Biogeochemical processes in an urban ecosystem, metropolitan Phoenix, Arizona

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Urban ecosystems provide an opportunity to examine especially pronounced human alterations of biogeochemical cycles. Biogeochemical research in the CAP LTER has focused both on the whole ecosystem and on patterns and processes within and between urban landscape patches (Fig. 1).

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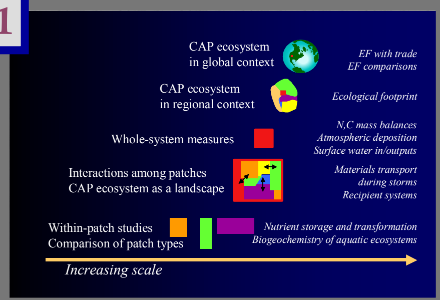

Research projects

Whole ecosystem scale and above:

- Mass balances – nutrient budgets for N, C, salts
- Upstream-downstream comparison of water chemistry
- Atmospheric deposition monitoring and modeling*
- Ecological footprint of CO_2 assimilation
- Lichen accumulation as indicator of elemental deposition*

Within- and between-patch scales:

- Soil nutrient and organic matter storage (200-point survey)*
- Nutrient storage on asphalt
- Nutrient transport during storms
- Recipient systems: retention basins, urban lakes, urban greenways
- Aquatic biogeochemistry*

Integrative opportunities:

- Effects of socioeconomic setting and human use on soil biogeochemical processes and input-output balance at neighborhood scale (part of Parks Project)
- Extension of the ecological footprint to incorporate human dimensions*

* *Poster at CAP LTER 3rd Annual Poster Symposium*

Ecosystem Scale

Questions at the whole ecosystem scale include:

- Is the city a source or a sink for different elements?
- What are the hot spots of element retention in the urban landscape?
- How are elements transported in airshed-watershed interactions?

A mass balance for N showed that most of the input occurred via anthropogenic means, either deliberate (import of food, fuels, etc.) or inadvertent (conversion of N2 to NOX as a by-product of fossil fuel combustion). Furthermore, inputs exceeded outputs (Fig. 2), indicating either an underestimated sink or accumulation of N in the ecosystem.

Novel methods for describing the dependence of the city on external systems for food and water and assimilation of C wastes produced, based on the ecological footprint concept, reveal the temporal heterotrophic nature of the urban ecosystem (Fig. 3). Note that the size of the CAP study area is approx 4,000 km².

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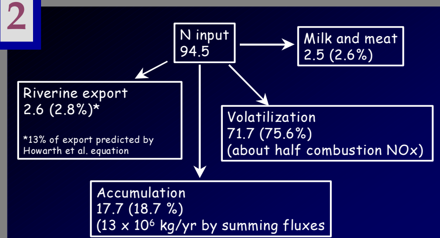

Summary of CAP N balance
(values in 10^6 kg N/yr)
L.A. Baker, D. Hope, J. Edmonds, L. Lauver, and Y. Xu

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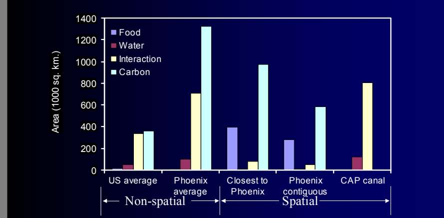
Comparing EF methodologies for Phoenix
M. Luck, G.D. Jenerette, J. Wu, and N.B. Grimm



Comparison of element transport via surface water into and out of the city, another whole-system measure, revealed much higher concentrations of nutrients and major ions downstream from the city than upstream (Fig. 3). However, hydrologic inputs exceed outputs because most of the water is retained by the city (Table 1).

Atmospheric deposition of many elements also conformed to a gradient of reduced deposition from more urban to more rural sites. Nitrogen deposition is being modeled to generate a more accurate estimate of N flux to the CAP ecosystem (see posters).

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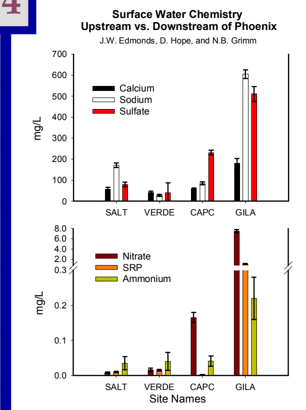

Fig. 4. Two-year averages of surface water chemistry from frequent, channel-wide, depth-integrated surface water samples collected upstream (CAP canal, Verde River, Salt River) and downstream (Gila River) from the city. Results suggest significant alterations in biogeochemical cycling as water moves through the city and a large increase in salt export from the city.

Table 1. POC and DOC mass balance through the Phoenix, AZ urban infrastructure system for January 1, 1996 through March 31, 1998 based upon USGS daily flows and monthly NAQWA DOC and POC concentrations. P. Westerhoff.

	Cumulative volume of water (m³)	Cumulative DOC Loading (kg)	Cumulative POC Loading (kg)
Inputs			
Salt River (P2)	12.6×10^8	4.7×10^6	8.9×10^6
Verde River (P4)	10.4×10^8	5.2×10^6	5.8×10^6
CAP Canal*	10.5×10^8	3.2×10^6	1.6×10^6
Outputs			
Salt River (ED4)	2.91×10^8	2.4×10^6	0.30×10^6
Percentage Output	9%	18%	2%

Patch Scale

Questions at the patch scale include:

- How does urbanization affect nutrient dynamics?
- What are the hot spots of element storage and transformation in soils?

Material storage and movement varies among patches. Examination of soil samples, although preliminary, reveals that urban patches (residential, commercial/ industrial, and institutional) have higher nutrient contents than desert or intermediate agricultural sites Fig. 5). Nutrient and metal loads that might be expected to enter watercourses during storms were estimated for asphalt surfaces in different patches within the urban area, and were shown to exceed by an order of magnitude loads predicted from desert soils.

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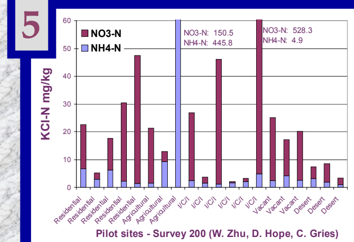

Recipient systems for materials transported during rainstorms and flash floods include retention basins, artificial urban lakes, highly modified urban washes ("greenways"), and dry river channels. Preliminary indications are that both pool sizes and flux rates are large in these systems (e.g., Table 2).

Soil denitrification
W. Zhu, N. Dillard, N. Grimm

Site Type	Denitrification rate (kg ha⁻¹ y⁻¹)
Old field – undeveloped*	.1726
Riparian – undeveloped*	4 - 16
Riparian – developed*	7.1 - 38.5
Prairie landscape*	26.3
Retention basin – developed	8.6 - 228.5

*literature values

Table 2. Denitrification potentials were measured in soils of retention basins in Mesa and Tempe. This basins, which often serve as neighborhood parks, receive runoff from neighborhoods during rainstorms. Water seeps into soils and drains through drywells relatively rapidly; however, denitrification potentials associated with these soil wetting events are very high.

Aquatic biogeochemistry research includes investigations of canals, streams, and artificial lakes in the metropolitan area. Most of these systems are highly designed, manipulated, and managed as well as subject to higher nutrient loads. Experiments in an urban wash show that nutrient limitation of algal growth can occur even in this highly altered ecosystem (Fig. 6).

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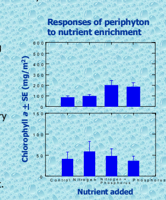
What is the limiting Nutrient in Indian Bend Wash and how does it vary spatially and temporally?
Aisha M. Goettl and Nancy B. Grimm

Nutrient limitation has been investigated using nutrient diffusing substrates in the spatially heterogeneous, urban stream, Indian Bend Wash during both the summer and fall of 2000. While there was little spatial variation within a sampling period, preliminary data indicate a possible switch in nutrient limitation from phosphorus to nitrogen limitation between the summer and fall seasons. We believe that autumnal flooding may be partially responsible for this shift.



Long-term monitoring of trace N gas fluxes, soil nutrients, and nutrient loads in runoff from residential and other permanent plots will begin in spring 2001. Opportunities for integration of biogeochemical research with other areas will be exploited in integrative research such as the urban parks project, which will examine variation in human uses of parks along a socioeconomic gradient, and the ecosystem consequences of that variation (for example in trace gas fluxes).

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