Climate Change Resilience & Stormwater Management: A Social-Ecological Approach to Green Infrastructure

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Lawmaker: 'Did climate change kill two people in Ellicott City?'

Heavy rain Saturday led to dramatic flooding scenes and property damage in both Ellicott City and Baltimore.

By Erin Cox . Contact Reporter
The Baltimore Sun

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Maryland state senator asks: "Did climate change kill two people in Ellicott City?"

AUGUST 1, 2016, 2:25 PM

A state lawmaker suggested Monday that climate change could be to blame for the flash-flood that killed two people and destroyed much of historic Ellicott City

From this article

University of Balti aid director killed

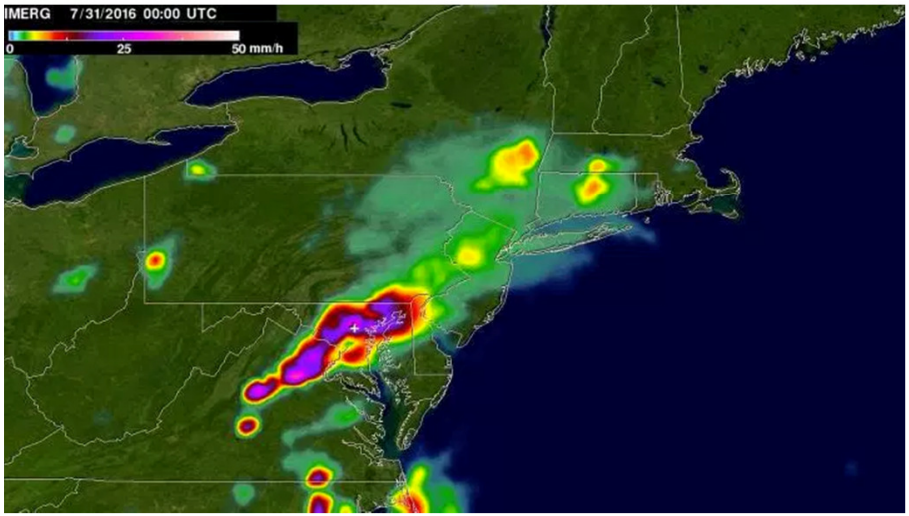
EXPERT BLOG › BECKY HAMMER

Maryland Flood Highlights Need for Climate Change Planning

August 01, 2016 | Becky Hammer

This weekend, a historic flash-flooding event killed two people and caused massive destruction in Ellicott City, Maryland. The town received more than 6 inches of rain over the span of two hours. According to the National Weather Service, an event like this should statistically happen only once every 1,000 years, based on historical data.

But because of climate change, extreme events like this one are happening more frequently, and scientists expect that trend to continue into the future. Our past experiences with floods are no longer a reliable indicator of our present or future risk.



Overview

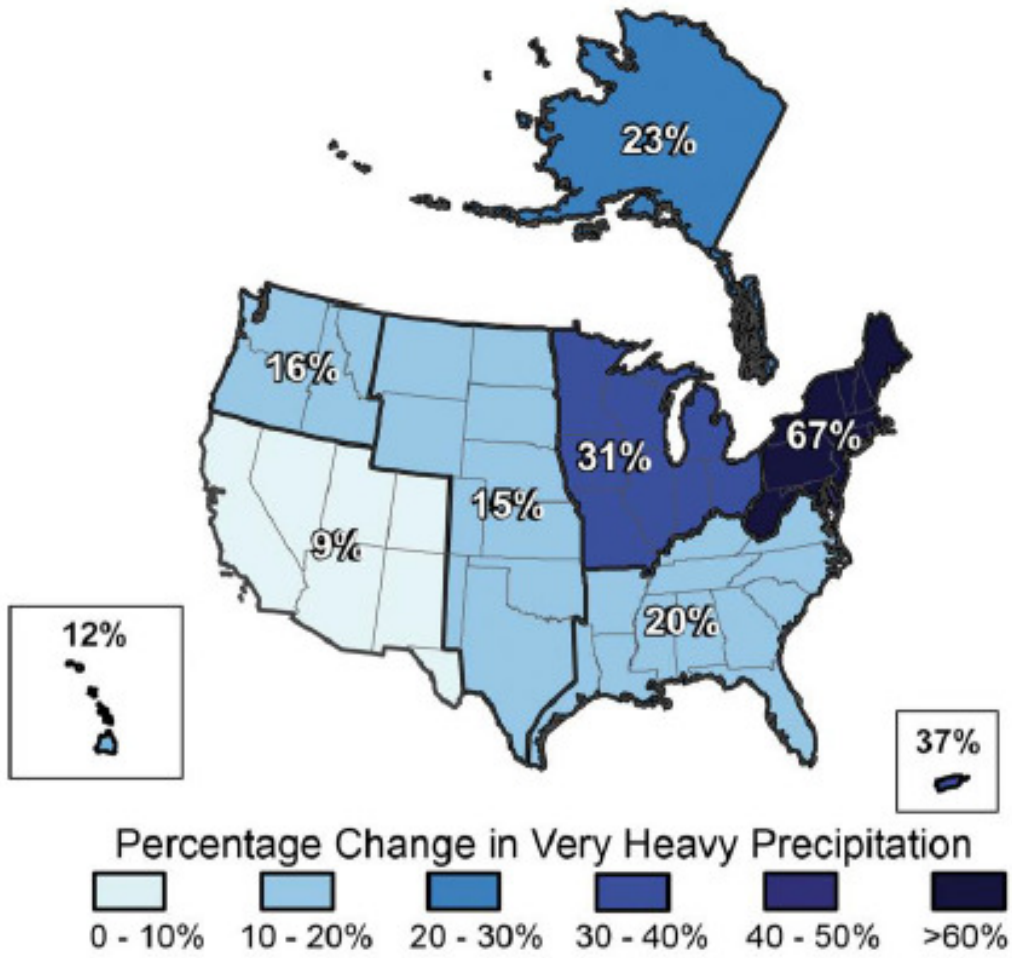
1. **Climate Adaptation Planning and Resilience** needs a broad view of the built environment
2. **Ecosystem Services of Green Infrastructure** may enhance climate resilience

- Climate change pressures
- Ecological perspectives on resilience
- Resilience of green infrastructure
  - Literature review
  - Modeling in Anacostia
- Social-ecological perspectives

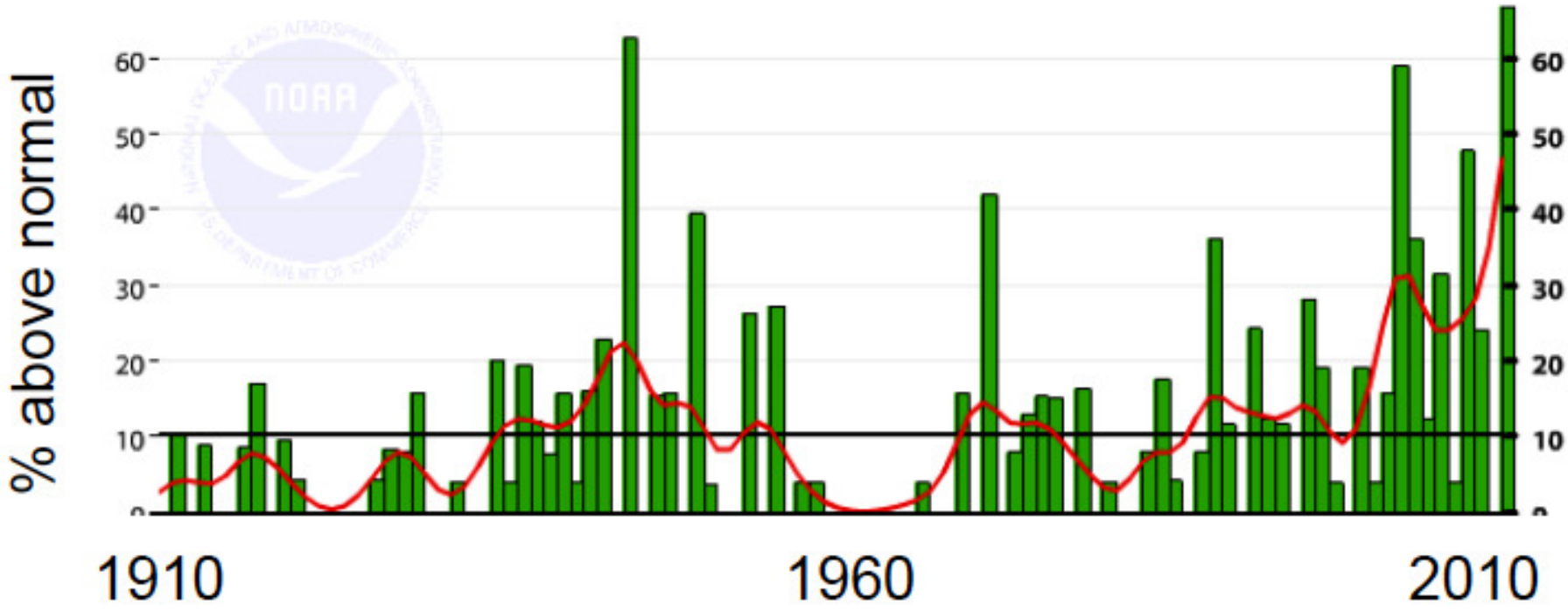
More Intense Storms

Historic Return Interval	Current Return Interval
100	60
50	30
2	1.4

DeGaetano 2009



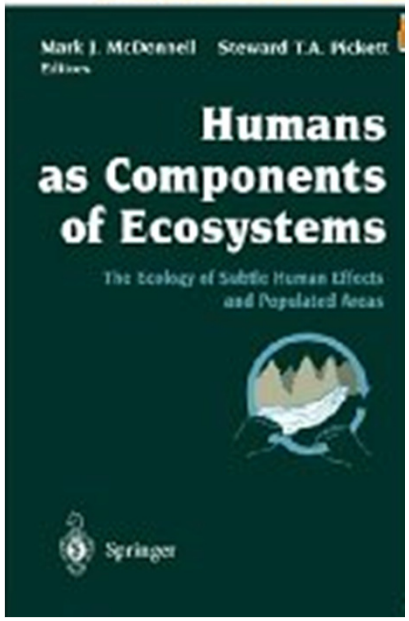
More Rainy Days

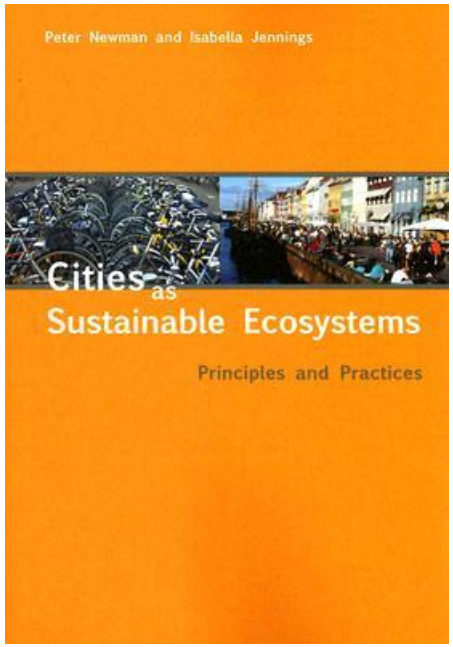


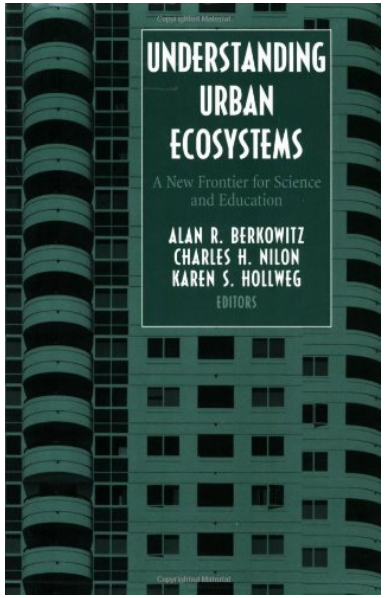
In MD, August and September of 2011 were the wettest the state has seen in 117 years

A New Ecological Paradigm

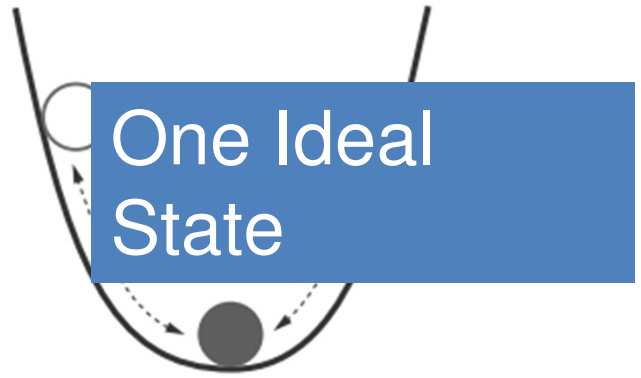
- City is an object of ecological investigation
- Cities result from ecological, physical, and human forces







Concepts of Resilience



Engineering resilience concept

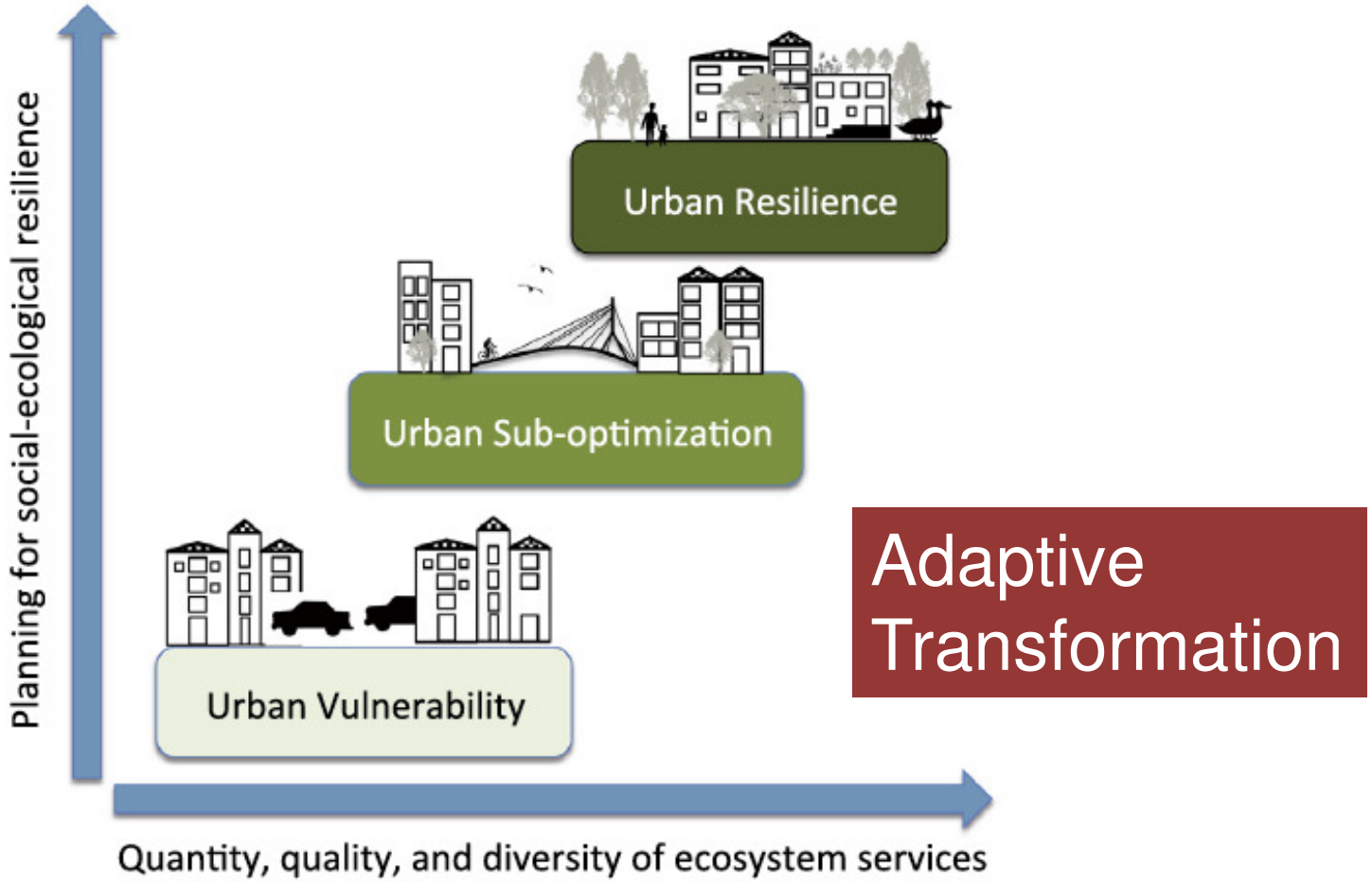
Ecological resilience concept

Engineering Resilience
rate of return to the valley

Ecological Resilience
probability of staying in the valley

Liao 2012, following Scheffer et al. 1993, Peterson et al. 1998, Walker et al. 2004

Resilience of and through urban ecosystem services



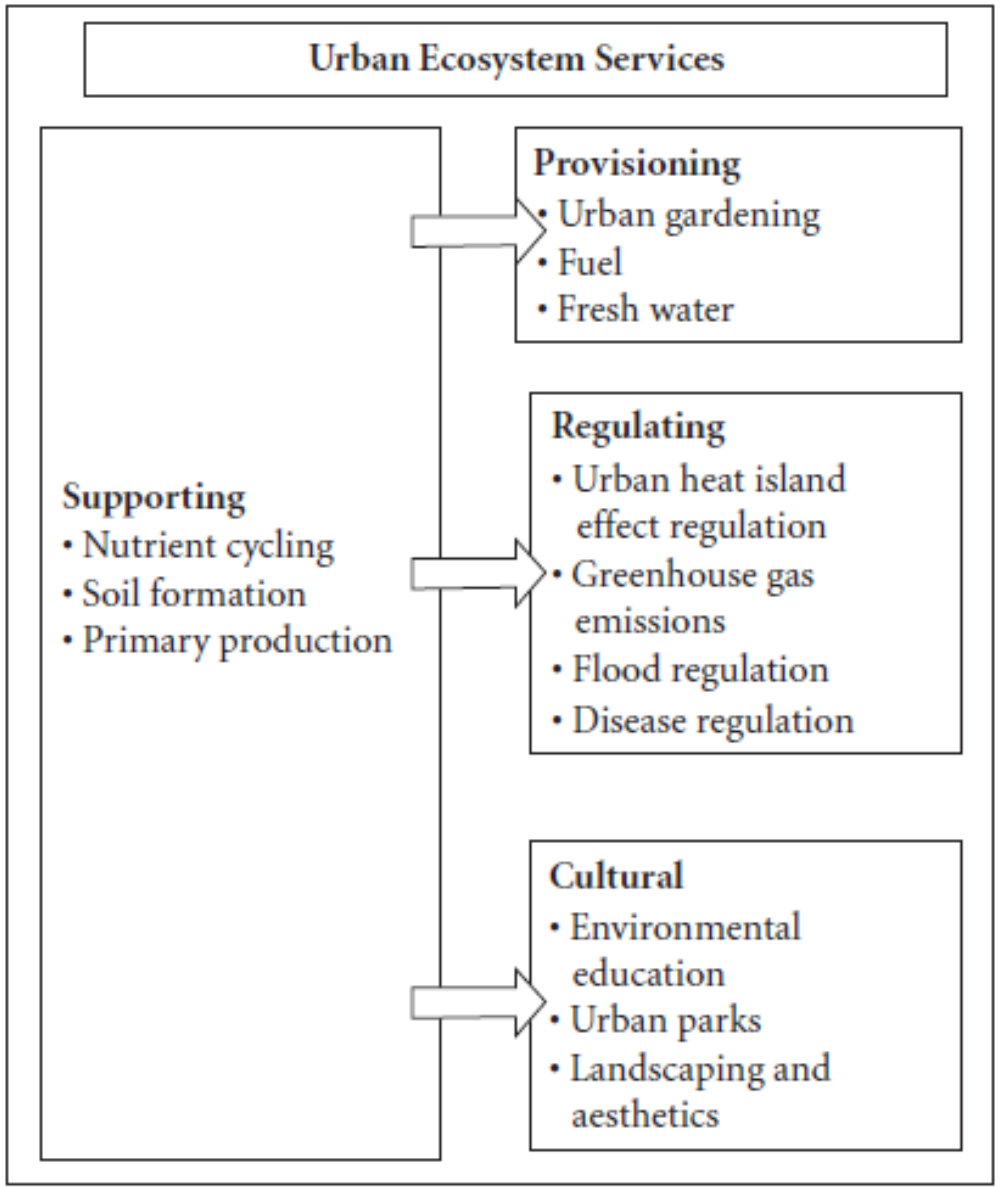
McPhearson et al. 2014

Ecosystem Services:

the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfill human life (Daily 1997)

The benefits people obtain from ecosystems (MEA 2005)

Urban Ecosystem Services



Pavao-Zuckerman, 2012

Abiotic

- Flood protection
- Reduce urban heat island effects
- Improve air quality

Biotic

- Biomass and food production
- Bioremediation
- Reservoir of diversity

Social

- Recreation and health
- Environmental education
- Supports economics

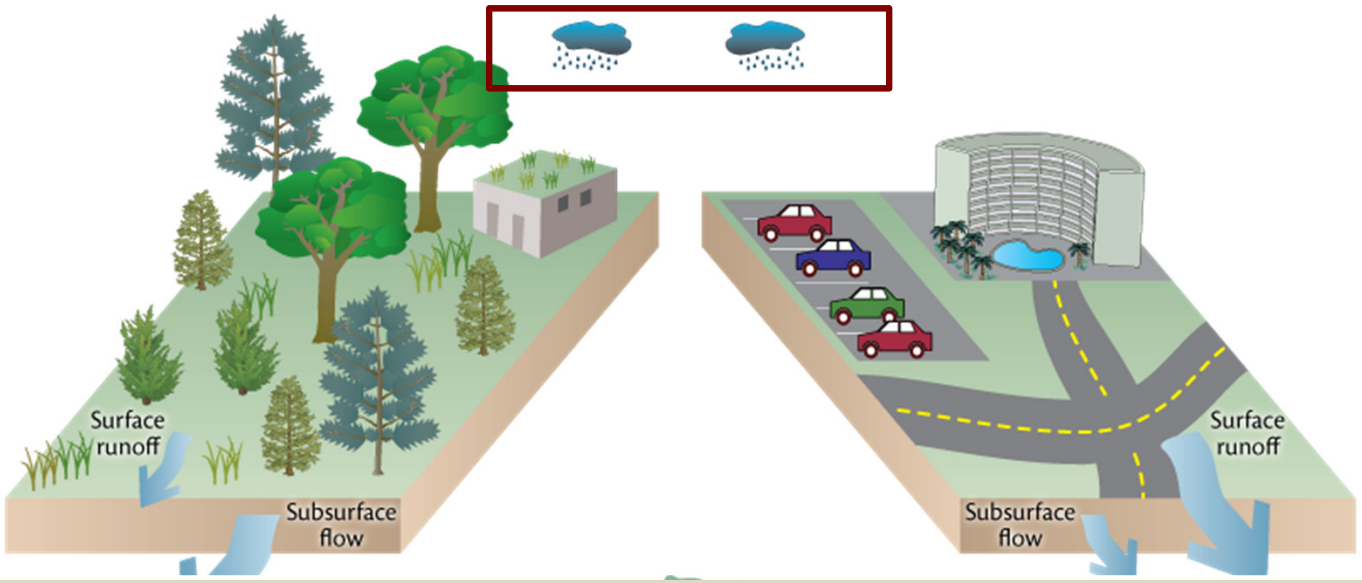
Ahern 2005

Green Infrastructure

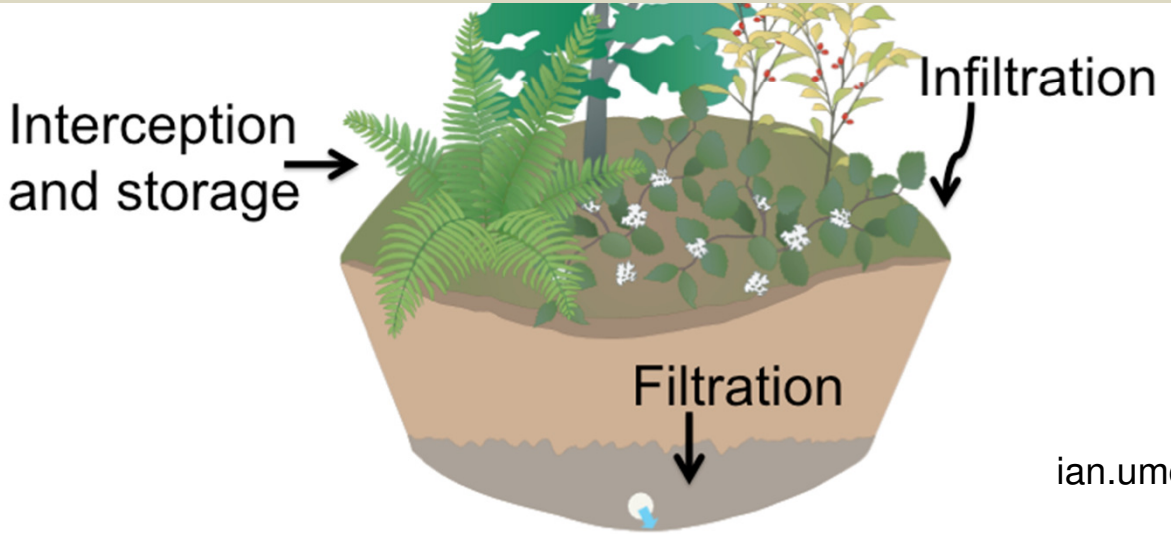
- Using ecological principles to augment ecosystem services

- Modify ecosystem storage/discharge for water, nutrients, pollutants, energy

- Supplement/replace the “grey” infrastructure



Is GI Stormwater Management resilient to climate change?



ian.umces.edu/imagelibrary/

Literature review

Is GI resilient to climate change?

- **Site** and **watershed** scale
- Excluded any that did not address **urban BMPs**

- 17 studies identified
- Most address only <u>one</u> aspect- **hydrology**, or **water quality**, none on **human health aspects**

Resilience of Green vs. Gray

- Intense storm to represent climate change caused increased overflows in Richmond, VA
- Green scenario: bioretention, green roof, porous pavement, planters
- Gray scenario: tunnel storage

- **Reduction of Overflows: Green < Gray**

Lucas and Sample 2015

Resilience of Existing Features

Citation	Management (baseline)	Simulated climate (year or condition)	Pollution load	Overflow volume
Fischbach et al. 2015	Multiple BMPs	2035-2045	↑	NA
Hathaway et al. 2014	Bioretention	2055-2058	NA	↑
Forsee and Ahmad 2011	Ponds	1.2X increase in 6-hr 100-yr storm	NA	↑
Moglen and Vidal 2014	Ponds	2041-2070	NA	↑

Simulated Future BMP Implementation

1. Most studies show increased negative impacts of stormwater in a future without BMPs,
2. Most (but not all) studies show some degree of urban watershed adaptation to climate change via BMP implementation.

Usually a significant investment in GI enhances resilience

- reduction impervious cover in Boston (fr. 25 to 16%)
- Porous pavement over 33% of Seoul
- 100% green roofs in Manchester, UK

Pyke et al. 2011, Kim et al. 2015, Gill et al. 2007, Zahmatkesh et al. 2015, Waters et al. 2003

Catchment evaluation - model

Is GI resilient to climate change?

- Will runoff volume, peak flow rates, N, P or sediment loads respond to future climate scenarios?

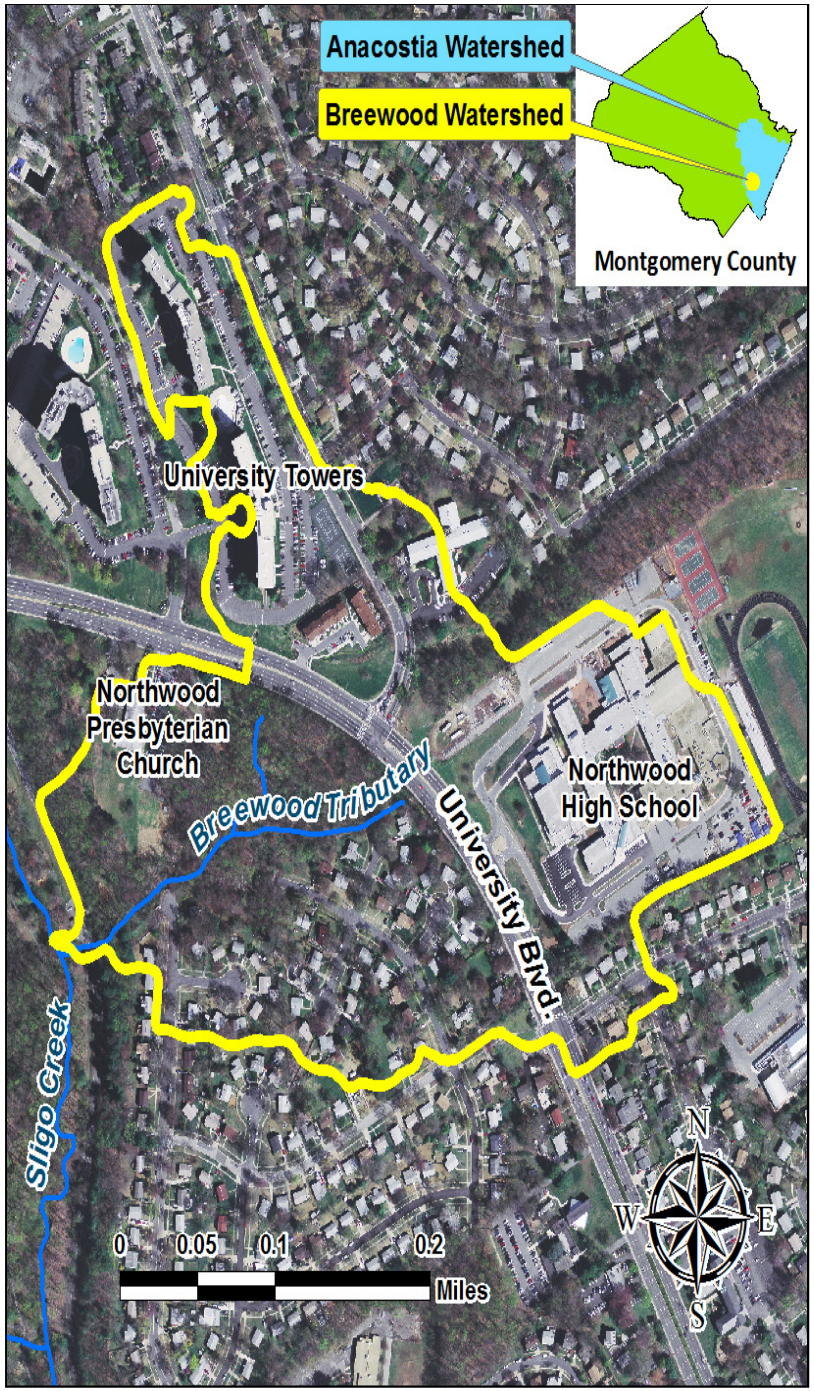
- Will existing GI provide the same relative reductions?

- Will expanded GI implementation improve watershed resilience to climate change?

Breewood catchment
Upper Sligo Creek

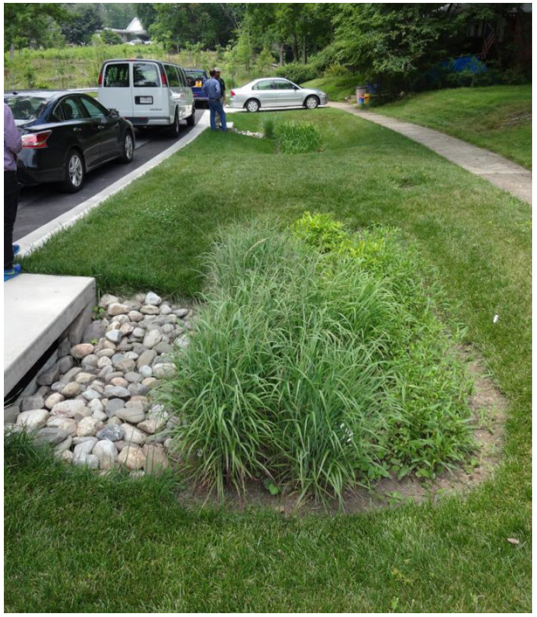
38% impervious area

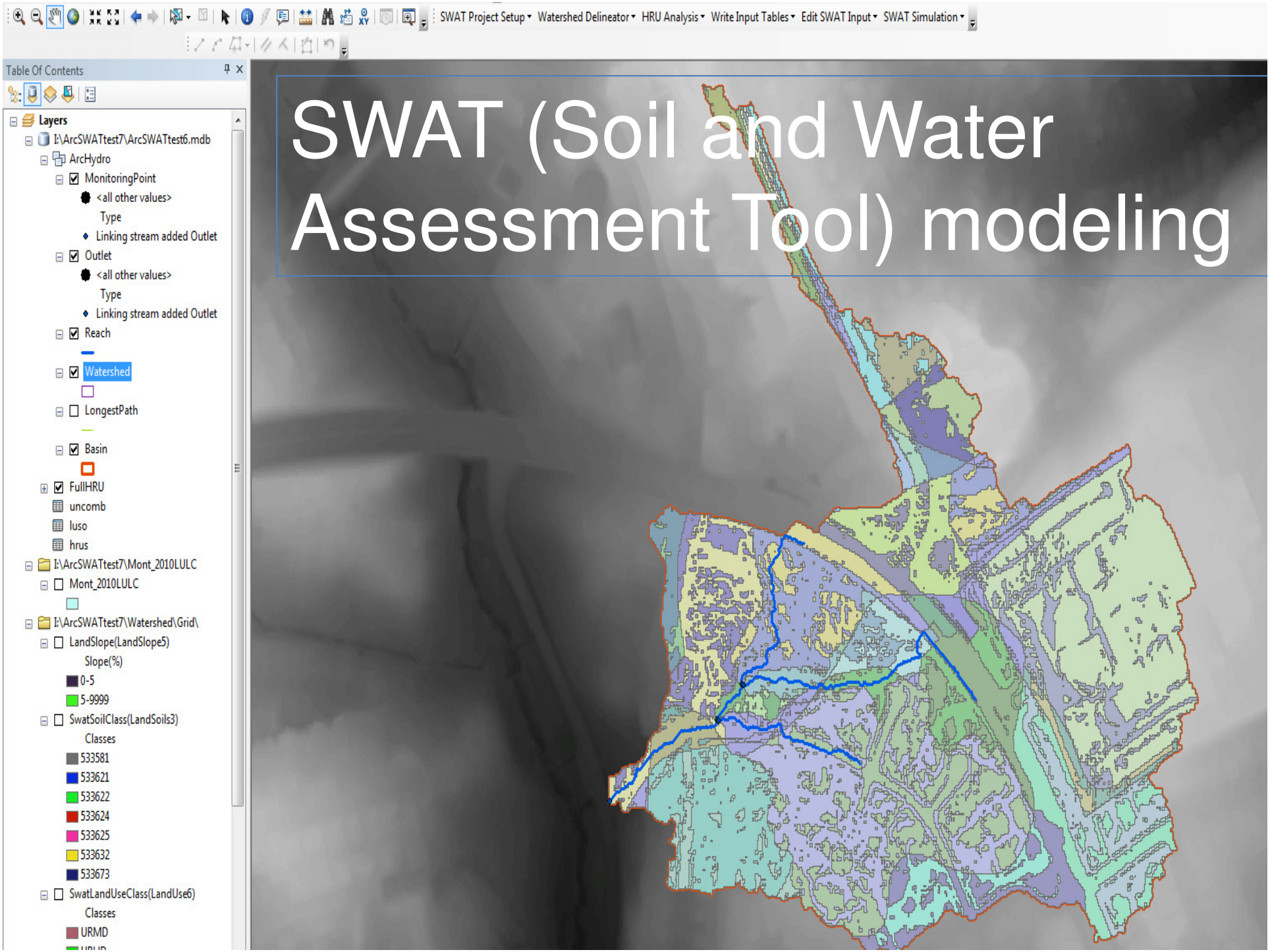
Land Use	Area
Medium Density Residential	38%
High Density Residential	18%
Institutional	24%
Commercial	2%
Deciduous Forest	18%
Total area	**63 acres**



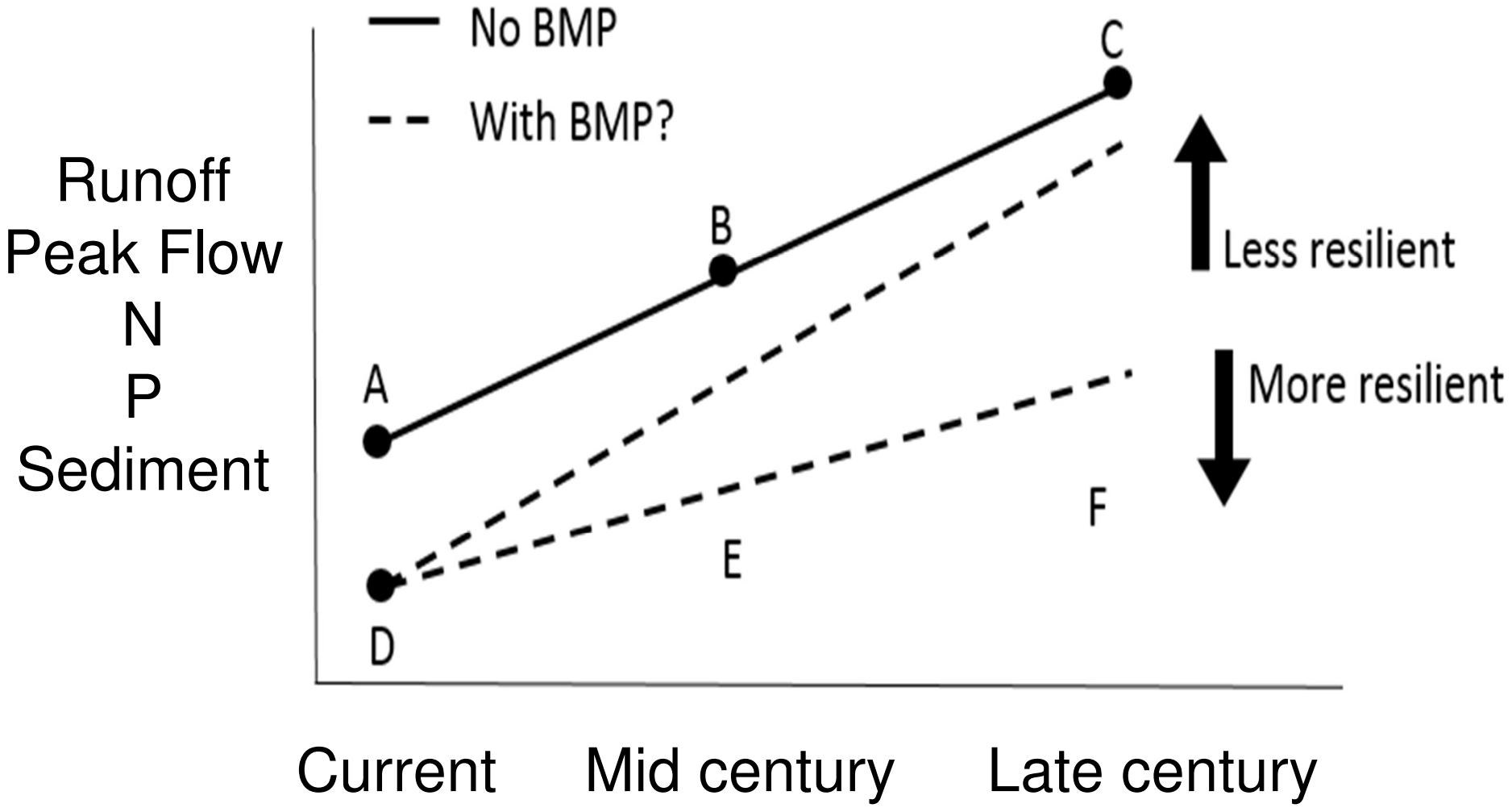
Management actions:

- 10 LID retrofits installed in 2014
- Stream monitoring before and after installation

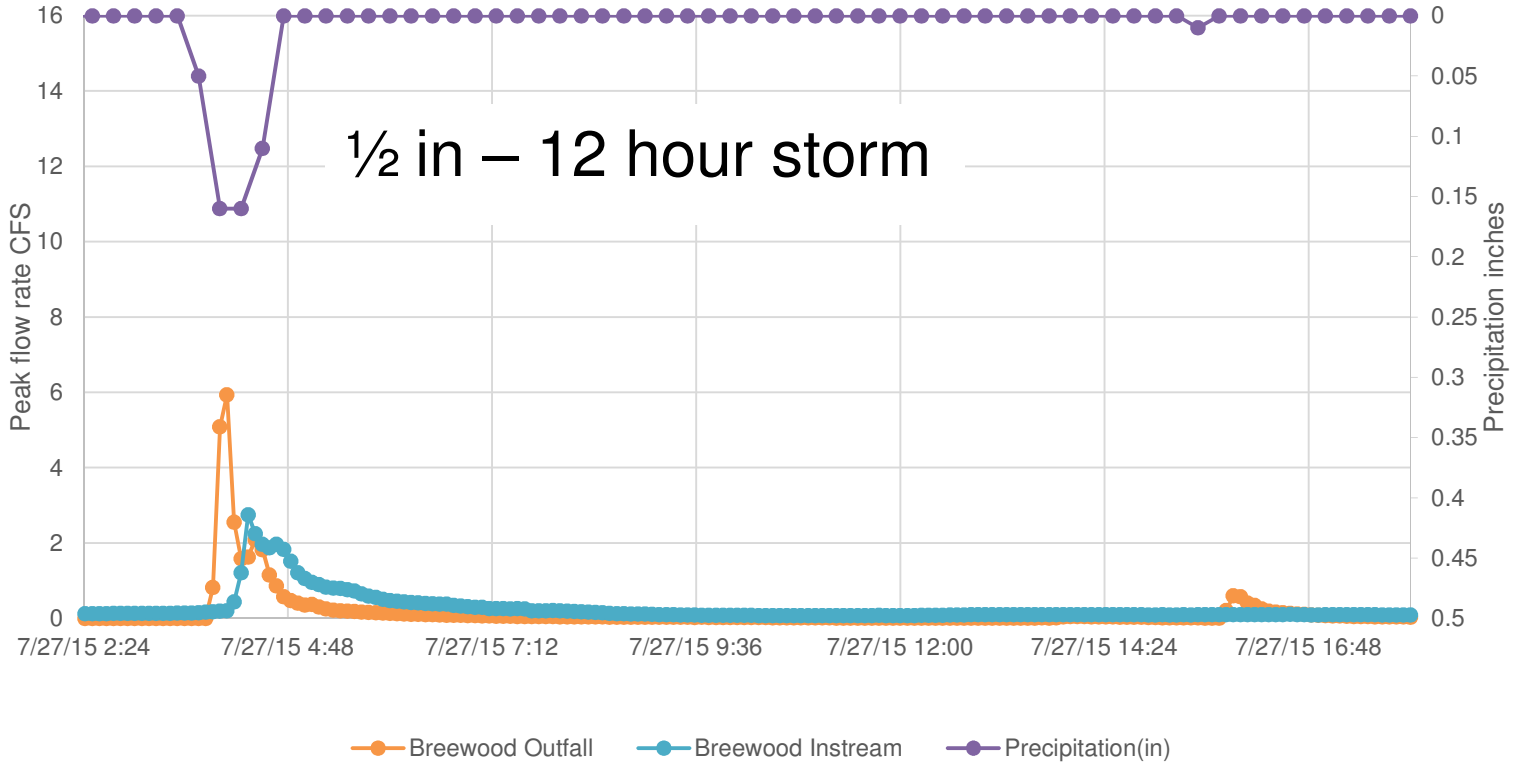



SWAT Project Setup
Watershed Delineator
HRU Analysis
Write Input Tables
Edit SWAT Input
SWAT Simulation
Table Of Contents
Layers
I:\ArcSWATtest7\ArcSWATtest6.mdb
ArcHydro
MonitoringPoint
<all other values>
Type
Linking stream added Outlet
Outlet
<all other values>
Type
Linking stream added Outlet
Reach
Watershed
LongestPath
Basin
FullHRU
uncomb
luso
hrus
I:\ArcSWATtest7\Mont_2010LULC
Mont_2010LULC
I:\ArcSWATtest7\Watershed\Grid\
LandSlope(LandSlope5)
Slope(%)
0-5
5-9999
SwatSoilClass(LandSoils3)
Classes
533581
533621
533622
533624
533625
533632
533673
SwatLandUseClass(LandUse6)
Classes
URMD
SWAT (Soil and Water Assessment Tool) modeling

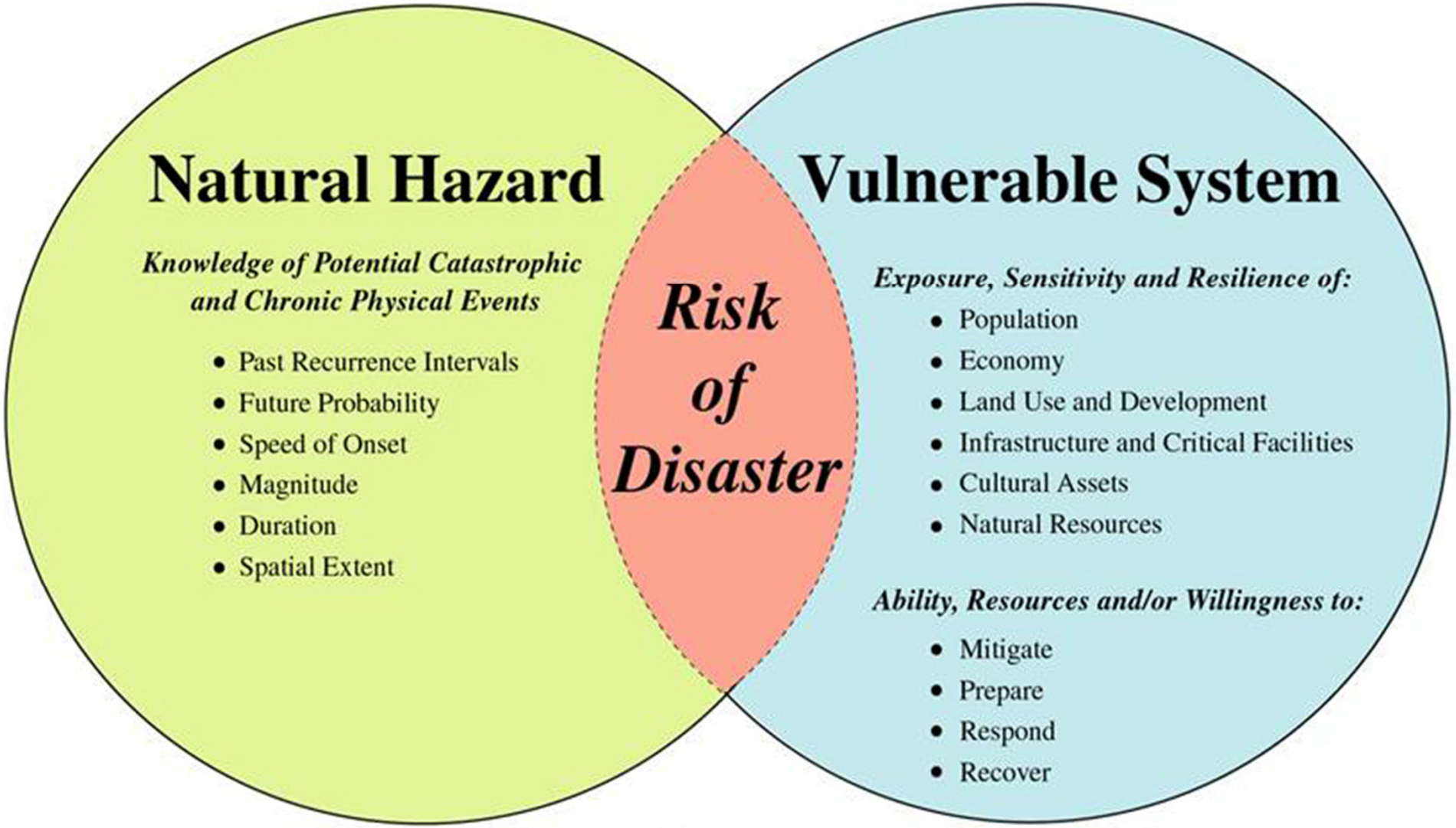
Predictions & Evaluation
Run SWAT for Event Sizes



Calibration and Validation



Risk & Social-Ecological Systems



http://pubs.usgs.gov/fs/2011/3008/

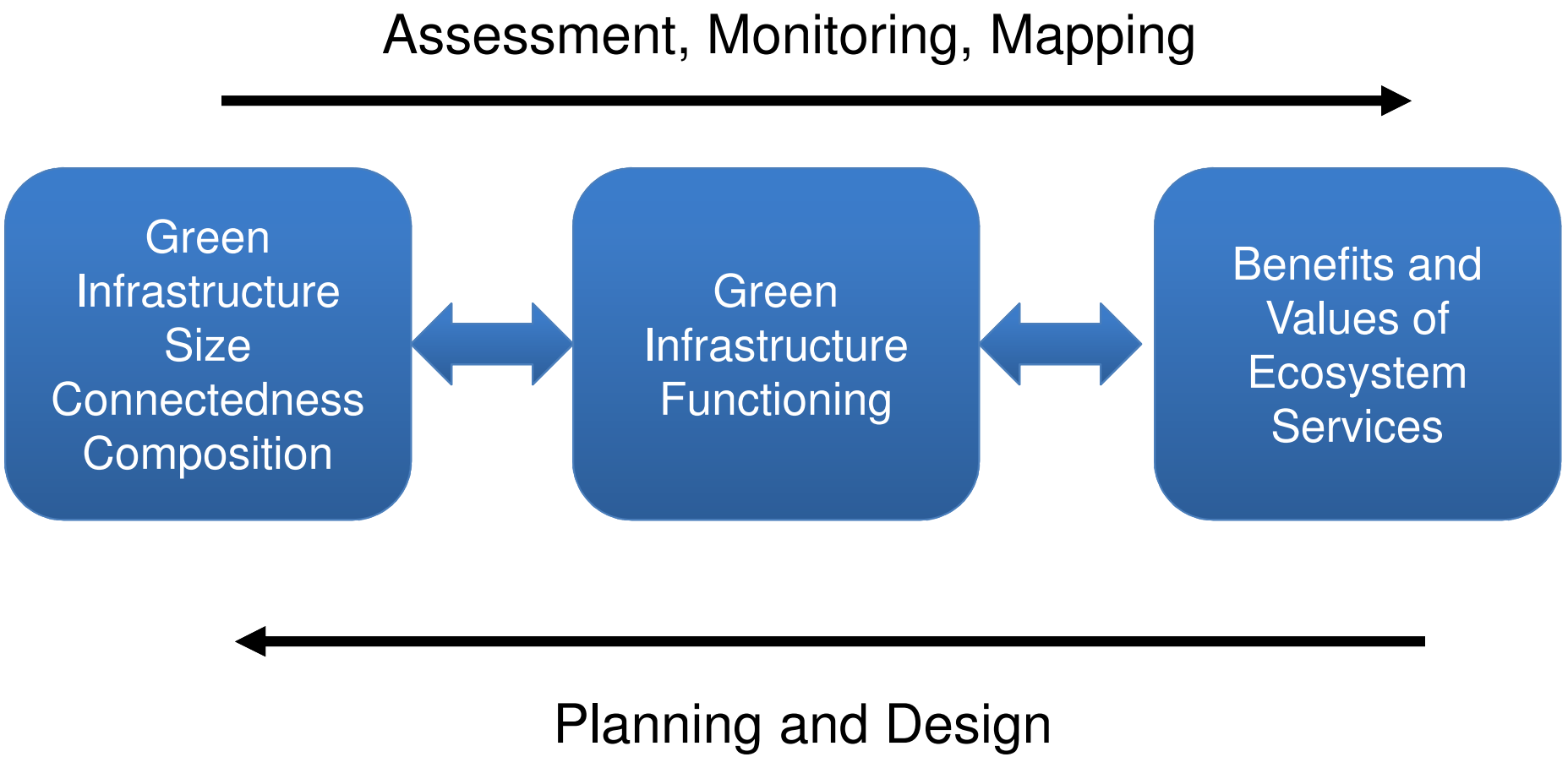
Enhancing Resilience ≈ Reducing Vulnerability

Resilience Enhances Adaptive Capacity

Element of resilience	**Local Actions**	**Regional/Global Action**
Exposure to hazard	• Maintain and enhance ecosystem function	• Mitigation of drivers • Enhanced responsiveness
Adaptive capacity	• Ecological diversity • Economic diversity • Inclusive governance	• Integrating response organizations • Networks to promote learning

Building on Adger et al. 2005

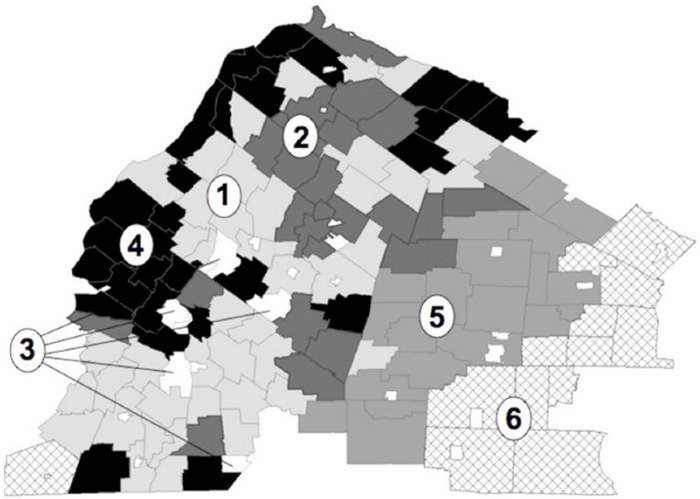
Green infrastructure provides services which is a form of “added value”

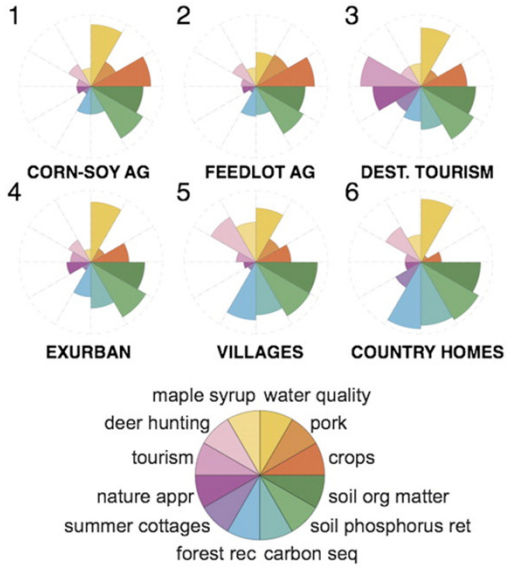


Modified from Opdam 2013

Ecosystem Service Trade-offs Affect Planning, Design, Management

Multifunctionality is a Planning Goal

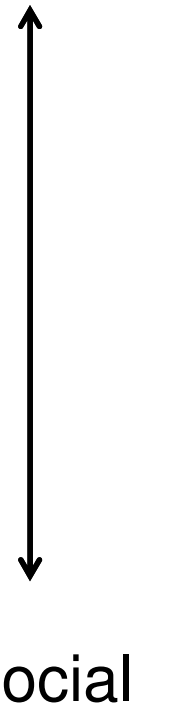




Raudsepp-Hearne 2010

Climate Resilience & GI Knowledge

- How services are provided in place, role of green infrastructure
- How to map, how to manage, how to integrate governance and resilience
- Preference, aesthetics, equity, justice issues
- **Ecologists, designers, managers and planners need to collaborate better and earlier**



Existing infrastructure - not resilient

Stormwater GI - effective climate adaptation

Image sources: U.S. Army Corps of Engineers, Chesapeake Bay Program

Expanded implementation likely needed

Social-Ecological Dimensions

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