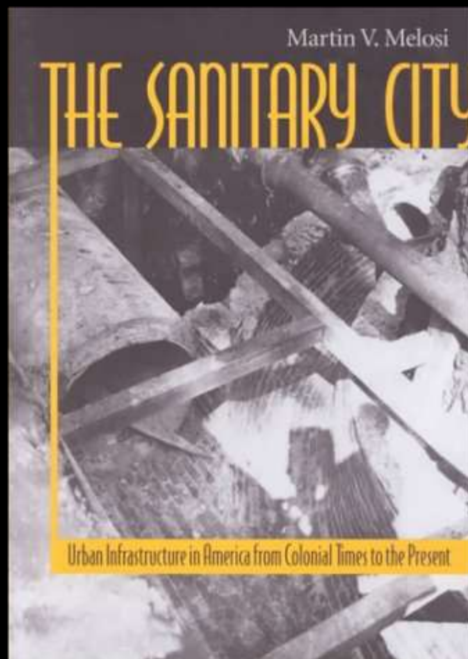
- Water cycle
- Carbon cycle
- Nitrogen cycle
- Phosphorus cycle
- Other trace minerals and metals
- Short-circuiting Cycles
- **Recycling and Sustainability?**

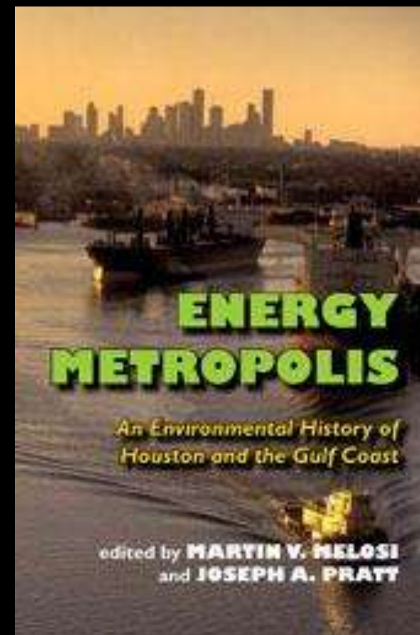
Version 2 – Urban Environmental History

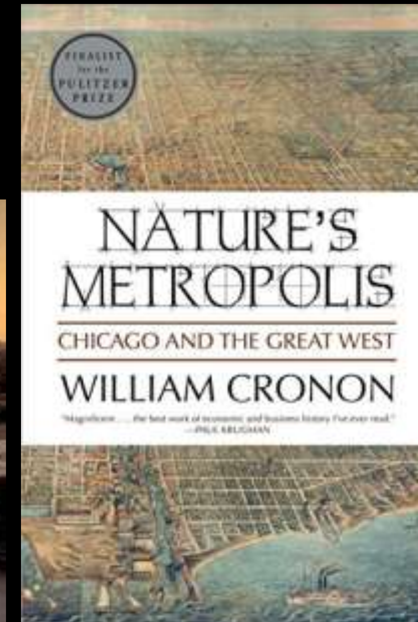
Urban Infrastructure and Urban Development

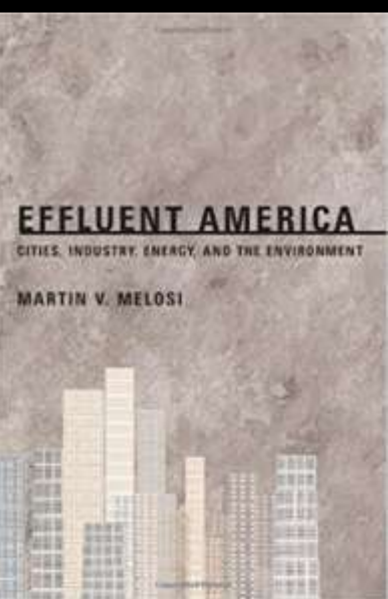
Urban Planning, History, Power, Economics

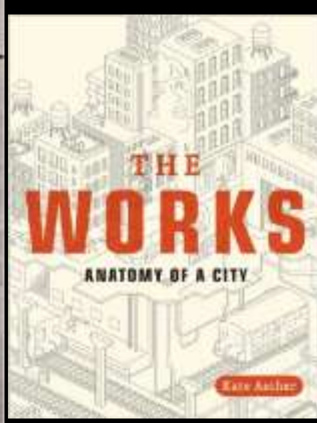


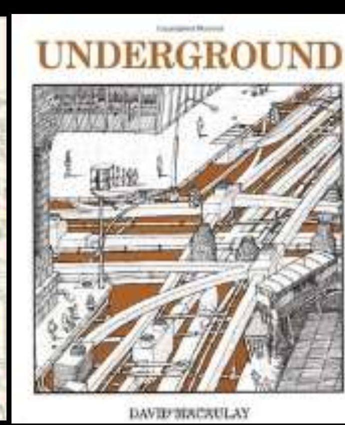


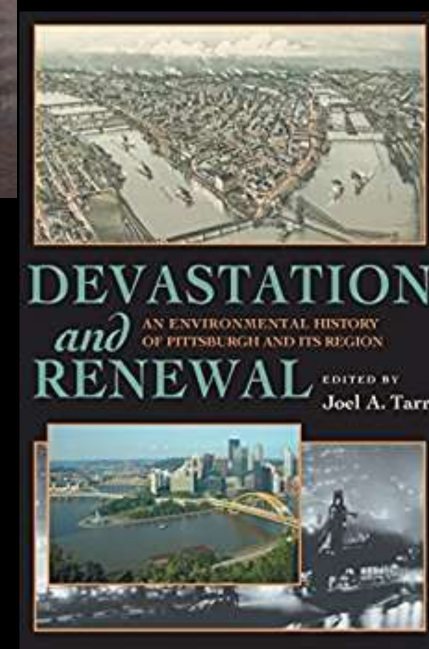












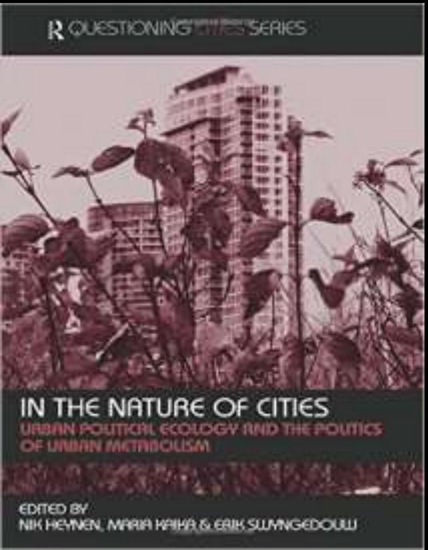
Version 3 – Urban Political Ecology

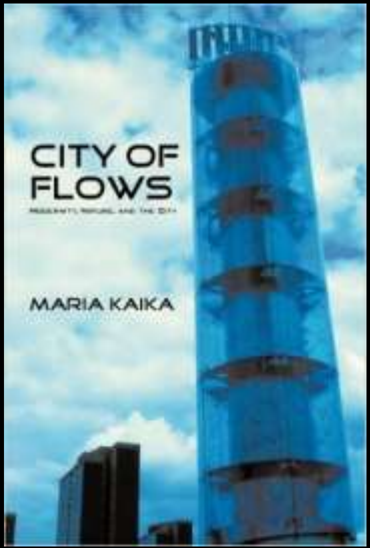
Urban Metabolism + Sociecological + Politics/Capital

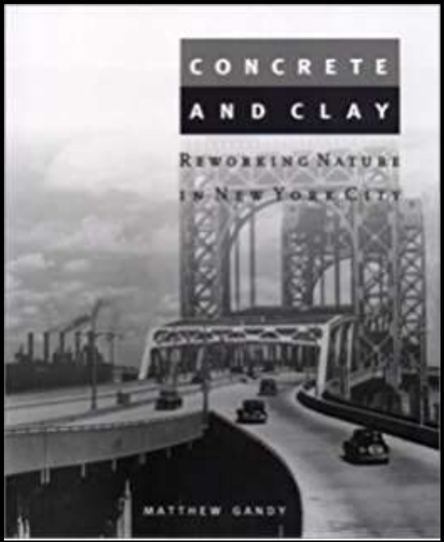
“To the extent that cities are ***produced through socio-ecological processes***, attention has been paid to the political processes through which particular socio-environmental urban conditions are made and remade.” - Nik Heynen, et. al. (2006) *In the Nature of Cities*

“Cities are dense networks of interwoven socio-spatial processes that are simultaneously human, material, natural, discursive, cultural, and organic…***the analysis of the circulation of socially and physically metabolized ‘nature’”*** - Maria Kaika (2005) *City of Flows: Modernity, Nature, and the City*

“Nature is a biophysical fabric or network“
- Matthew Gandy (2002) *Concrete and Clay: Reworking Nature in New York City*







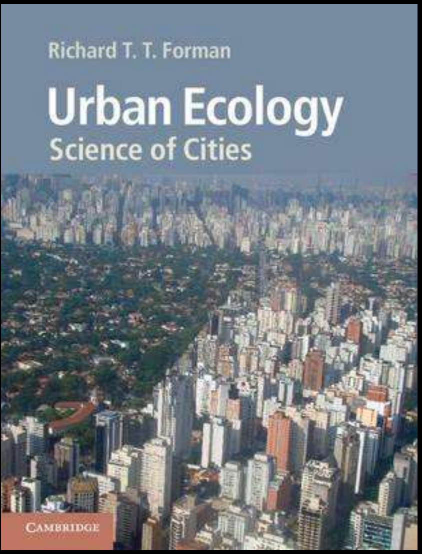
Version 4 – Science and Environmental Management

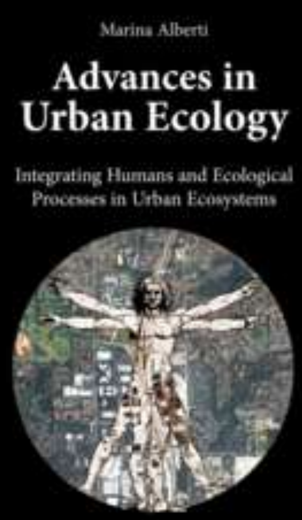
Urban Ecology

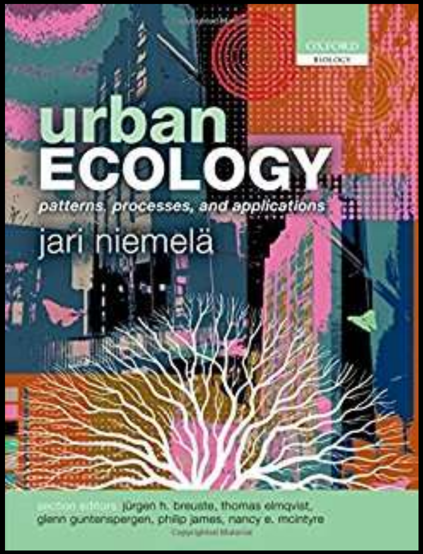
Urban ecology is the scientific study of the relation of living organisms with each other and their surroundings **in the context of an urban environment**.

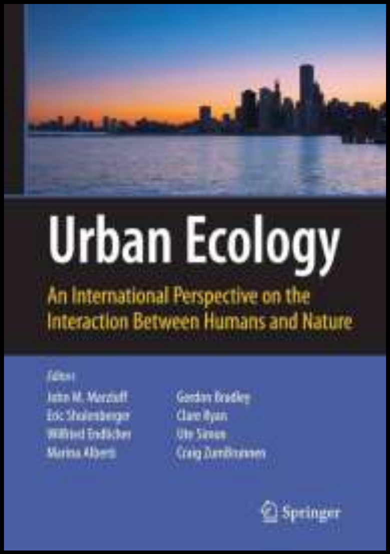
The urban environment –

- Dominated by high-density residential and commercial buildings, paved surfaces, and other urban-related
- The Problem - A unique landscape ***dissimilar to most previously studied "natural" ecosystems in the field of ecology.***

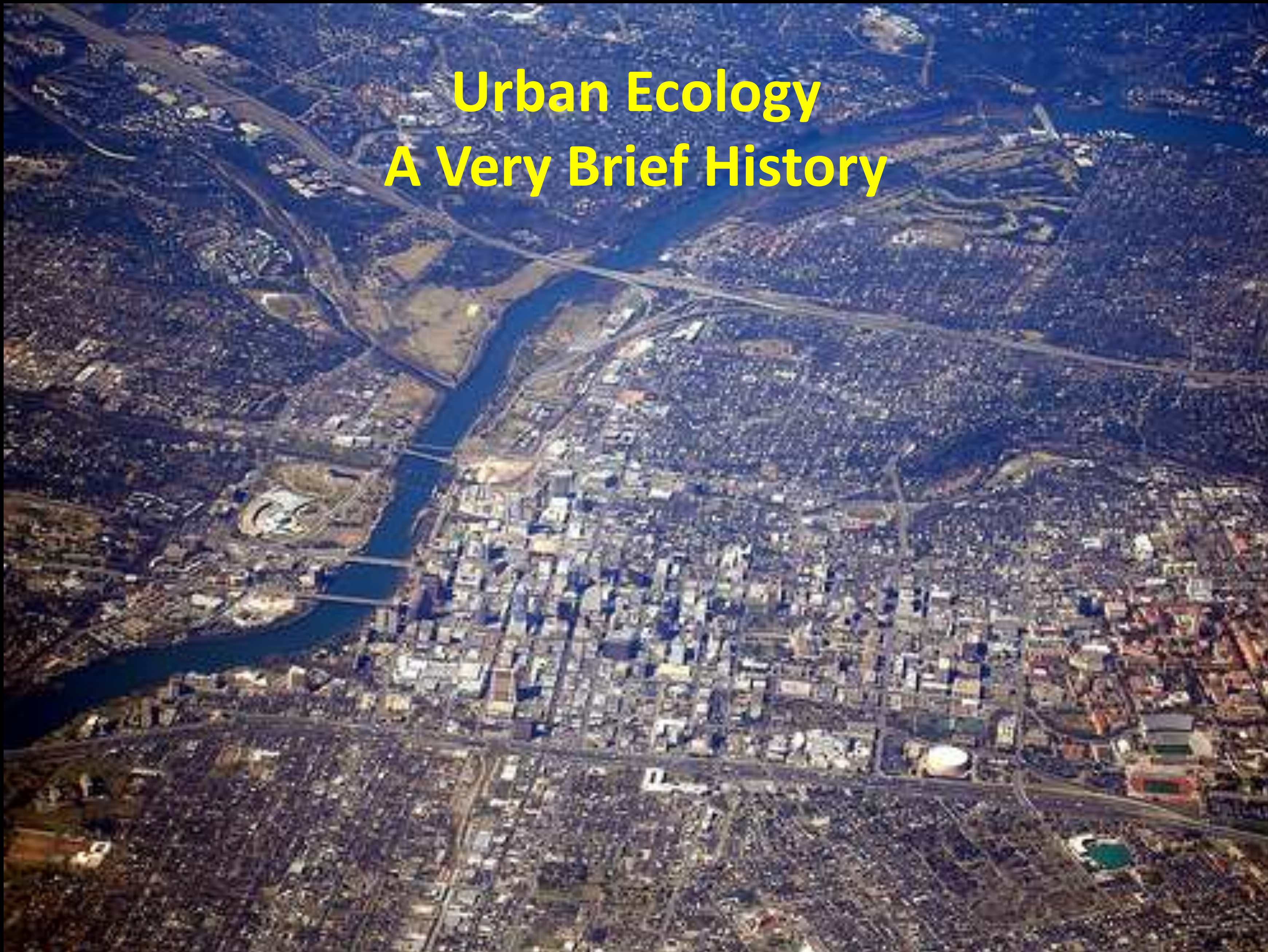






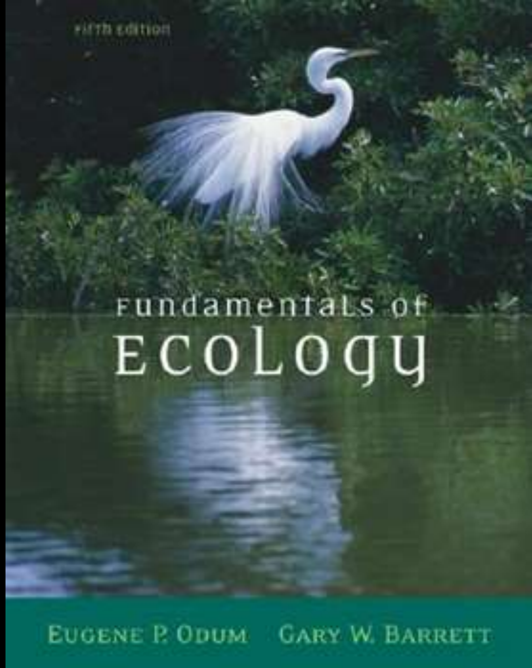


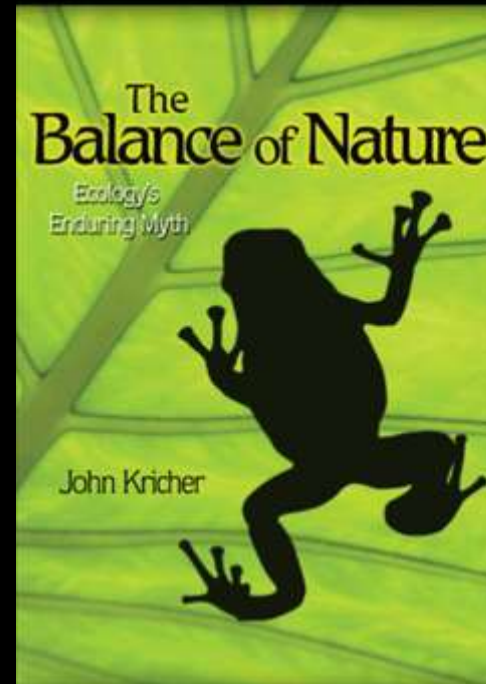
Urban Ecology
A Very Brief History

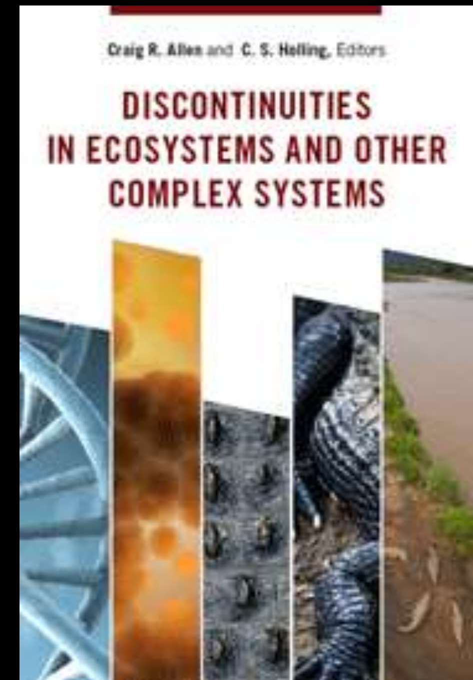


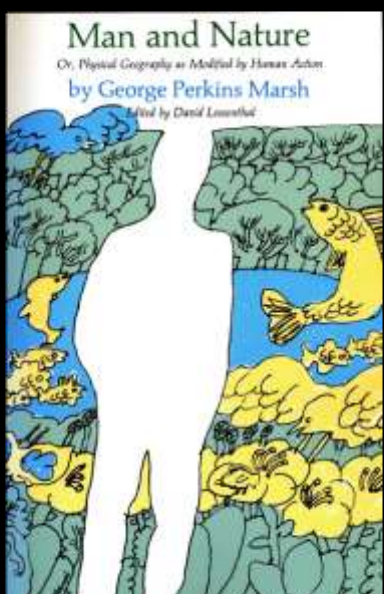
“Old” Ecology 1864-1960s – Humans the Great Disruptors

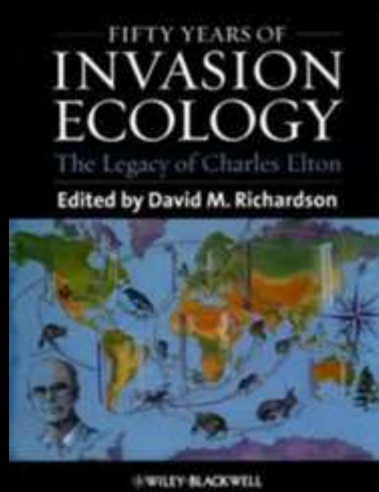
“New” Ecology 1973 onwards – Disruption is how nature works

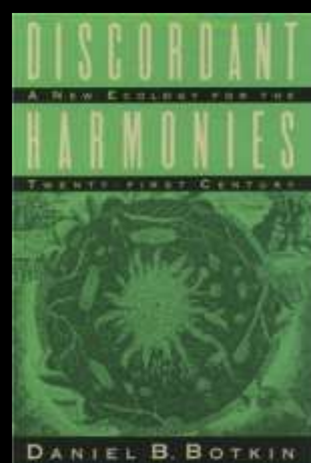












German urban ecologist - Herbert Sukopp

The Problem of Urban Ecology - The ecology "in" cities or The ecology "of" cities

One of the eminent pioneers of urban ecology who works in Berlin since the late 1950s and is often referred to as the founder of the "Berlin School of Urban Ecology".

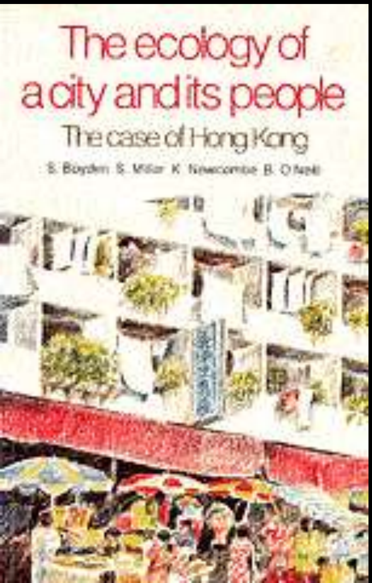
At a time when most ecologists sought out remote, pristine ecosystems, Sukopp and his colleagues focused on urban wastelands, known in German as Brachen. They reminded him of volcanic rubble—ecological clean slates ripe for species to colonize.

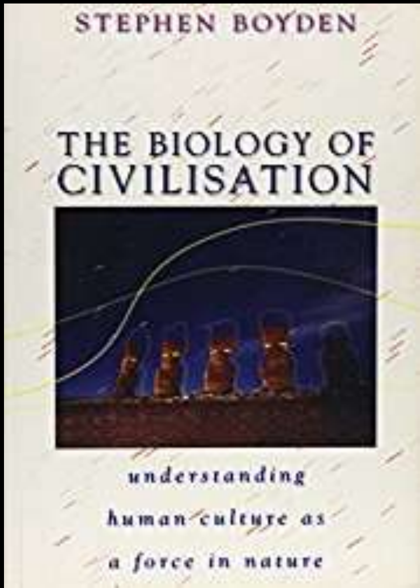
Urban ecosystems are: "***A cosmopolitan community of uniquely adapted organisms***"

The ecology “of” cities – Hong Kong and Man and the Biosphere

The Ecology of a City and its People: The Case Study of Hong Kong
Stephen Vickers Boyden, et. al. (1981)

- The first classic book on the ecology of a city.
- This book provides a comprehensive account of the Hong Kong Human Ecology Program which was the first comprehensive ecological study of a city and was composed of a multidisciplinary group of researchers from the Australia National University.
- The program started in 1972 and became the first pilot program of the UNESCO Man and the Biosphere Program (MAB) in 1974.



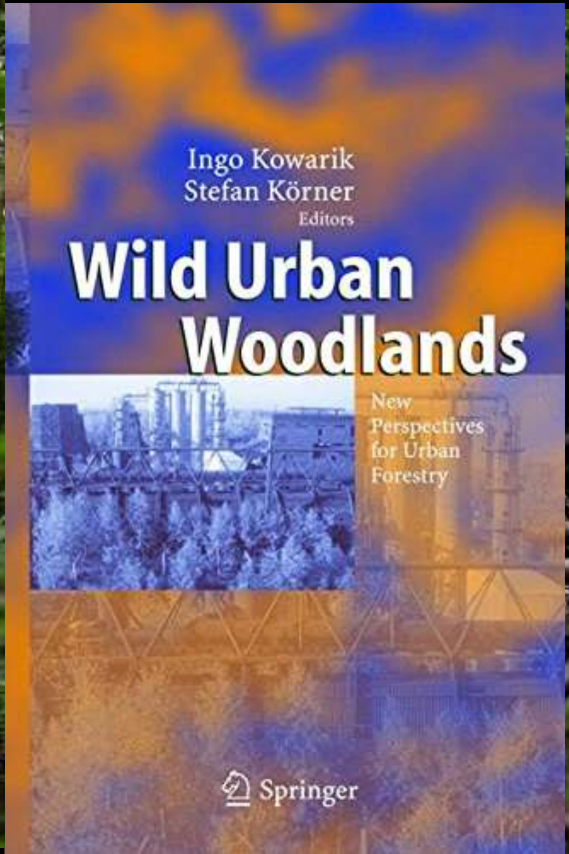


Ingo Kowarik

Professor of Ecosystem Science/Plant Ecology, Technische Universität Berlin, Germany

Understanding the Problem of Urban Ecology

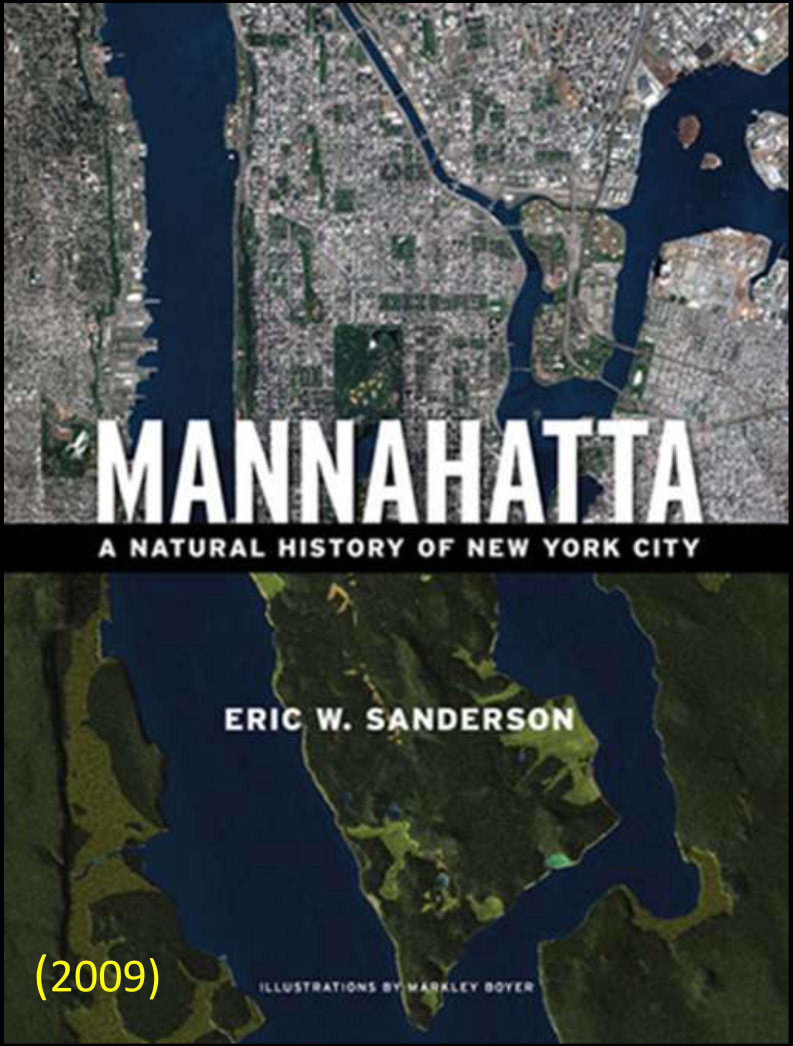
Retrospective Ecology vs. Prospective Ecology



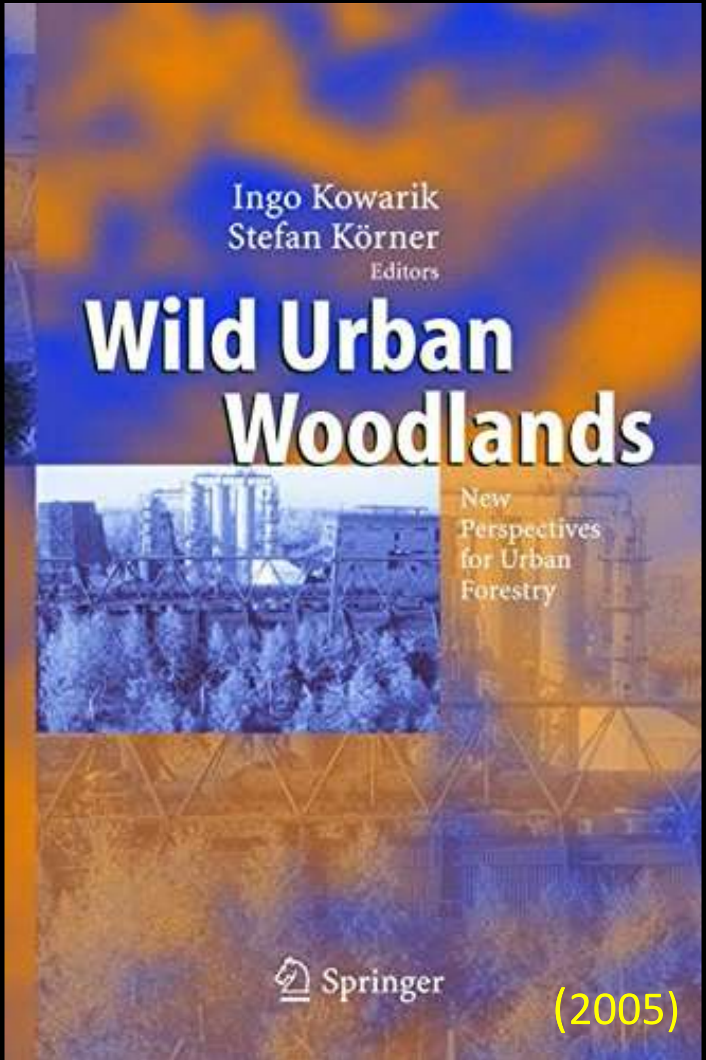
21st Century Ecology and the City

The Problem of Scientific Knowledge and Urban Ecology

Retrospective Ecology vs. Prospective Ecology



(2009)



(2005)

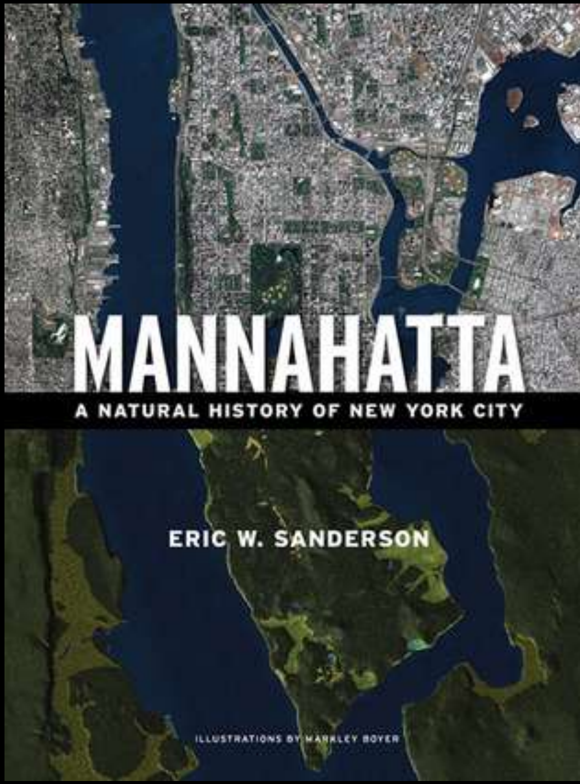
Retrospective Ecology, Historical Naturalness

American Urban Ecology – Perception Problem

Perceptions of American Urban Biologists, Ecologists, and Environmentalists

Good Nature vs. Bad Nature
Native vs. Nonnative

- The Mannahatta Project began in 1999, when landscape ecologist Dr. Eric Sanderson moved to New York City to work for the Wildlife Conservation Society….
- "to fully appreciate the concrete landscape of streets and buildings that was his new home, he would have to 'go back in time' to recreate the its ecology from the ground up"
- Going back to ***1609*** allows us to see what New York City was before it was a city and to reimagine the city's development in a way that would incorporate more of the natural cycles and processes (such as the hydrological cycle) ***that made the island the ecological gem that it was."***



Retrospective Ecology

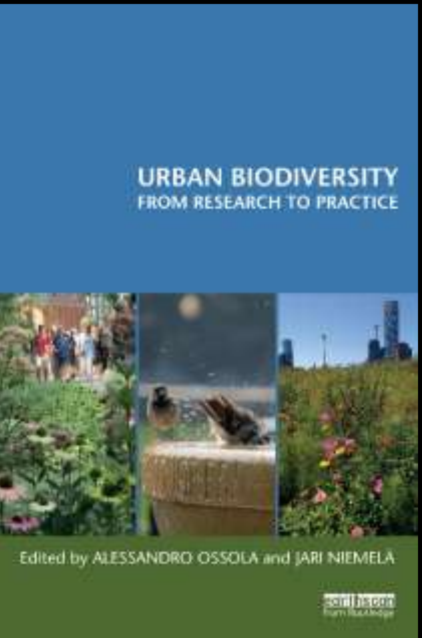
Perceptions of American Urban Biologists, Ecologists, and Environmentalists

Ecology "in" cities (not "of" cities)

Urban Ecosystems are: ***A weedland community of inappropriate nature*** needing restoration back to historical naturalness

"**(**Urban growth) replaces the native species that are lost with widespread "weedy" nonnative species. This replacement constitutes the process of biotic homogenization that threatens to reduce the biological uniqueness of local ecosystems."

Michael L. McKinney, "Urbanization, biodiversity, and conservation". *Bioscience* 52(10), (2002), 883–890.



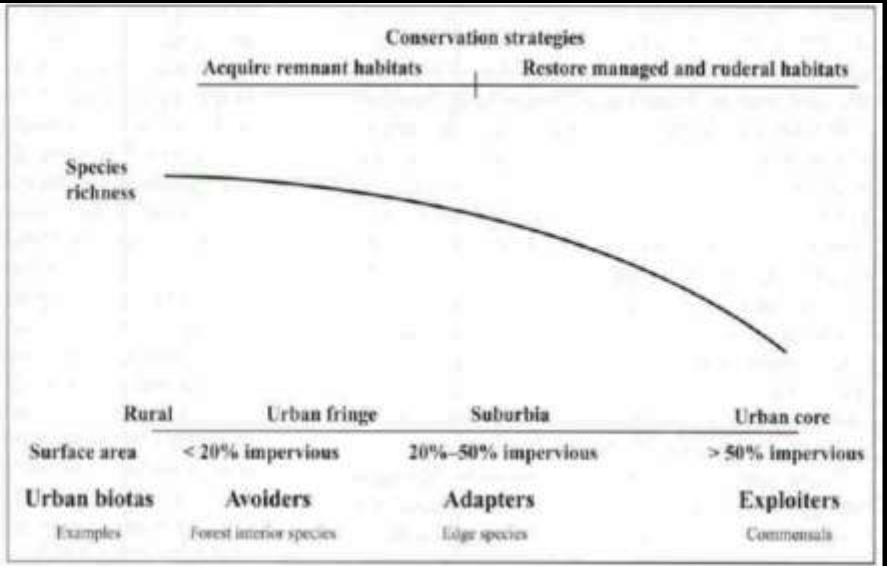
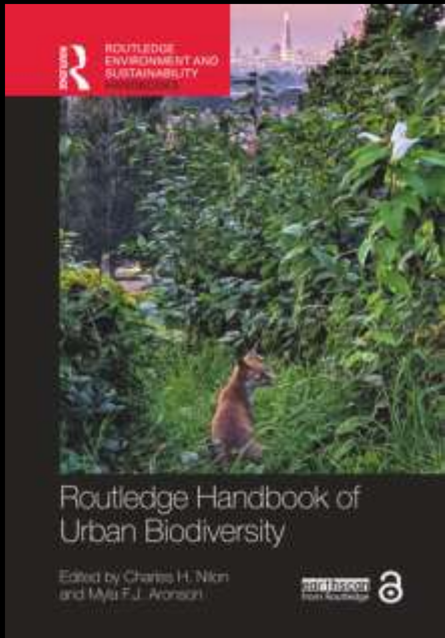


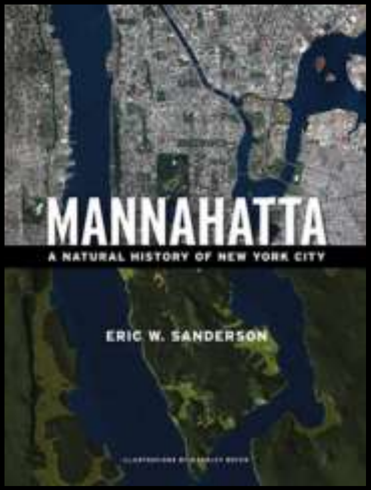
Figure 2. Urban–rural gradient. This is a very generalized and simplified depiction of changes in surface area, species richness, and composition, as compiled from a number of sources discussed in the text. Two basic conservation strategies with respect to urban sprawl are shown at the top.



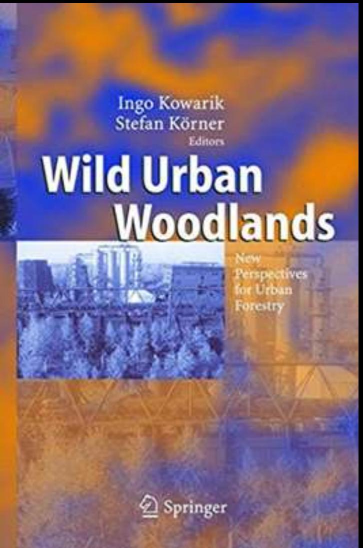
Retrospective Ecology vs. Prospective Ecology

Retrospective Naturalness - Native Historical Habitats

- "The point of reference is therefore, **pristine vegetation uninfluenced by humans**. Based on the cultural history of the relevant area, **the reference period may lie decades or a few millennia in the past**."
- "remnants of pristine woodlands are **most natural**."
- "the development back to nearly natural or **natural woodlands composed of historical native species can be analyzed well**."



The Problem of Wild Urban Woodlands

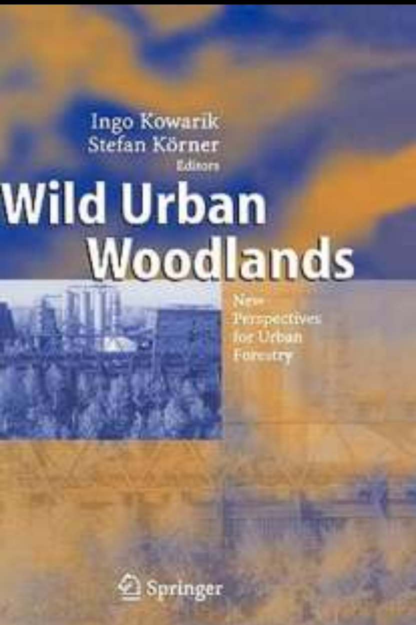


"With the evaluation of **new development of 'wild' urban woodlands**, however, the traditional concept of naturalness oriented toward ***historical comparisons runs aground***."

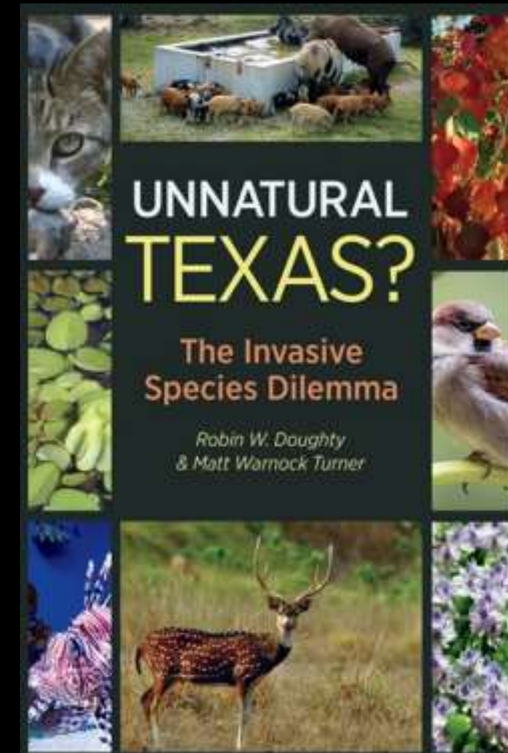
New/Novel Wild Urban Woodlands cannot be "analyzed well" with a list of historical native species

Prospective naturalness?
Permanence and Change

The Problem of Wild Urban Woodlands – Waller Creek 7th Steet Bridge



2024

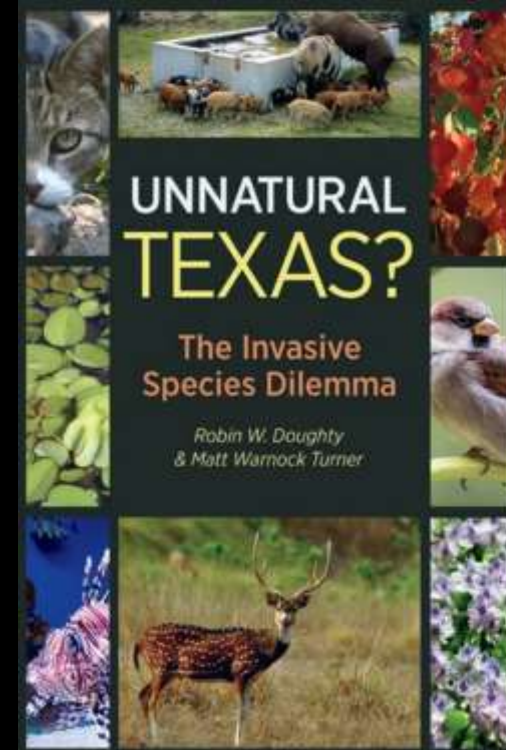


2005

2009

2012

2017



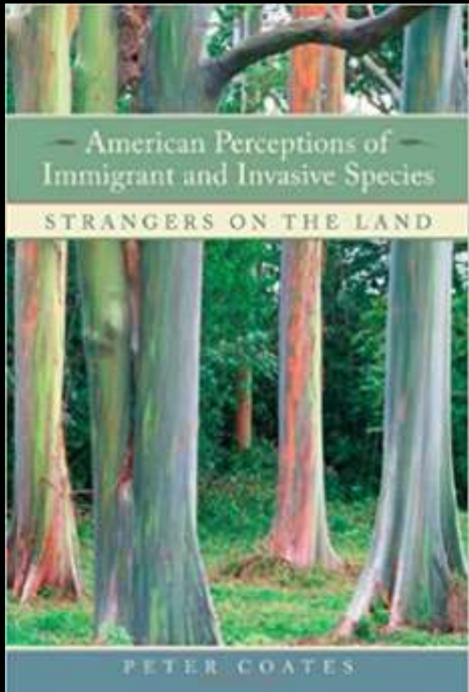
"Maybe it's not really nature at all, not a real ecosystem, just a bunch of weeds and exotics mixed up with human junk."

Narrative of Socioecological War – Invasive Species

The Worst of the Wild - **non-native species** - must be eradicated because they are disruptive aliens. The most controversial of these aliens are called "invasive species".

- *Trash Animals: How We Live with Nature's Filthy, Feral, Invasive, and Unwanted Species* (2013)
- *American Perception of Immigrant and Invasive Species: Strangers on the Land,* Peter Coates (2006)

Retrospective/Restorative Urban Nature = Native Species

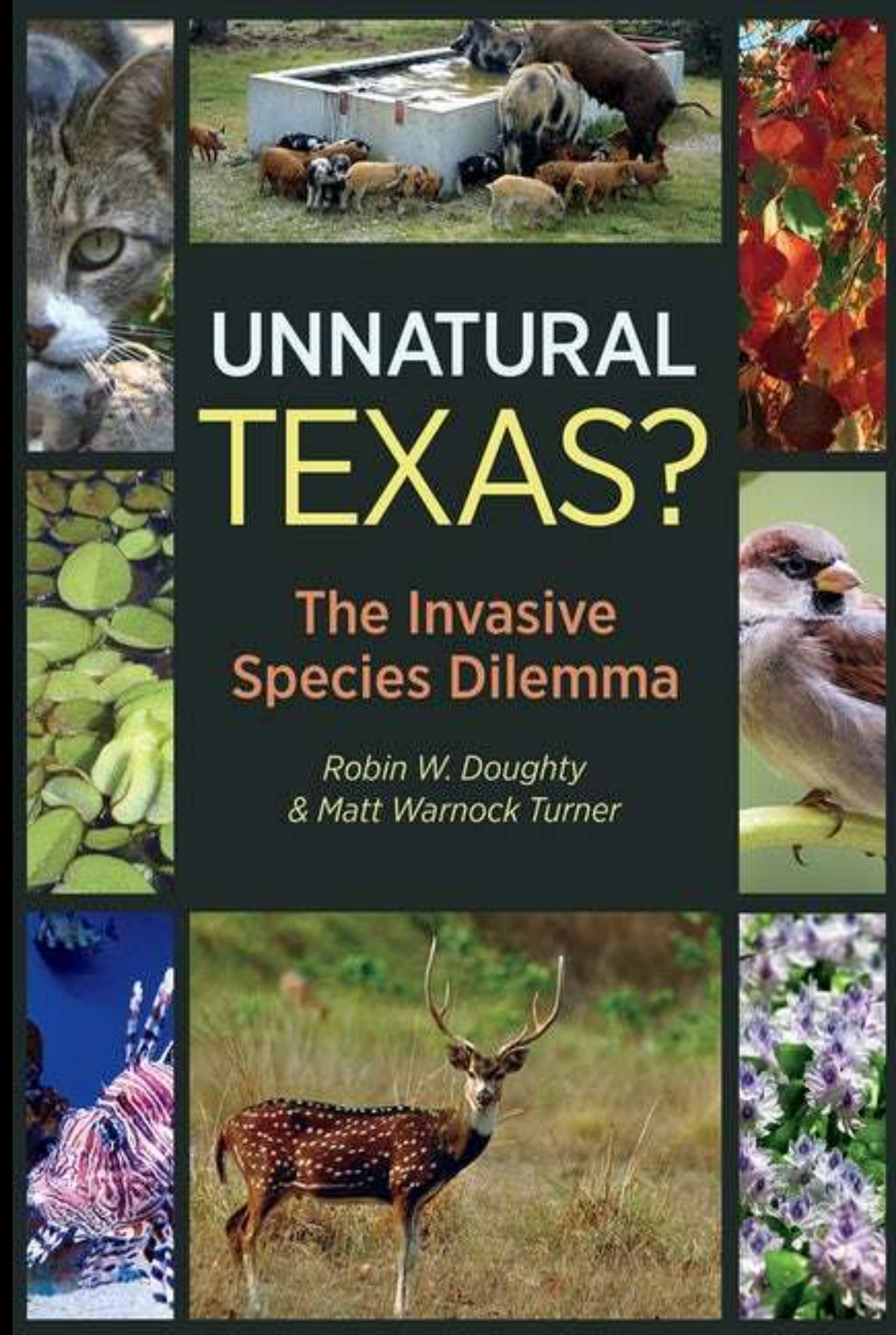


Narrative of Socioecological War
Permanence and Change

“The distinctions between native and invasive are not hard and fast, and perceptions of what is invasive have changed over the centuries…

There is not a one-size-fits-all solution for invasives, and removal or complete eradication may not be possible or even desirable.

The dilemma of what to do about invasive species also raises moral, social, economic, and cultural questions.”



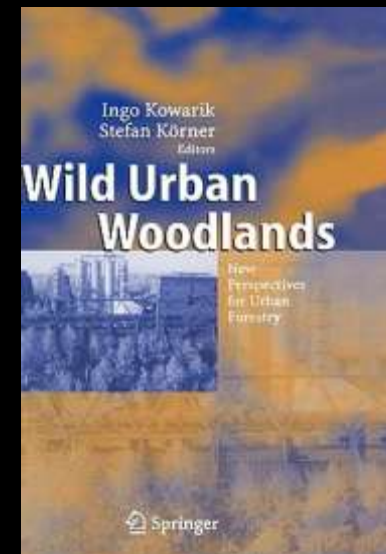
The Problem of Scientific Knowledge and Urban Ecology

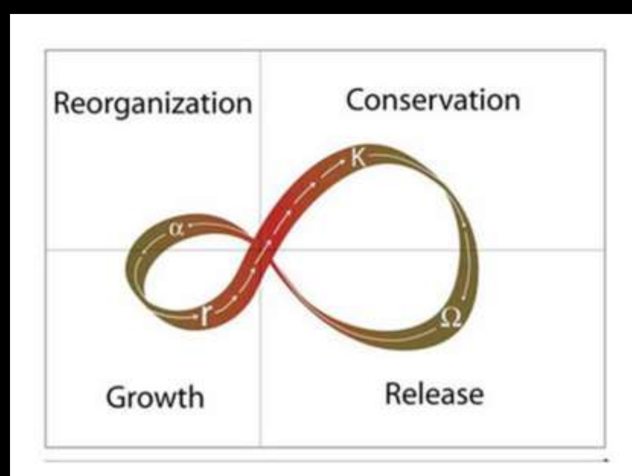
The Solution - Prospective Naturalness

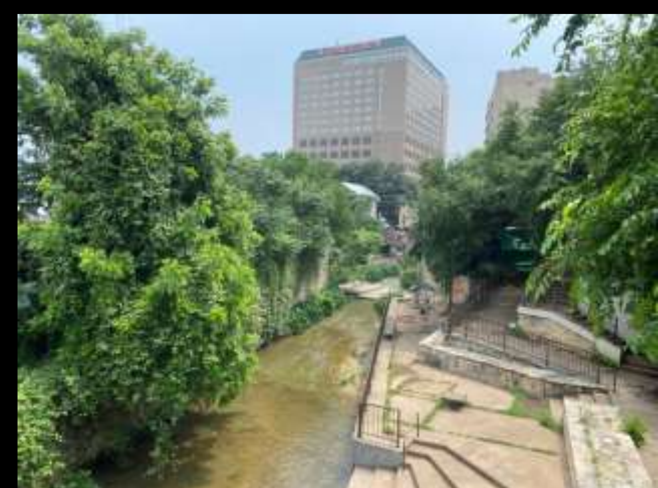
Permanence and Change = Process

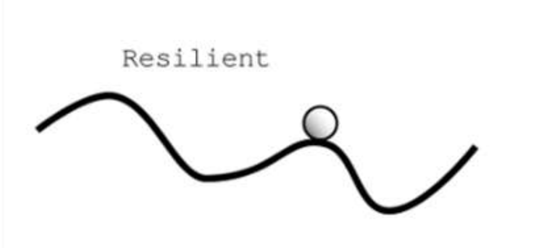
“**the reference point is not an original condition of a natural landscape**, but rather a condition defined based on the current site potential and the greatest possible degree of self-regulation.

From this perspective, therefore, **the natural capacity for *process*** is the central point, **not a particular, retrospectively determined and often idealized, *picture* of nature**.” - Kowarik





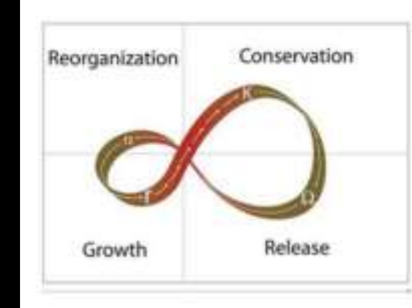




The New Ecology of Change

Ecological Resilience

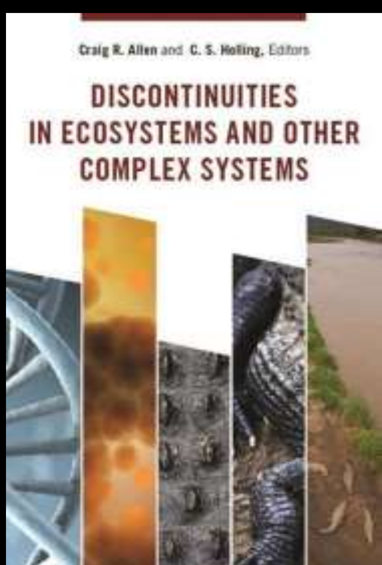
Permanence vs. Change

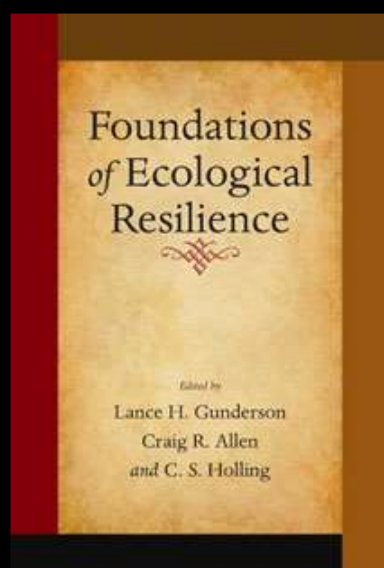


- **The concept of resilience** - first introduced by the Canadian ecologist C.S. Holling in 1973 ***to describe the persistence of natural systems in the face of changes in ecosystem variables due to natural or anthropogenic causes***.
- **Resilience**, derived from its Latin roots 'to jump or leap back', is the ability to recover from or adjust easily to misfortune or change.
- Ecosystem resilience is **the capacity of an ecosystem to tolerate disturbance**.

Holling, C.S. (1973). "Resilience and stability of ecological systems“

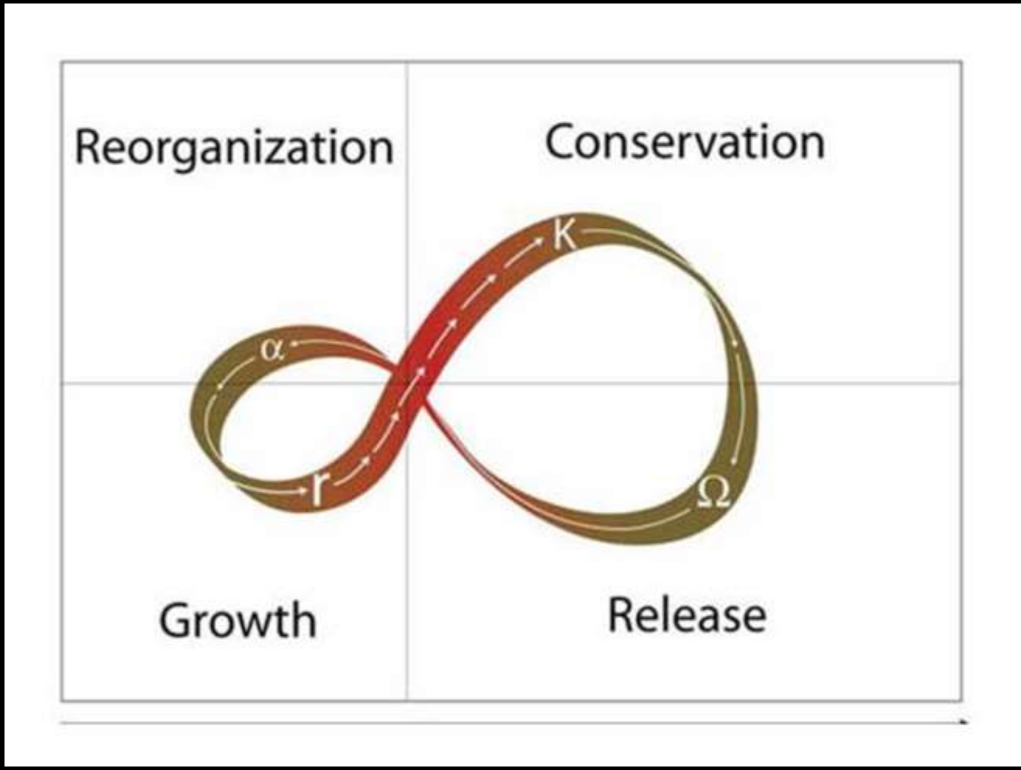
C.S. Holling 1930-2019



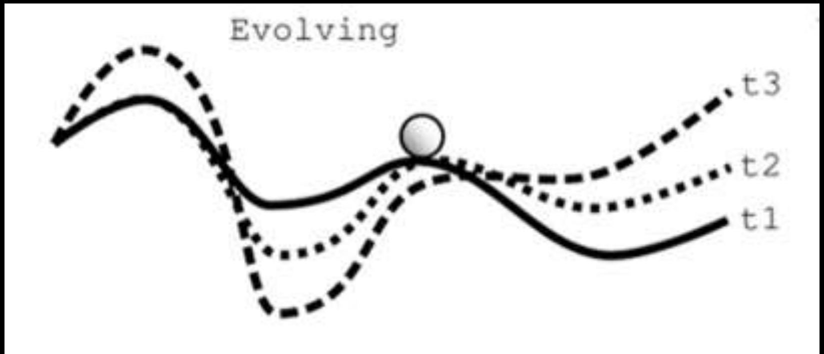


How Does Nature Work?
The Adaptive Cycle

- **Growth** - species and systems grow and diversify to exploit new opportunities and develop entirely new ecological ways of being.
- **Conservation** - species are tightly connected and organized, and systems “stabilize” into often hierarchically nested systems, where there is little or no room for innovation or growth.
- **Release** – where “mature” systems destabilize and collapse and become increasingly discontinuous and chaotic
- **Reorganization** – systems return in new ways, which creates a new field of conditions and possibilities for the next growth phase



- **Incremental change** in the r and K phases, which are smooth and fairly predictable
- **Abrupt change** in the transitions from K through Ω and α



How does Nature work?

Biotic Change - Integrity and Instability

New Nature - Novel Ecosystems

- Assemblages of species in a given area that have not previously occurred.
- They lack historically natural analogs
- Novel ecosystems are not really all that novel, except in their species composition.

The interplay between change and persistence

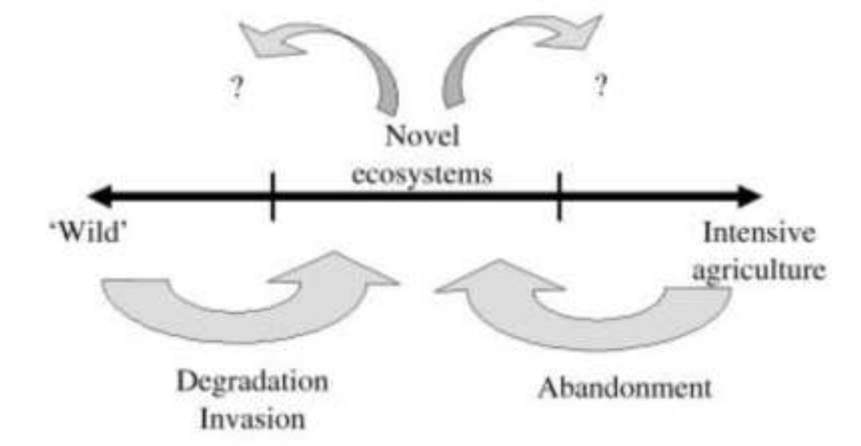
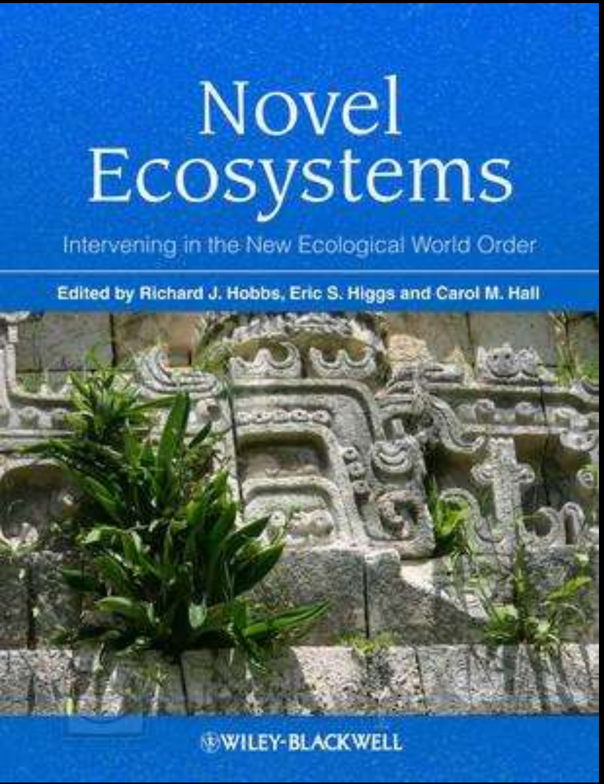
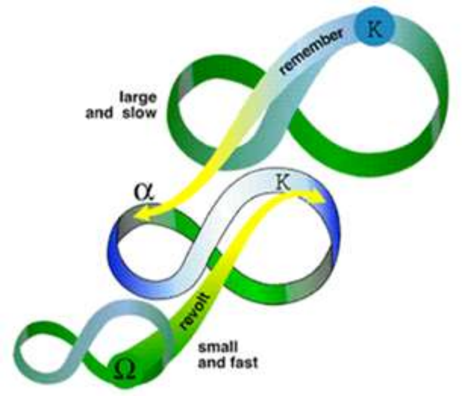
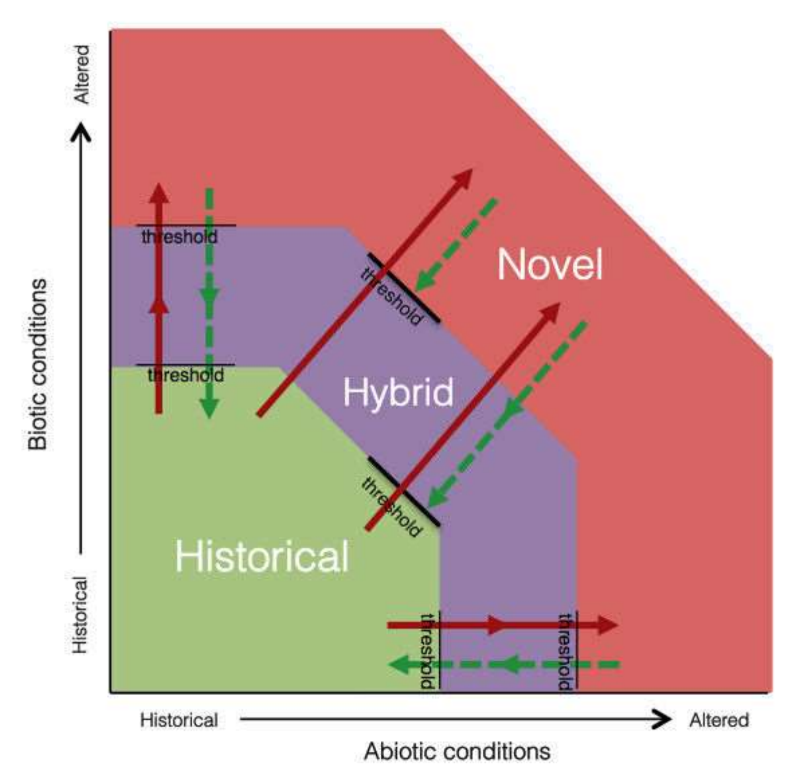


Figure 1 Novel ecosystems arise either from the degradation and invasion of 'wild' or natural/seminatural systems or from the abandonment of intensively managed systems.







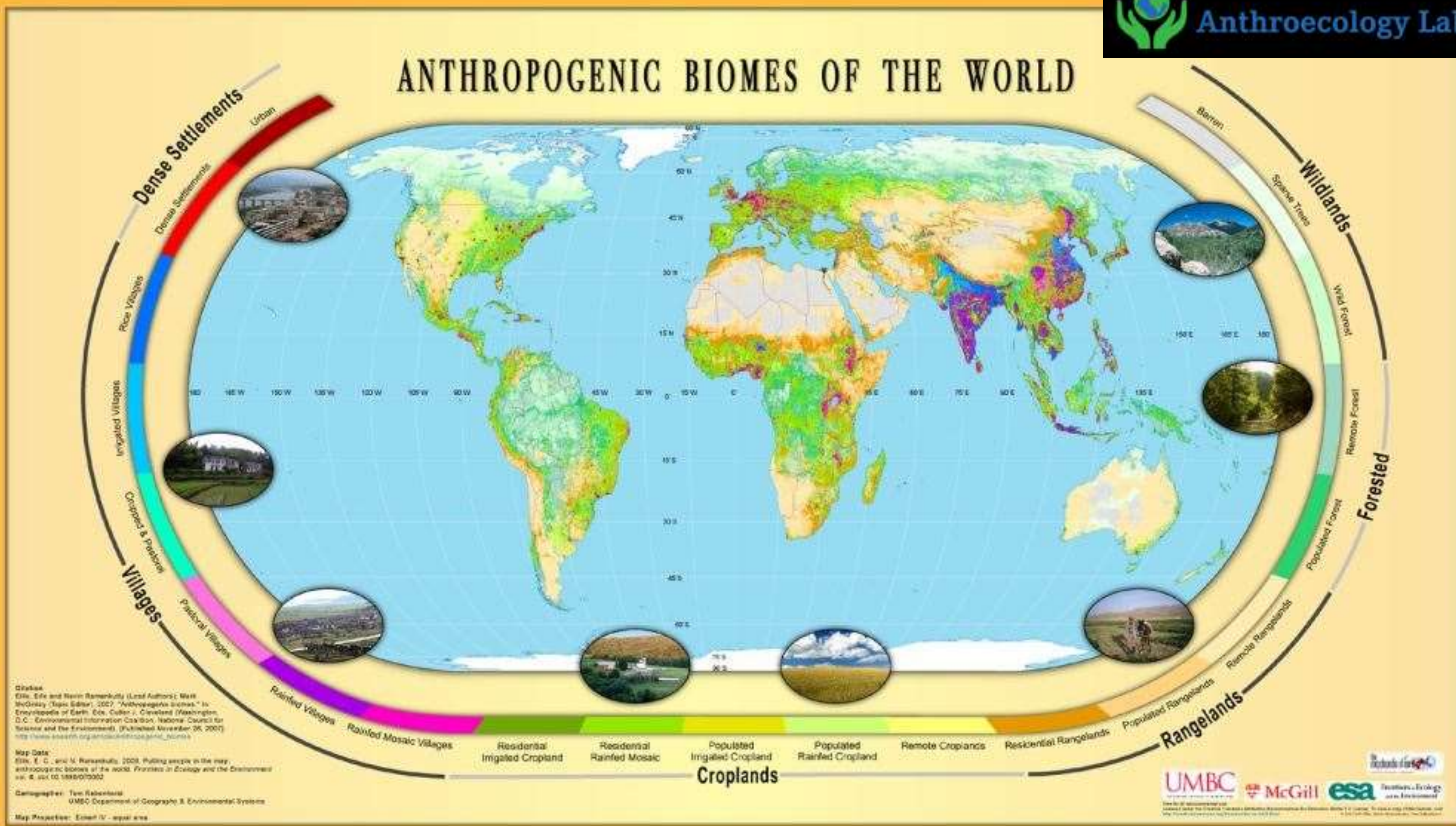
The Socioecological Earth – A Coproduction

Erle Ellis, University of Maryland

Anthropogenic Biomes ("Anthromes")

“Global ecological patterns shaped by humans”

Anthroecology Lab



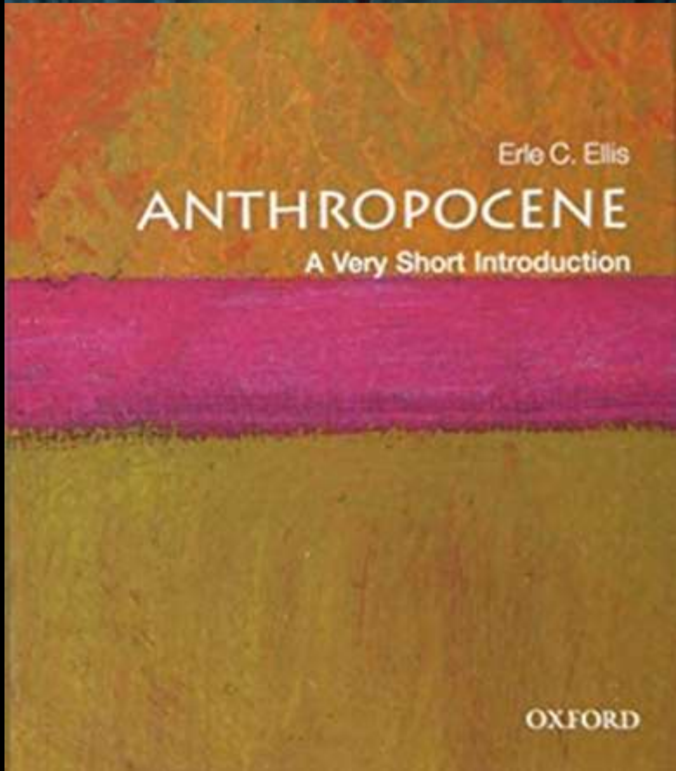
Anthropocene
A Completely Different Story

“Anthropogenic biomes point to a necessary turnaround in ecological science and education, especially for North Americans.

Beginning with the first mention of ecology in school, the biosphere has long been depicted as being composed of natural biomes, perpetuating an outdated view of the world as ‘natural ecosystems with humans disturbing them’.

Anthropogenic biomes tell a completely different story, one of ‘human systems, with natural ecosystems embedded within them’.

This is no minor change in the story we tell our children and each other. Yet it is necessary for sustainable management of the biosphere in the 21st century.”
Erle Ellis

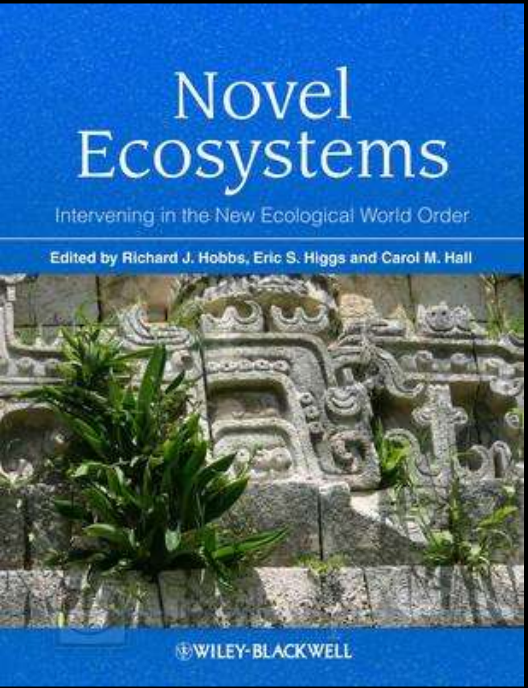


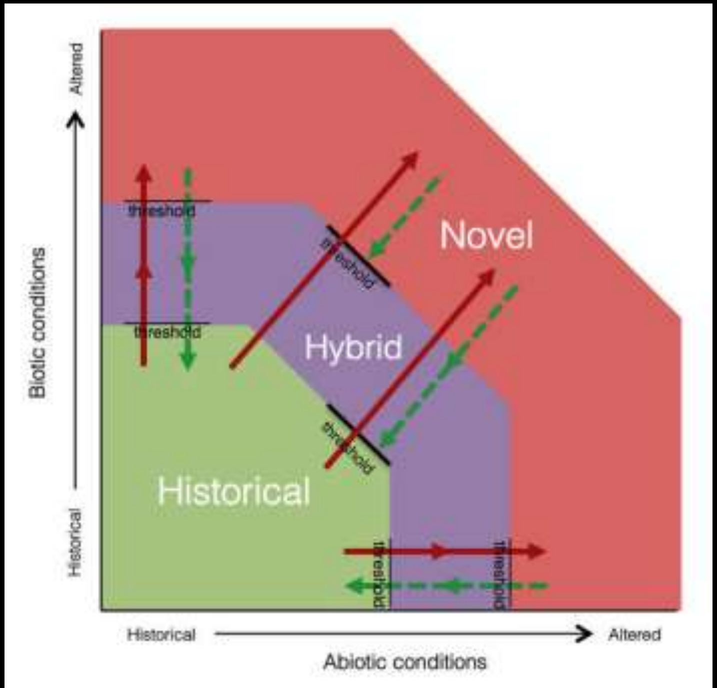
Global Change and the Biosphere
Anthropocene – the Age of Humans

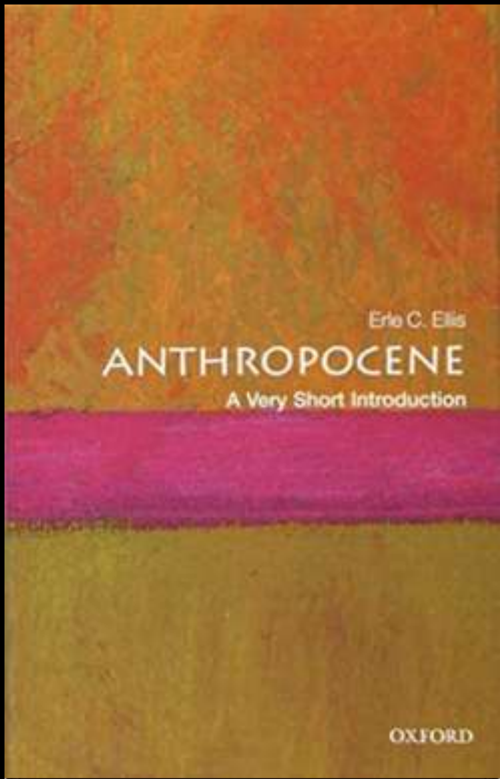
Nearly all humans live in anthropogenic landscapes, especially in urban, suburban and densely populated rural village landscapes.

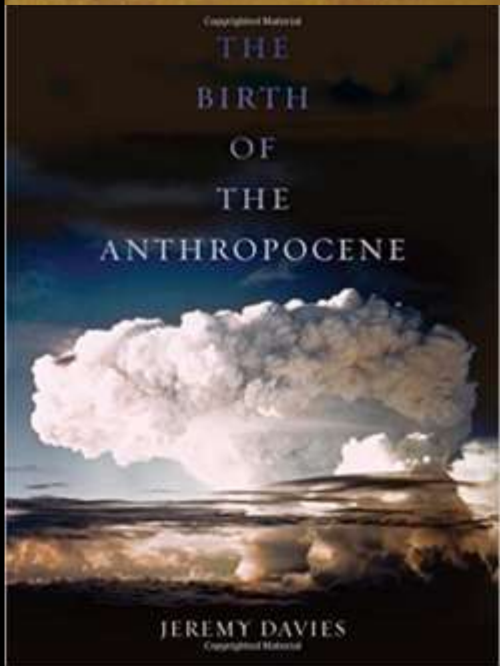
Anthropogenic landscape transformation (land-use change) is one of the primary drivers of global changes in climate, biodiversity and biogeochemistry.

Ecological processes in anthropogenic landscapes are different than those of historical ecosystems.





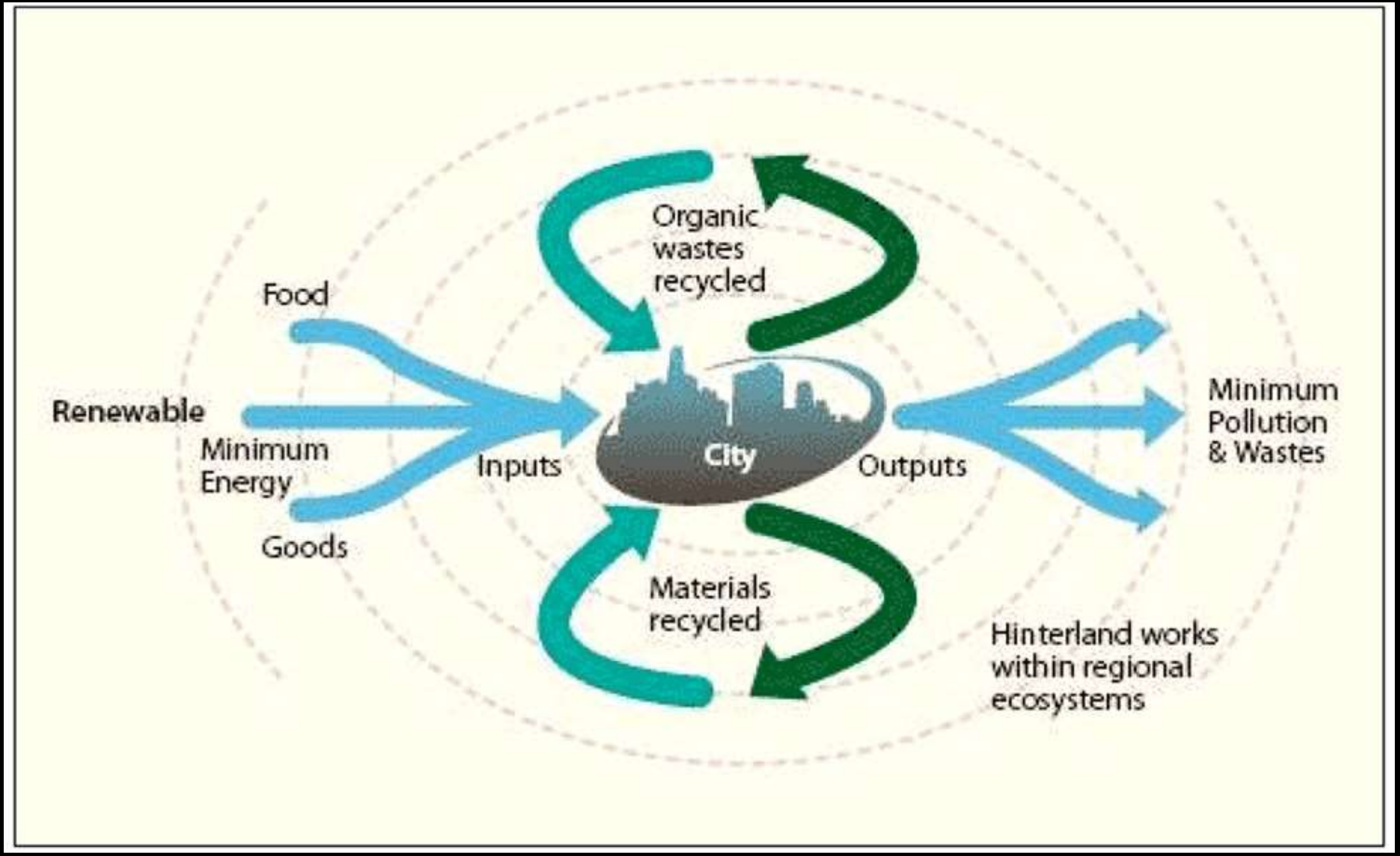




The Socioecological Elemental City

The Problem of Urban Ecology

The ecology “in” cities
or
The ecology “of” cities



The Recent Emergence of American Urban Ecology
A Very Brief History

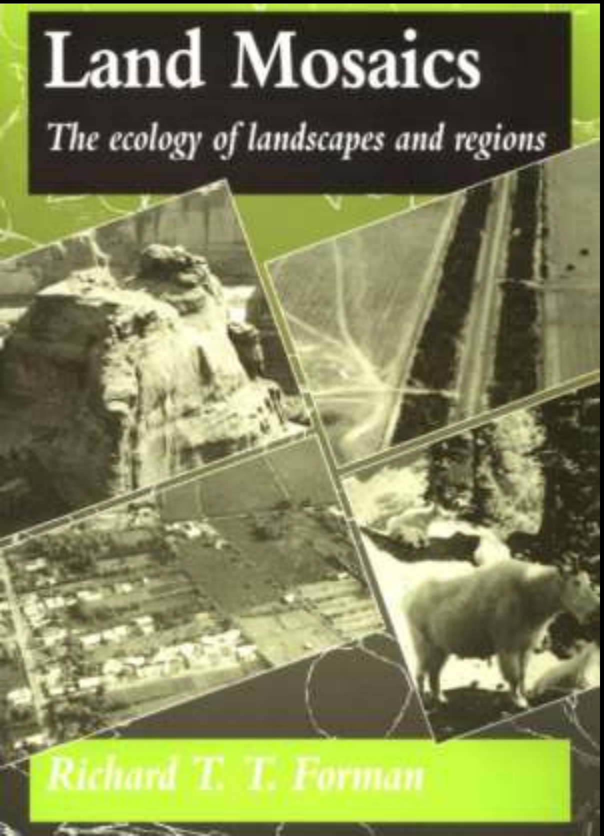
Contemporary American Approaches to Urban Ecology

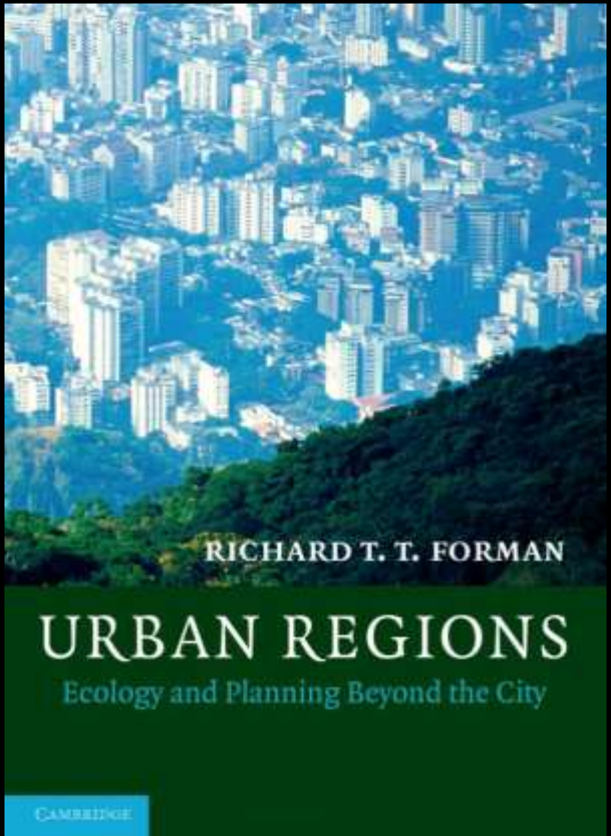
Richard Forman – Harvard University, Professor of Advanced Environmental Studies in the Field of Landscape Ecology

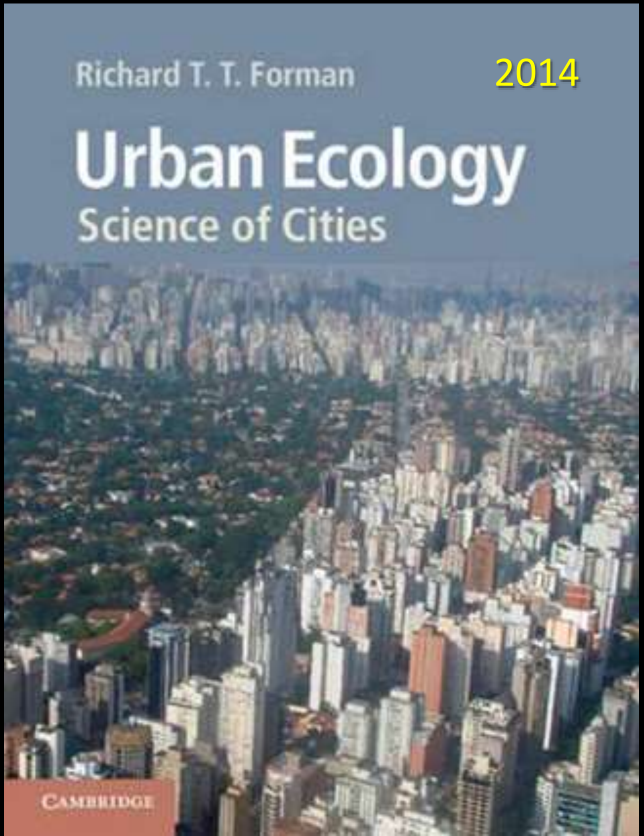
Spatial Patterns – **Cities as heterogeneous mosaics**

Two approaches to the study of urban ecosystems

- The ecology "of" cities (not just ecology "in" cities)
- The ecology of urbanization gradients







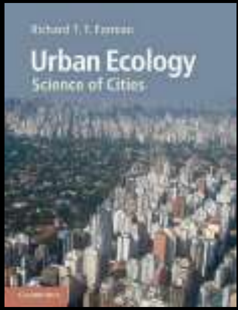
2014

The ecology “of” cities - Distinctive attributes and hierarchical scales

1. Habitats and Species

- Usually diverse intermixed greenspaces and built patches cover the area.
- Small sites tend to have few species, whereas large areas are often species rich.

2. **Patches and Areas**



- Housing developments and house plots emphasize rectilinear repetition.
- Boundaries are overwhelmingly straight, abrupt, and in high density.
- Mowed grassy areas range from abundant to essentially absent.

3. **Corridors and Flows**

- Rectilinear road networks channel hordes of moving vehicles and people.
- Underground branching conduits permeate and connect the place.
- Animal movement is often along stepping stones rather than continuous strips.

4. **Change**

- Many ecological changes are human-caused, rapid, and drastic.
- Abundant species from afar endlessly arrive, while both native and non-native species disappear.
- The city expands directionally over suburbs, and suburbs over rural land.

“For a natural or agricultural landscape, these patterns would be bizarre. In urban areas, they predominate.” Forman

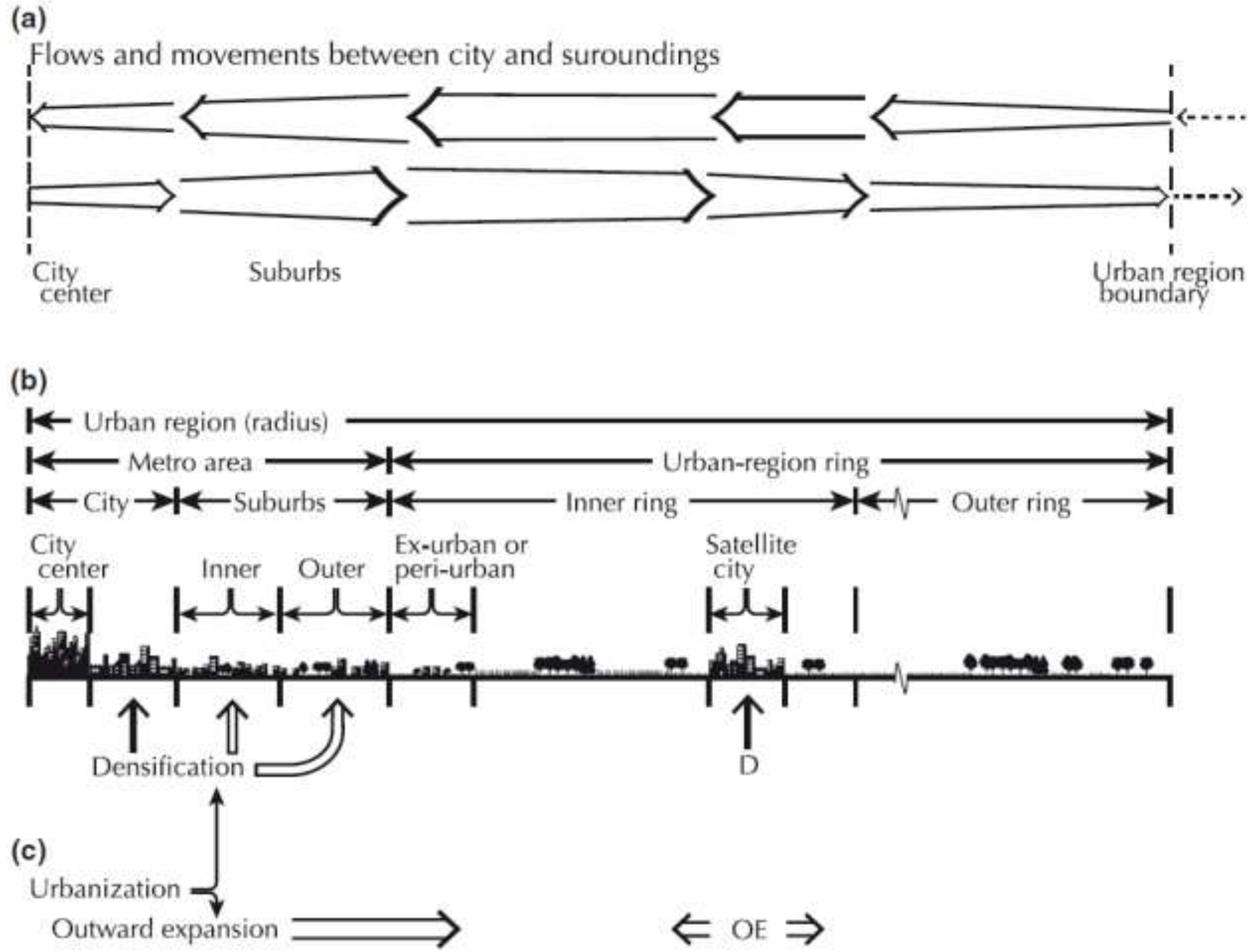
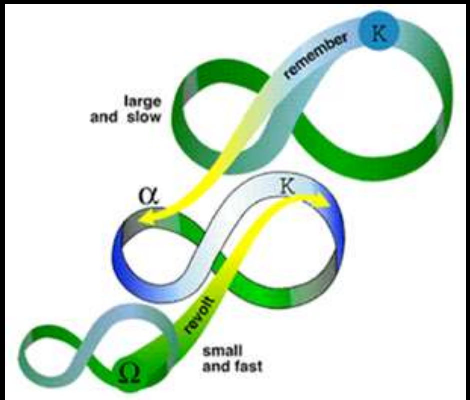
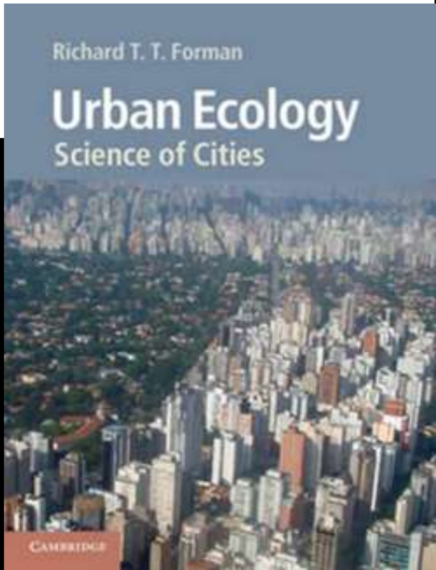


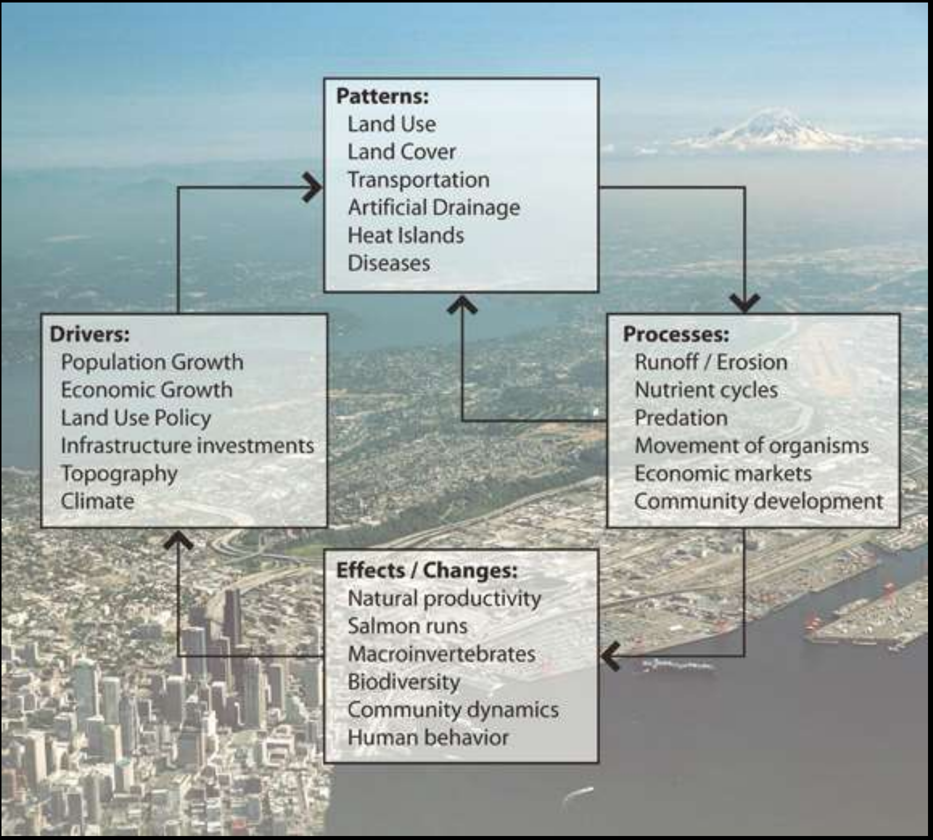
Figure 1.4. Concepts and terms for urban ecology. Metro area extends outward to the edge of the essentially continuous all-built area. Some suburbs extend beyond the metro area, and include some or all of the exurban or peri-urban zone. The urban-region ring also contains separate towns and villages. (a) Width of arrows roughly proportional to amount of flows and movements. (b) Concepts and terminology used in this book. (c) The two components of urbanization in different areas [see (b)] of the urban region. (d) Examples for bits of green cover (in built space) = window box, street trees, back yard space, green roof; examples of created greenspaces = city plaza/square, cemetery, vacant lot, dump, waterworks, golf course. Based on Forman (2008) and other sources.

Change

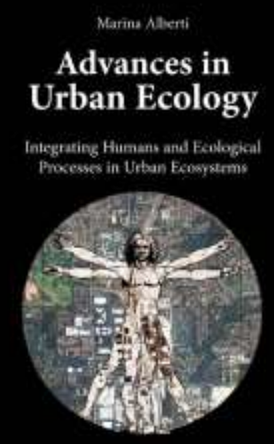
The Ecology of Urbanization Gradients







2008



Ecological Modeling - Spatial Patterns, Material Flows, Complex Systems Theory

Marina Alberti, University of Washington

- Complex systems theory provides the conceptual basis and methodology for studying urban ecosystems to decode “emergent” phenomenon, such as urban sprawl, and devise effective policies to minimize their effects on ecosystem function.
- Her research focuses on the interactions between urban development patterns and ecosystem function, urban eco-evolutionary dynamics, and the properties of urbanizing regions that enhance their resilience and socio-ecological innovation.

Current Trends in Urban Ecology

Today's major urban-ecology approaches and centers of research include:

(1) Habitat/biotope mapping and related analyses (especially in Europe)

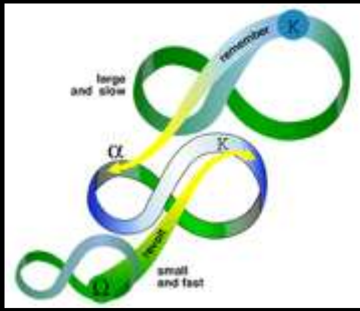
(2) Species types and richness (Berlin, Melbourne)

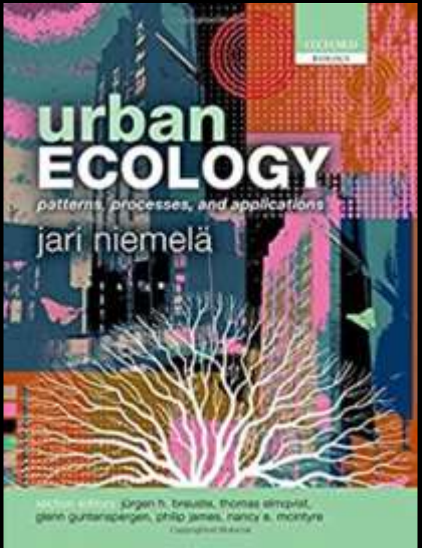
(3) City-to-rural gradient (Melbourne, Baltimore)

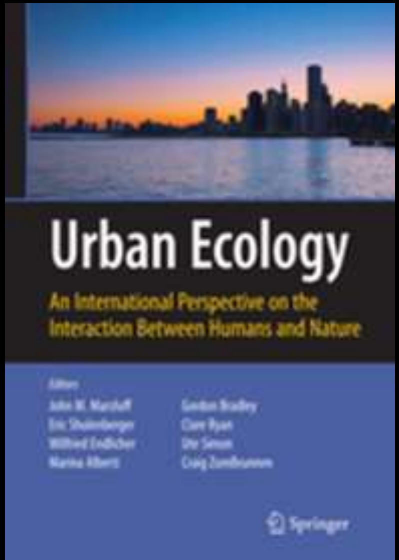
(4) Modeling and biogeochemical/ material flows (Phoenix, Seattle)

(5) Coupled biophysical-human systems (Phoenix, Baltimore, Seattle)

(6) Urban-region spatial patterns, processes, and changes (worldwide analyses)

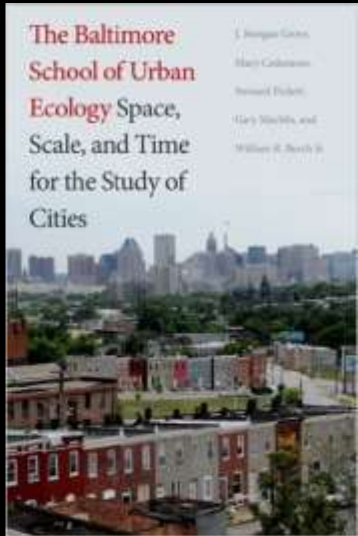






Central Arizona-Phoenix
Long-Term Ecological Research
CAP LTER

BALTIMORE
ecosystem
STUDY



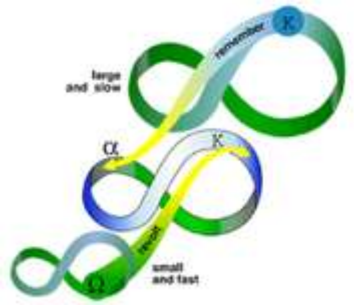
Trends and Urban Nature

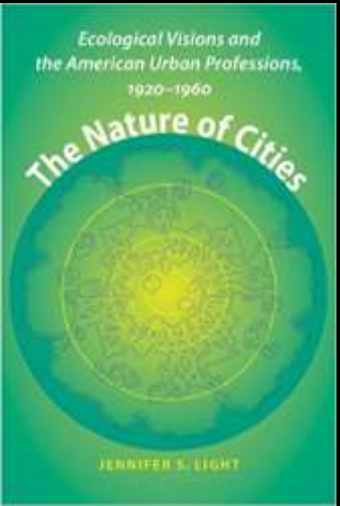
Redemptive? Restorative? Functional? Other?
Urban Design, Management, and Science

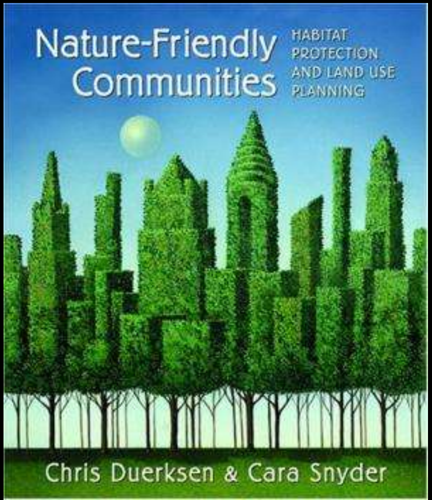
The Nature of Cities is a "boundary organization" interested in ideas at the frontiers of science, design, policy, and the arts — ***an idea hive*** that puts different approaches and points of view together, to discover what novel perspectives might emerge.

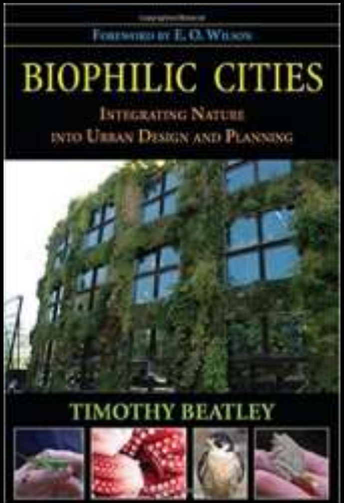
a virtual magazine and discussion site

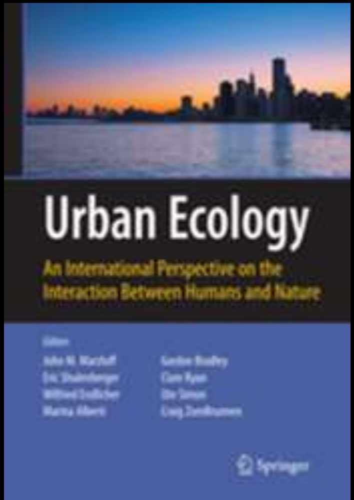
https://www.thenatureofcities.com/







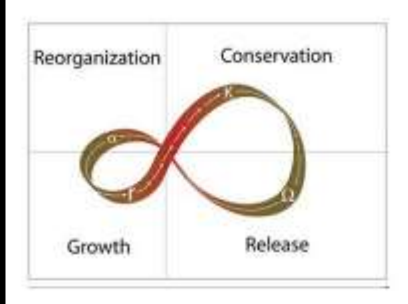


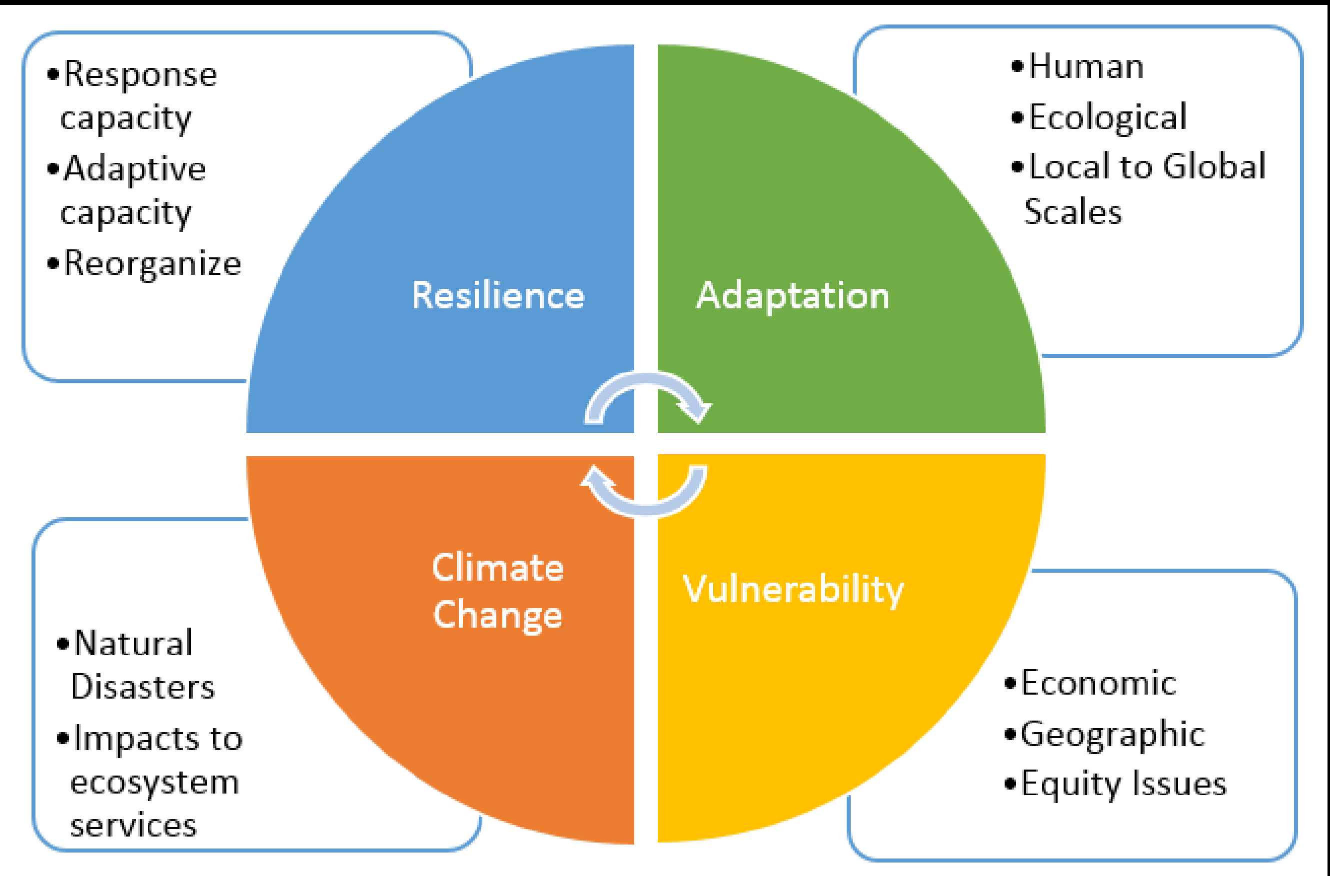


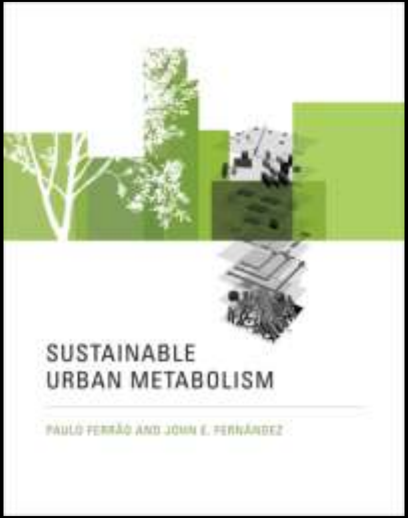
Resilience and Urban Metabolism – Homeostasis

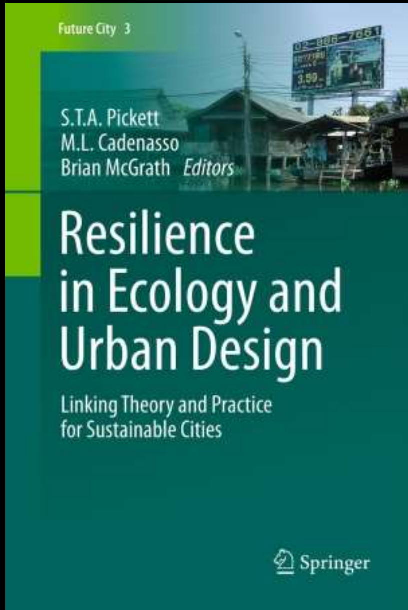
The characterization of flows and the relationships between anthropogenic urban activities and natural processes and cycles defines the behavior of urban production and consumption.

Sustainability = Homeostasis - Self-regulating process by which biological systems tend to maintain stability while adjusting to conditions that are optimal for survival.

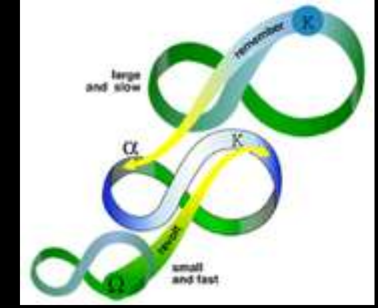






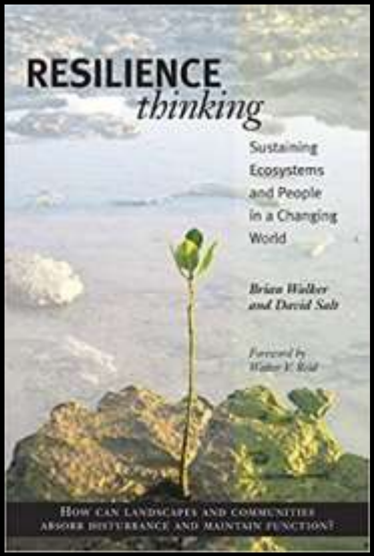


Resilience, Urban Ecology, and Socioecological Systems



Resilience - The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks - and therefore the same identity.

- non-linearity, alternate regimes and thresholds
- adaptive cycles
- multiple scales and cross-scale effects
- adaptability
- transformability
- general versus specified resilience



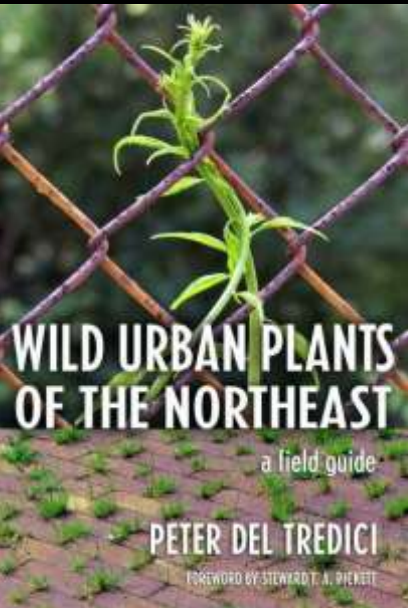
http://www.resalliance.org

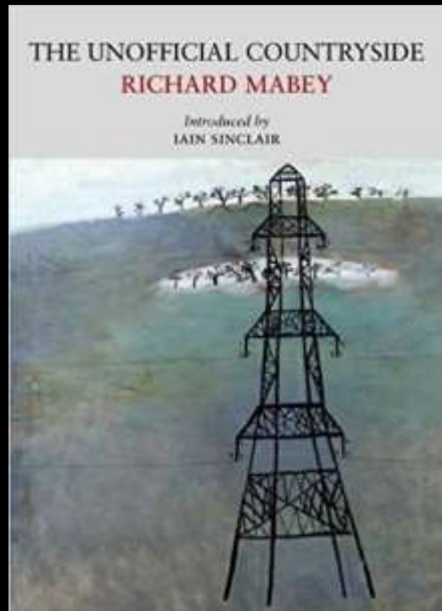
Resilience Alliance

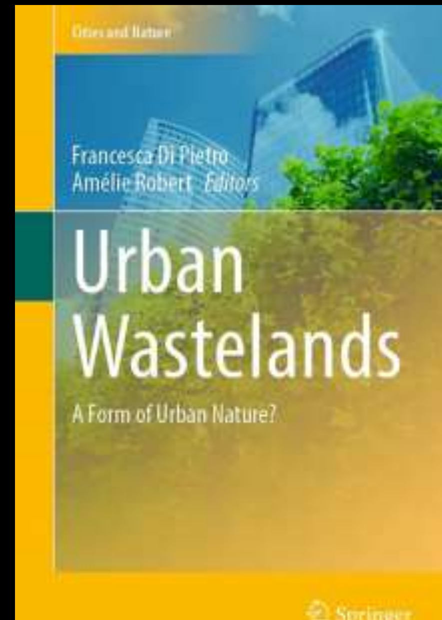
research on resilience in social-ecological systems - a basis for sustainability

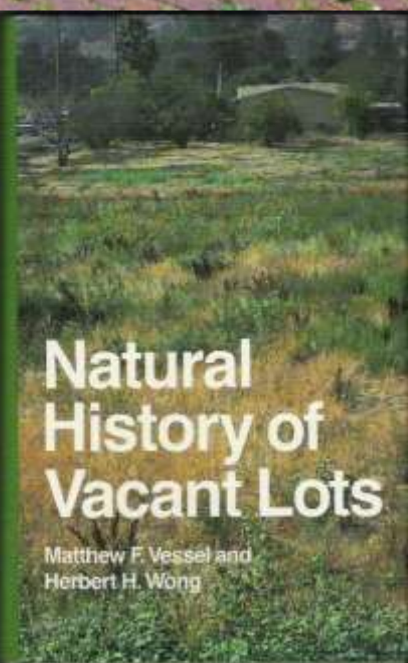
Marginal Nature: Urban Wastelands and the Geography of Nature

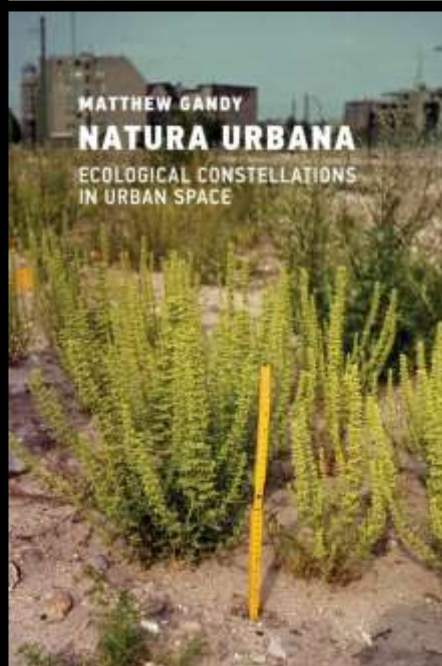
Anderson 2009

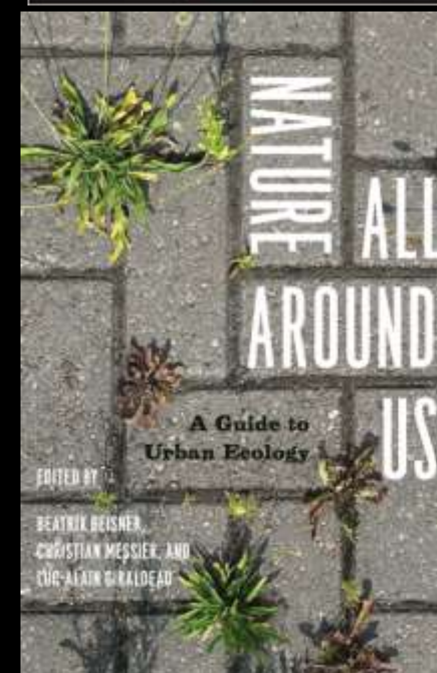




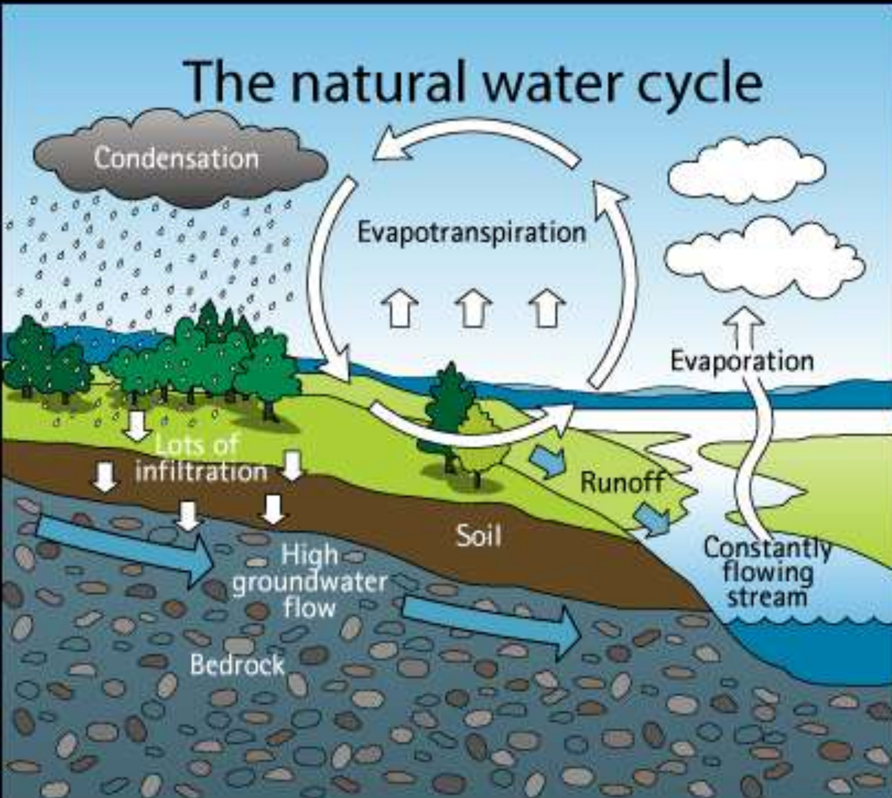


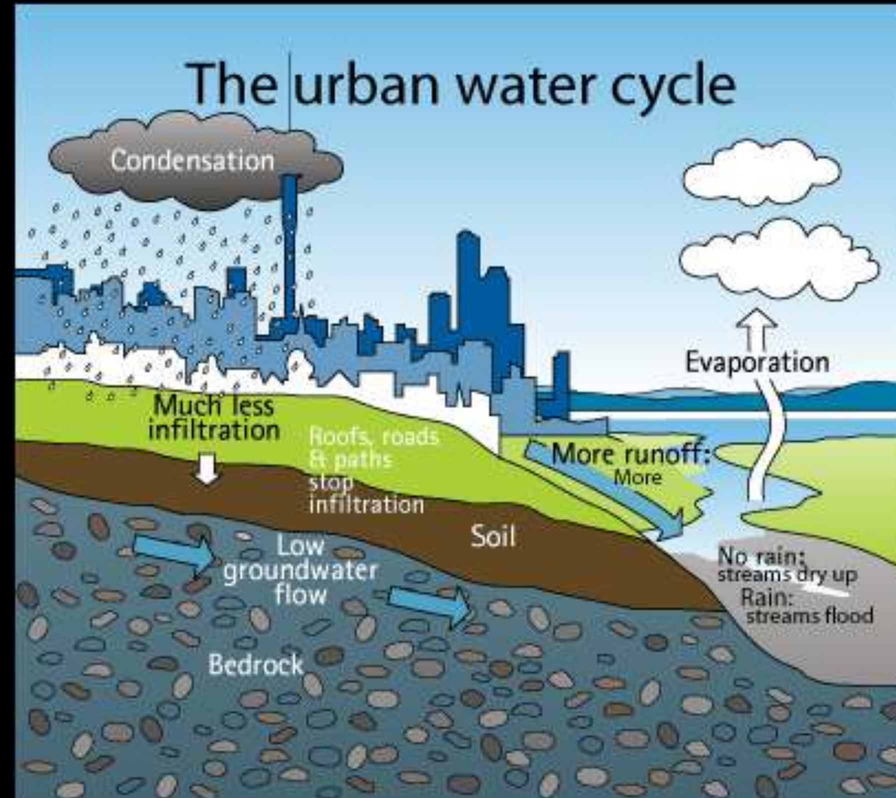


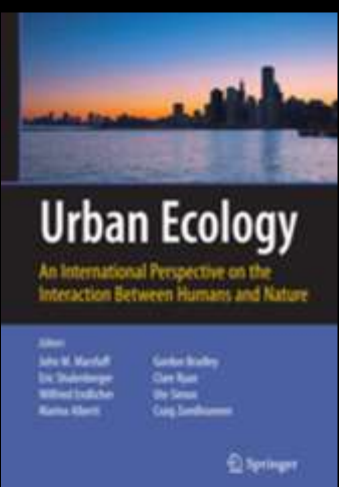


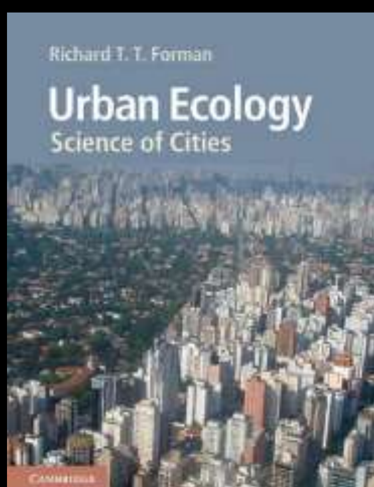


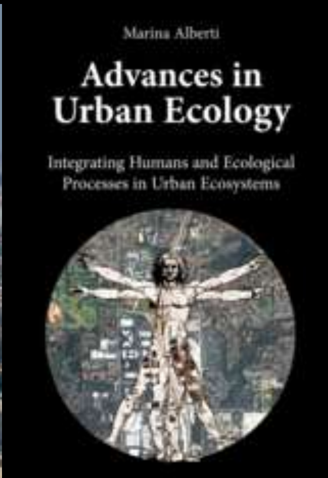
Narrative of Functional Urban Nature - Urban Ecology

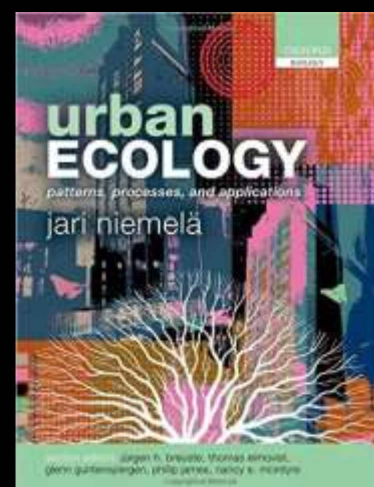












BALTIMORE ecosystem STUDY

Central Arizona-Phoenix Long-Term Ecological Research CAP LTER

What is a City?

Cities as part of Nature - Cities as Ecosystems

Urban Ecology = Ecology in cities

Cities as Socioecological