Systematic Review of Ecosystem Services from Green Space

Katherine von Stackelberg
E Risk Sciences (kvon@erisksciences.com)
John Heinze
Environmental Health Research Foundation

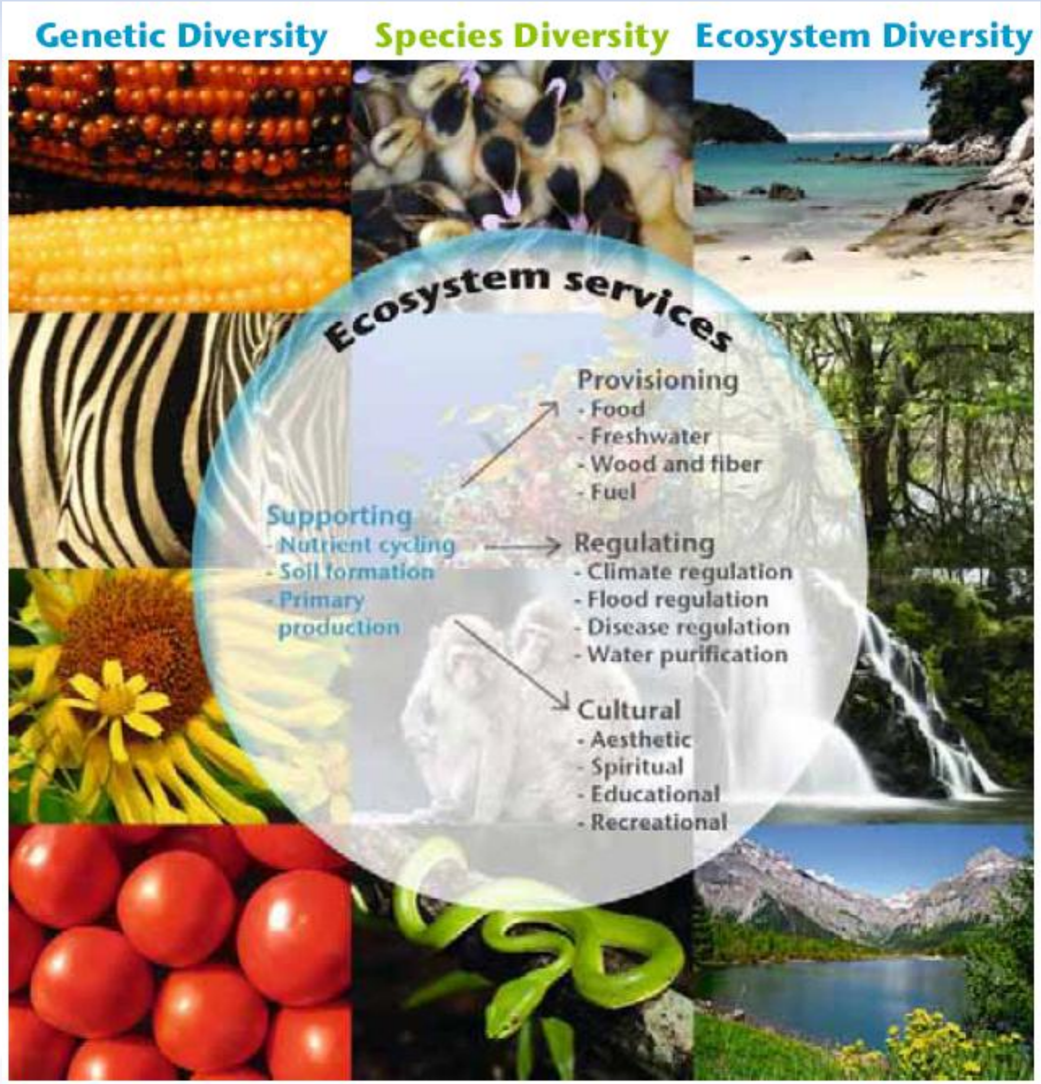
E RISK SCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

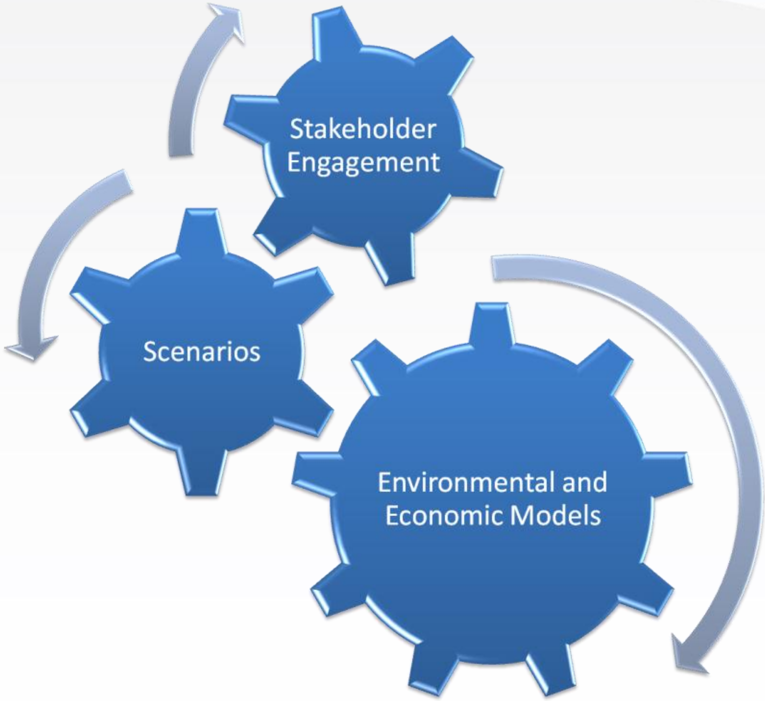
Summary and Highlights

- Green space provides important environmental services, especially in increasingly urbanized areas.
- Environmental disservices also exist relative to maintaining environmentally-beneficial green space.
- The challenge for policymakers and urban planners is to balance ecosystem services and disservices in a manner that maximizes the net ecosystem services associated with well-maintained green space.

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Ecosystem Services as a Guiding Principle





E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Turf Grass Characteristics

- 80% of US population lives in an urban area (USGS, UDR, 2000)
- Turfgrass = 16 – 20 million hectares
- 80 million single family homes with 0.08 hectare average lawn size
- Small parks, triangles, urban green spaces
- Net ecosystem service flows

Estimates of turf grass area by state in km^2

	Mean	Upper 95%CI	Lower 95%CI
Alabama	3,130	3,741	2,520
Arizona	2,559	3,178	1,941
Arkansas	2,098	2,519	1,679
California	11,159	13,890	8,434
Colorado	2,478	3,047	1,910
Connecticut	2,429	2,429	1,913
Delaware	533	644	422
District of Columbia	57	86	28
Florida	11,570	14,221	8,925
Georgia	5,688	6,848	4,530
Idaho	942	1,133	751
Illinois	5,729	7,102	4,359
Indiana	3,843	4,679	3,008
Iowa	2,227	2,772	1,822
Kansas	2,004	2,453	1,555
Kentucky	2,446	2,935	1,958
Louisiana	3,377	4,099	2,656
Maine	975	1,157	793
Maryland	2,471	3,013	1,929
Massachusetts	4,183	5,054	3,314
Michigan	4,538	5,598	3,480
Minnesota	3,176	3,866	2,487
Mississippi	1,969	2,362	1,578
Missouri	3,442	4,217	2,669
Montana	735	884	585
Nebraska	1,149	1,401	898
Nevada	928	1,162	694
New Hampshire	1,126	1,339	913
New Jersey	3,942	4,885	3,002
New Mexico	1,545	1,860	1,231
New York	6,320	7,770	4,873
North Carolina	8,112	9,715	6,512
North Dakota	572	693	452
Ohio	6,733	8,213	5,257
Oklahoma	2,689	3,294	2,086
Oregon	1,977	2,406	1,549
Pennsylvania	7,293	8,789	5,799
Rhode Island	506	622	390
South Carolina	4,034	4,822	3,248
South Dakota	692	829	555
Tennessee	4,201	5,064	3,339
Texas	13,187	16,242	10,138
Utah	1,207	1,493	922
Vermont	524	621	427
Virginia	4,544	5,510	3,581
Washington	3,479	4,345	2,814
West Virginia	1,459	1,731	1,189
Wisconsin	3,110	3,764	2,457
Wyoming	554	665	444
Total U.S.	**163,812**	**199,679**	**128,106**

Source: Milesi C, Running SW, Elvidge CD, Dietz JB, Tuttle BT and RR Nemani. 2005. Mapping and modeling the biogeochemical cycling of turfgrasses in the United States. Environ Manag 36:426-438. DOI: 10.1007/s00267-004-0316-2.

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Benefits of Green Space and Green Space Access

- Erosion control and runoff prevention
- Soil, water and nutrient stabilization
- Recreation and Exercise (reduced obesity)
- Water and air purification
- Temperature modification
- Oxygen generation
- Carbon sequestration
- Stress reduction
- Noise abatement
- Aesthetic value

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Ecosystem Service: Turf Grass Impact On Erosion Control & Water Quality Protection

- Reduces Mass Water Flow & Run-off
  - Turf can withstand a maximum permissible velocity of around 5 ft/s with an absolute maximum of 8 ft/s. *(Source: USDA 1954. Handbook of Channel Design for Soil and Water Conservation. Technical Paper TP-61.)*
  - Less than 1% to 13% of total water applied as runoff *(Source: Watschke TL. 1990. J Env Turfgrass 2(1):1)*
  - Grass selection and density affects run-off *(Source: Linde DT et al. 1999 J Turfgrass Mgmnt 2(4):11-34, DOI: 10.1300/J099v02n04_02)*
- Erosion reduced by 90-99% *(Source: University of Florida)*
  - A dense lawn is 6 times more effective than a wheat field and 4 times better than a hayfield at absorbing rainfall. *(Source: http://www.michigan.gov/mda/0,%201607,7-125-1570_2476_2481-9345--,00.html, Univeristy of Florida)*
  - High shoot density increases erosion control potential *(Source: Beard JB and RL Green. 1994. J Env Qual)*

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

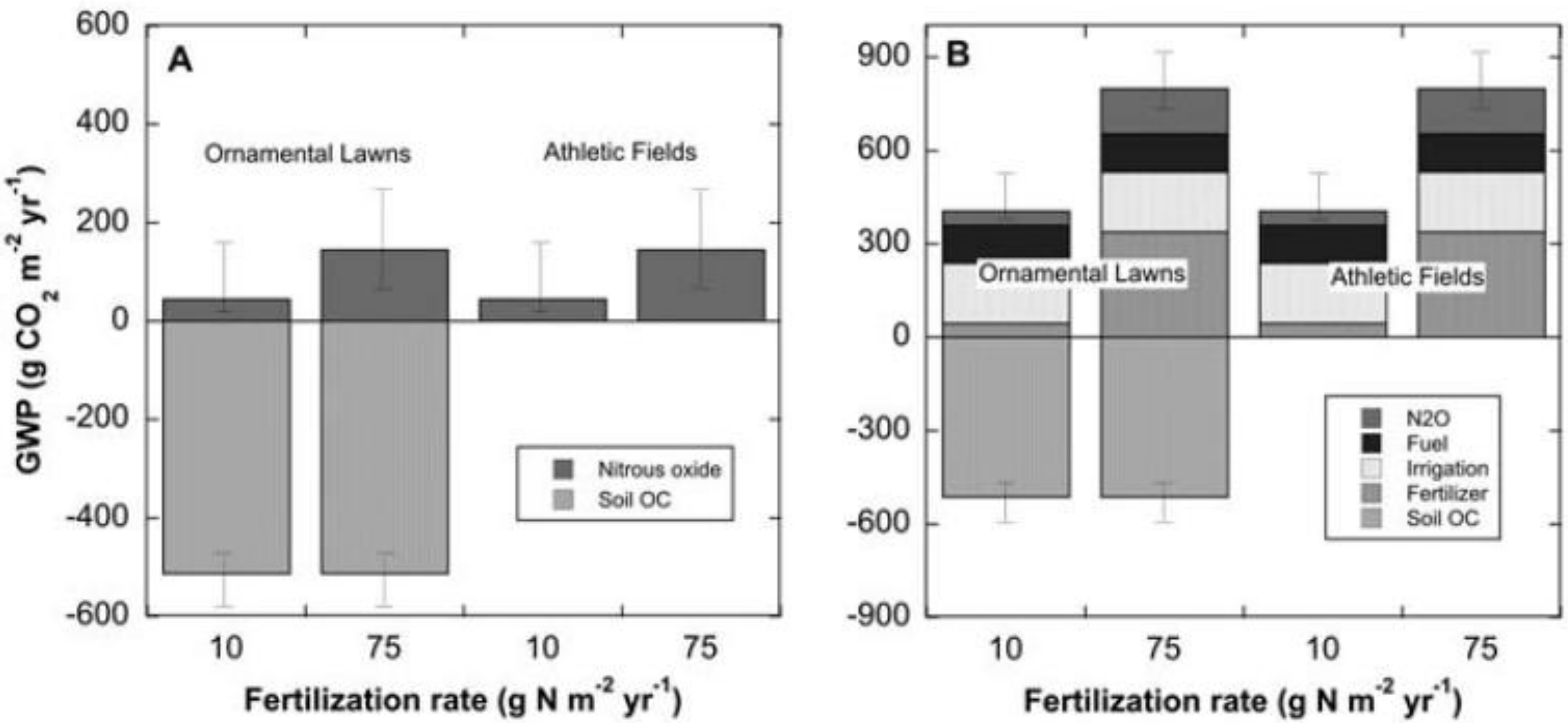
Ecosystem Service: Temperature Control

August Temperature Comparisons			
	Maximum daily Temp deg F		Nocturnal minimum temp
Surface	Surface temp	3” above surface	Surface temp
Green, irrigated turf	88°	89°	76°
Synthetic turf, dry	158°	96°	84°
Brown, dormant turf	126°	95°	79°
Bare soil, dry	102°	91°	78°

Source: Beard, J.B., 1990. J Env Turfgrass 2(1): 6.

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Ecosystem Service: Carbon Sequestration Potential



Ornamental urban lawns can effectively sequester CO_2 depending on management assumptions.

Source: Townsend-Small A and Czimczik. 2010. Geophysical Research Letters, 37:L06707, doi:10.1029/2010GL042735.

Ecosystem Service: Carbon Sequestration Potential

Table 4: US grassland annual soil organic carbon accumulation rate			
	Minimal input lawns	DIY lawns	BMP lawns
	g/m2/year		
SOC	46.0 - 127.1	46.0 - 127.1	129 - 235
Fertilizer SOC	0	78	78.0 - 98.0
Irrigation SOC	0	0.5 - 1.5	1.5 - 10.0
Gross SOC	46.0 - 127.1	124.5 - 206.6	129.0 – 235.1
Mowing HCC	12.9 - 20.6	12.9 - 20.6	12.9 - 20.6
Irrigation HCC	0	0.1 - 0.3	1.6
Fertilizer HCC	0	10.1 - 20.4	15.5 - 49.5
Pesticide HCC	0	0.4 - 2.6	0.8 - 5.6
Gross HCC	12.9 - 20.6	23.6 43.9	30.8 - 77.3
Total net sequestration	25.4 - 114.2	80.6 - 183.0	51.7 - 204.3
SOC = soil organic carbon; HCC = hidden carbon cost			

Source: Zirkle G, Rattan L and B Augustin. 2011. Modeling carbon sequestration in home lawns. Horticultural Science 46(5):808–814.

- Rate of soil organic carbon sequestered in home lawns is 0.5 to 1.5 Mg C/ha/year
- Greater than rate for U.S. cropland of 0.3 Mg C/ha/ year (Lal and Follett 2009)
- Bruce et al. (1999) predicted 0.6 to 1.9 Mg C/ha/year for worlds grasslands.

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Ecosystem Service: Impacts on Human Health

- Obesity a significant public health issue
- Body mass index of children shows an inverse relationship to exposure to green space *(Source: Bell 2008; Pataki 2011)*
- Important psychological impacts (general well-being) *(Source: Mitchell R and F Popham. 2008. Lancet 372:1655–60.)*
- Reduce socioeconomic inequalities *(Source: Mitchell R and F Popham. 2008. Lancet 372:1655–60.)*

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Not All Green Space Has the Same Value

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Ecosystem Service: Maintained Green Space Reflects "Green Value"

- Real property values
- Donations to conservation/easement
- Use fee
- Inclusion in redevelopments
- Average household WTP in Holland ranged from 401 to 1455 Euro for a one percent increase of parks and public gardens in a 500 meter circle around the house. *(Source: Rouwendall J and J van der Straaten. 2008.)*

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Green Space Ecosystem Services & Disservices

ECOSYSTEM SERVICES

1. Erosion control and runoff prevention
2. Soil, water and nutrient stabilization
3. Recreation and Exercise (reduced obesity)
4. Water and air purification
5. Temperature modification
6. Oxygen generation
7. Carbon sequestration
8. Stress reduction
9. Noise abatement
10. Aesthetic value

ECOSYSTEM DISSERVICES

1. Fertilizer use/runoff (hardscape or impervious surfaces)
2. Potential health effects (improper use)
3. Potential environmental effects (improper use)
4. Carbon use
5. Energy usage
6. Water usage

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Modeling Urban Characteristics Relative to Ecosystem Services

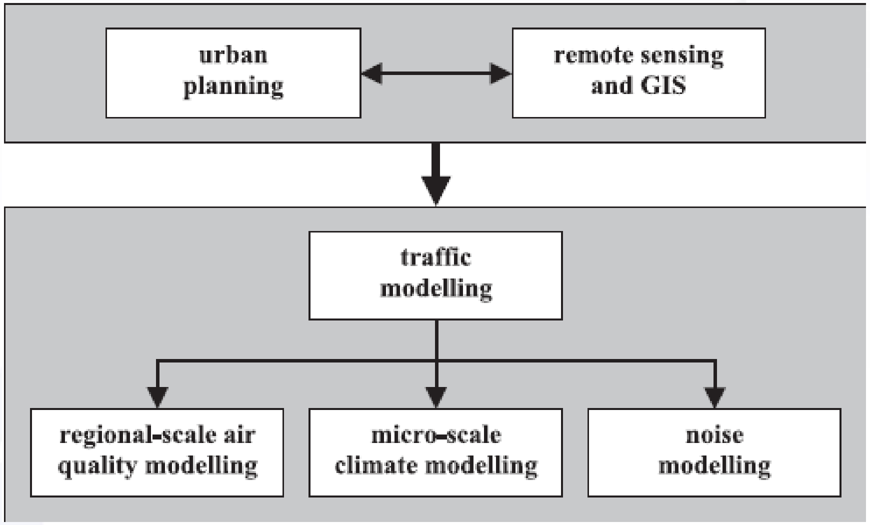
- Five UK cities
- Demographic characteristics
- Biodiversity potential
- Runoff from typical storm events
- Carbon sequestration potential
- Temperature
- Conclude that patchy green space provides greater services than impervious surfaces and housing

Source: Tratalos J, Fuller RA, Warren PH, Davies RG and KJ Gaston. 2007. Urban form, biodiversity potential and ecosystem services. Landscape and Urban Planning 83:308–317.

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Ongoing European Research Project

- Benefits of Urban Green Space (BUGS) is a methodology to assess the impact of green space and settlement patterns on urban environmental quality and social well-being and to formulate recommendations regarding the use of green space as a design tool in urban planning strategies. www.vito.be/bugs

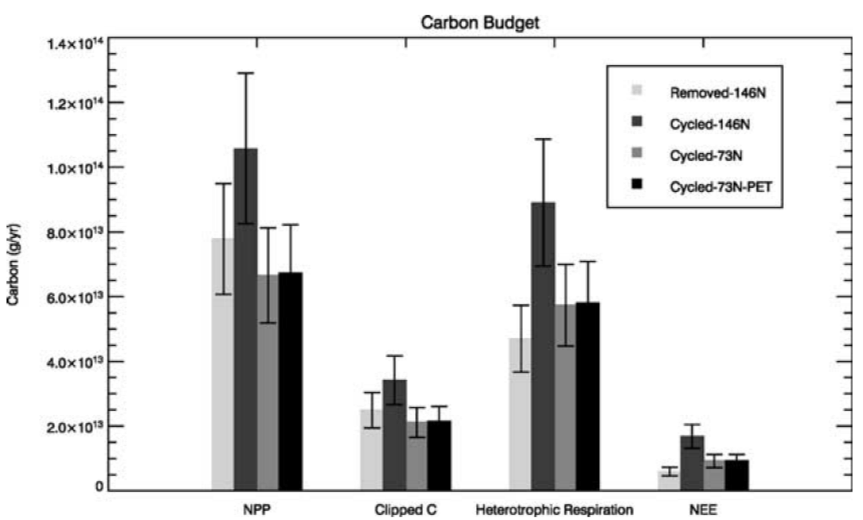


Source: De Ridder K, Adamec V, Banuelos A, Bruse M, Bürger M, Damsgaard O, Dufek J, Hirsch J, Lefebre F, Perez-Lacorzana JM, Thierry A and C Weber. 2004. An integrated methodology to assess the benefits of urban green space. Sci Tot Env 334– 335:489–497.

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Integrated Analyses

- Biome-BGC ecosystem process model
- Models warm-season and cool-season turf grasses under different management scenarios
- Simulates potential carbon and water fluxes assuming well-maintained lawn management practices across several US locations
- Results indicate that well-watered and fertilized turf grasses act as a carbon sink but with a water cost.



Source: Milesi C, Running SW, Elvidge CD, Dietz JB, Tuttle BT and RR Nemani. 2005. Mapping and modeling the biogeochemical cycling of turfgrasses in the United States. Environ Manag 36:426-438. DOI: 10.1007/s00267-004-0316-2.

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

More Integrated Analyses

Table 1. Commonly discussed urban ecosystem services/ disservices associated with biogeochemical cycles, with their potential magnitudes (relative to the scope of the associated environmental problem) and uncertainty levels

Ecosystem service	*Potential magnitude*	*Current level of uncertainty*
C sequestration	Low	Low
Net GHG emissions	Moderate	High
Local cooling	High	Moderate
Stormwater mitigation	High	Moderate
Water-quality mitigation	High	High
Air-quality mitigation	Low	High
General human health	Moderate	Moderate

Ecosystem disservice	*Potential magnitude*	*Current level of uncertainty*
Water use	High	Moderate
Net GHG emissions	Moderate	High
Source of allergens	High	Low
VOC emissions	Moderate	Moderate

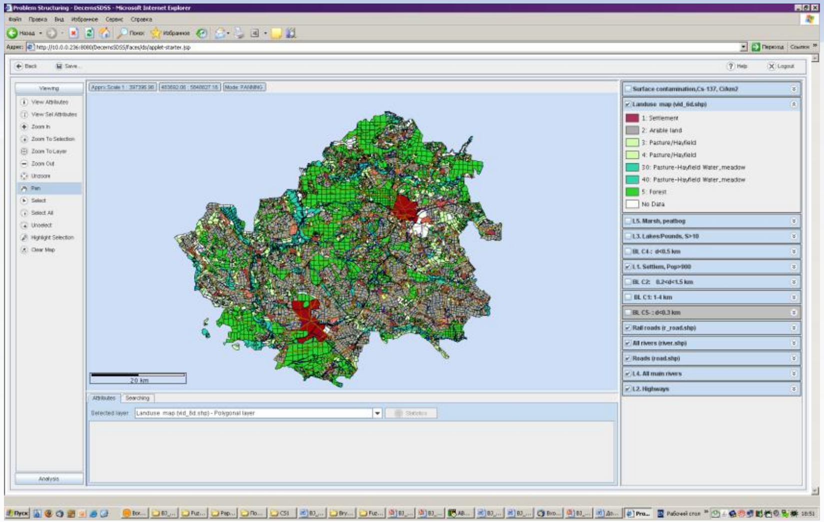
Notes: GHG emissions are listed as both a service and disservice because the impacts of plants or soils may be either positive (net cooling) or negative (net warming) in hot climates. VOC = volatile organic compounds, which are precursors to the formation of ozone pollution.

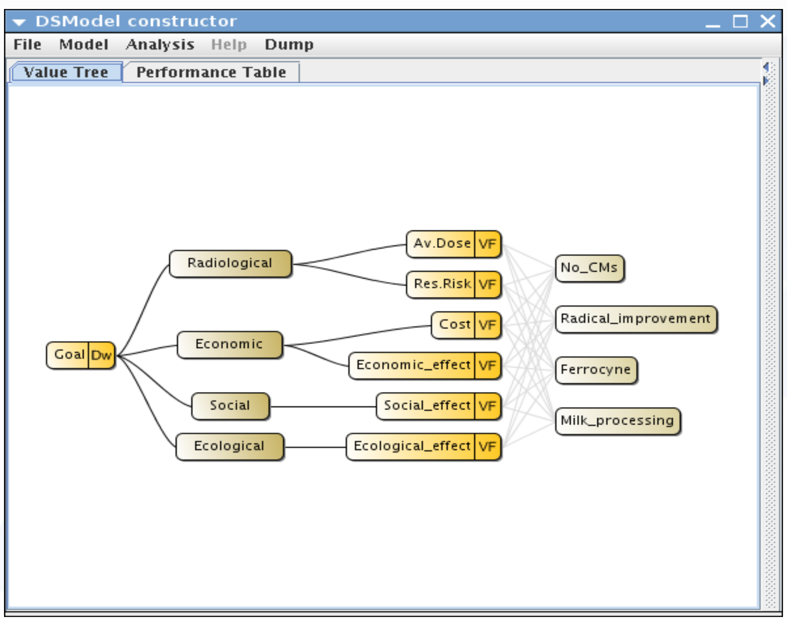
Source: Pataki DE, Carreiro MM, Cherrier J, Grulke NE, Jennings V, Pincetl S, Pouyat RV, Whitlow TH and WC Zipperer. 2011. Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. Front Ecol Environ 9(1):27–36, doi:10.1890/090220.

- Discuss services and disservices in urban environments
- Urban area and ecosystem specific
  - Arid areas
  - Population density
- Clearly articulate potential benefits

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Spatial Decision Support





- Formalized methods for evaluating alternatives against criteria to identify tradeoffs
- Link GIS, environmental models, and decision criteria and objectives
- Scenario development
  - Stakeholder involvement
  - Establishing criteria

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Potential Strategies To Maximize Services

- Minimize run-off and product deposition on hardscapes and support development of best management practices
- Encourage blended landscapes that feature lawns, rain gardens, shrubs, trees and green ground cover
- Changes in irrigation practices (e.g., use of rain collection, recycling wastewater)
- Educate consumers

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING

Conclusions

- Urbanization is increasing
- There are clear ecosystem service benefits associated with green space in urban areas
- Most beneficial green space may require additional maintenance which can lead to potential ecosystem disservices that can be managed
- GIS-based methods, integrated models, and decision analytic approaches can inform evaluation of tradeoffs
- Effective mitigation of disservices central to maximizing net environmental services
  - Solutions are needed to improve the amount and vitality of green space in urban areas

E RISKSCIENCES
ANALYSIS & TOOLS FOR DECISION-MAKING