Mapping and Planning for Green Infrastructure

Karen Firehock, Executive Director

TransportiCA – Webinar Series
August 30, 2018
Today

1. Green infrastructure defined
2. Mapping green infrastructure in rural and urban environments
3. Applications and examples
In 2006, based on a successful green infrastructure planning class I taught at the University of Virginia, I decided to form a not-for-profit center to expand the reach and capacity for this work. I still each at the university, but my main focus has become the Green Infrastructure Center (GIC). GIC helps communities evaluate their green assets and manage them to maximize ecological, economic and cultural returns. We do this by:

- Building landscape models
- Teaching courses and workshops
- Research into new methodologies
- Creating community green infrastructure plans

[www.gicinc.org](http://www.gicinc.org) find our projects here!

Webinar speaker:

Karen Firehock GIC Director
Based on 20 field tests in multiple states, our book provides the six-step process to create an effective green infrastructure strategy at any scale, right order thinking for building resiliency, working in rural and urban environments and making the case for this work. Chapter seven provides steps for using GIS to build a computer model to create a green infrastructure network. This was a selected read for TransportiCA’s book of the month.

To get a 40% discount, enter this code at checkout on Island Press website: MULTISCALE

Some case examples of recent work in urban landscapes...

**Summerville, SC**
Re-linking nature and history in a rapidly developing town

**Hot Springs, AR**
Revitalizing a city at the intersection of history, health and nature

**Jersey City, NJ**
Building the case for green infrastructure in a post-hurricane Sandy urban environment

**Richmond, VA**
Urban revitalization in a post-industrial city – regreening, regrowing
Infrastructure (n): the substructure or underlying foundation...on which the continuance and growth of a community or state depends.
What is green infrastructure?

Left shows the gray infrastructure including buildings and roads (left). Classified high-resolution satellite imagery (right) adds a green infrastructure data layer (trees and other vegetation).
Green Infrastructure = Natural Assets
Natural Assets Also Support Cultural Assets

Natural assets support the landscape context for historic features such as scenic roads.
Origin of the Term “Green Infrastructure”

Florida coined the term “Green Infrastructure.” in a 1994 report to the governor on land conservation strategies.

It was intended to reflect the notion that natural systems are important components of our “infrastructure.”
Green Infrastructure Definition Expands

In 2006, EPA added Best Management Practices such as raingardens to the definition. We consider this as ‘constructed green infrastructure.’

The key is to first consider natural infrastructure (trees, forests, rivers) protect them and connect them, build in the least impactful manner, then mitigate impacts.

So, *first conservation, then mitigation.*
Impacts of poor/no planning on environment

Traffic congestion
Impacts of poor/no planning on environment

Traffic congestion

Water quality
Impacts of poor/no planning on environment

Traffic congestion
Water quality
Air quality
Impacts of poor/no planning on environment

Traffic congestion
Water quality
Air quality
Loss of critical habitat
Impacts of poor/no planning on environment

Traffic congestion
Water quality
Air quality
Loss of critical habitat
Loss of working lands

While you viewed this slide, America lost another 3 acres of open space
Where to develop?

Smart Growth = Using Existing (grey) Infrastructure

But is this enough?
Typical Plan =

Save $\frac{1}{2}$
Build $\frac{1}{2}$

While this approach is simple, it does not conserve our best resources.
Need to consider:

What are all the assets?

Grey + Green = Smart + Green
The problem of green space planning when it doesn’t see past parcels...
<table>
<thead>
<tr>
<th>Traditional Development</th>
<th>Green Infrastructure Based-Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan for grey infrastructure first (roads, stormwater pipes)</td>
<td>First, assess natural features and functions and protect them.</td>
</tr>
<tr>
<td>Green spaces in leftover lands (e.g. steep slopes and floodplains)</td>
<td>Plan for parks, trails, habitat connections before siting buildings.</td>
</tr>
<tr>
<td>Work within confines of parcel = pocket parks, inner trails, gated systems</td>
<td>Connect land and water habitats to region and across ownerships</td>
</tr>
</tbody>
</table>
Urban trees have many benefits!

- Trees clean air – trees absorb pollutants, VOCs, filter runoff, cool the county.
- Well being and mental health - people heal faster when they can see or access green.
- Less crime occurs near trees.
- People will exercise if they can access green where they work or live.
- People shop longer and more often in tree-lined retail areas and spend about 12% more.
- Companies, especially those that are have well paid and skilled workforce place a strong importance on the “green” of the local environment.

So when budgeting for street trees, remember that they will pay you back!
Green Infrastructure: Planning For A Connected Landscape

It’s about connecting the landscape!

Not just key habitats but how we connect them!

Habitat cores connected by corridors!
What is a Habitat Core?

An intact area of similar natural landscape type that is not overly bisected.

Take a distance of 2-3 “canopy heights” from the edge. Then, multiply by 3 to get edge ~ 100 feet.

Subtract the edge zone from total area to get remaining “interior habitat.” Is it enough to be a core?

If smaller, it may still be a key “patch” or “site.”

Interior = Total Area – 3(h)

Ideal interior ≥ 100 acres
Core Shape Matters

Bigger is better and shape matters too.
The above images show edge area and interior. Notice which have the most interior.
Core Shape Matters

In nature, cores are not usually round. Fingers of green help animals move into and out of cores.
Boundary Shape Also Matters

A straight edge facilitates more parallel animal movement, while a more curvilinear edge facilitates movement into and out of the core.
How is intact landscape determined? First, what fragments the landscape?

Image: VA Dept. of Conservation and Recreation
All Land Cover + Fragmentation Features
Result: Which are intact habitat cores?
Corridor Analysis

Image: VA Dept. of Conservation and Recreation
More Edge = More Impact Zones
How does road planning affect cores?

Dividing a large core into two smaller cores = less interior habitat and more edge.
In California, the riparian songbirds, least Bell's vireo (*Vireo bellii pusillus*) and willow flycatcher (*Empidonax traillii*) are listed as endangered due to loss of riparian habitat and nest parasitism by brown-headed cowbirds.
Type of Edge Matters Too!

The hard edge (top) is not as conducive to supporting species’ diversity as the bottom soft (more gradual) edge.

California Quail
Prefers CA chaparral, sagebrush, oak woodlands, and foothill forests
Credit: GregTheBusker
Corridors May Not Be Uniform.

The ideal is 100 meters of safe space in the middle and 100 meters of edge.

minimum width = 300 meters wide
Who Can Use the Corridors? (300 meters is ideal...)}
When Direct Corridors Are Lost, Some Species Can Still Hop Across.
If cores or patches are too far apart, or if a core is lost, species may become isolated and decline over time.
Wildlife Crossings

Rendering of crossing over highway 101 in Agoura Hills, CA. Construction proposed in 5 years: 200’ L by 165’ W.

Design Resources: https://guides.libraryconnectivity.org/Wildlife_Crossing

Crab bridge at Christmas Island, Australia

Netherlands
Examples – Rural and Urban

*Smaller scales change focus*
EXAMPLE: GIC’s Model of SC’s Intact Habitats

GIC has built several state models – here is an example of our cores habitat model for South Carolina.

At right (red circle) is Berkeley County SC. We will show how the model is evaluated for county planning.
All cores are not equal. We also rank them (size and other factors).

- Total Area
- Depth of Interior
- Species Diversity
- Rare, Threatened, Endangered species
- Length of Streams Within Interior Forest
- Soil Diversity (USDA STATSGO/SSURGO)
- Area of Wetlands and Dunes
- Topographic Relief Index
- Area of Surface Water/Aquatic Habitat
- Fragmentation Index
Core Statistics

Use the tool to query the database for any core

Area: 3,673 acres
Core Depth: 2,174 feet
Species Richness: 143
Soil Diversity: 13
Perimeter/Area Ratio: 66.9
Stream Density: 24.7 ft/acre
Wetlands: 1,408 acres (38%)
Water: 16 acres
Topographic Diversity: 7.12
RTE Species Abundance: 1
RTE Species Diversity: 1
How do we prioritize what is most important and what is at risk?
GREEN INFRASTRUCTURE CENTER

Highest Ranked Cores (top 2 classes)
Highest Ranked Cores (top 2 classes) + adjacent cores
Highest Ranked Cores (top 2 classes)
+ adjacent cores

+ adjacent to stream or lake
Highest Ranked Cores (top 2 classes)
+ adjacent cores
+ adjacent to stream or lake
+ are fully or partially protected by conservation easements
Highest Ranked Cores (top 2 classes)
+ adjacent cores
+ adjacent to stream or lake
+ are fully or partially protected by conservation easements
+ key connections
Highest Ranked Cores (top 2 classes) + adjacent cores

+ adjacent to stream or lake
+ are fully or partially protected by conservation easements

+ key connections
+ riparian vegetation
4) **Risk Assessment** – What assets are most at risk and what could be lost if no action is taken?
Conservation Easements
+ Wildlife Management Areas
Conservation Easements
+ Wildlife Management Areas
+ US Forest Service Land
Active Forestry Land
Special Risk Factors
Assessing Development Pressures

- Distance to Major Roads
- Designated Growth Areas
- Proximity to Cities and Towns
- Proximity to Existing Development
- Zoned Residential
- Zoned for PUDs
- Small, undeveloped parcels
Back to Cores

- Distance to Major Roads
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Designated Growth Areas

Proximity to Cities and Towns

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Proximity to Cities and Towns
Proximity to Existing Development
Zoned Residential
Zoned for PUDs
Small, undeveloped parcels
Removing risk from current conservation areas
Network of intact, connected landscapes

Development pressures and risks to those landscapes
5) **Rank Your Assets and Determine Opportunities** – Based on those assets and risks you have identified, which ones should be restored or improved?
Regional Connections

Berkeley County is somewhat exceptional in that there is a large National Forest that occupies a large amount of land.

Looking at a regional view of green infrastructure assets can see how local assets can support regional strategies.
Regional Connections

Berkeley County is somewhat exceptional in that there is a large National Forest that occupies a large amount of land.

Looking at a regional view of green infrastructure assets can see how local assets can support regional strategies.
6) **Implement Opportunities** – Include natural asset maps in both daily and long-range planning (park planning, comp plans, zoning, tourism and economic development, seeking easements etc)
Zoom #2

A potential opportunity for coordinating development
A potential opportunity for coordinating development
Want to have your own model? You can! Based on GIC’s models for many states, Esri asked GIC to help them build a U.S. model. We provided the code to Esri to create the national map of habitat cores – free to everyone to use! For other countries, contact us to discuss options.

http://www.esri.com/about-esri/greeninfrastructure
Creating a Green Network in an Urban Landscape
Smaller scales ...

Trees and woodlots

Habitat patches

Streams and wetlands

Trails and smaller parks

Still can connect to larger networks …
Trails for transportation

In Lynchburg VA trails are used to commute to work and to enjoy nature in the city.

Dasani Blue Bikes offer free trail transport.
At Urban Scale – Canopy is Key

Studies have shown that urban canopy can reduce a city’s stormwater runoff by anywhere from two to seven percent (Fazio 2010)
The Image Classification Process

Image classification is the process of breaking an image into discrete ‘classes’, with one of the most common applications being to identify land use classes (urban, agriculture, forest, etc.)

While this project’s primary purpose is to identify tree canopy, a useful ‘byproduct’ will also be other land use classes like impervious surfaces, bare earth, etc.!
Supervised Classification

Involves carefully selecting ‘training samples’ from the imagery.

Each training sample contributes to building a ‘spectral signature’ for each land cover class.

The spectral signatures are used in the classification algorithms to predict the probability that a pixel is part a class (e.g. how well does a pixel match up with the spectral signature for the ‘tree’ class?)

Therefore, a number of techniques should be used to increase the probability that a pixel is put in the correct class, including field verifying the training samples, as well as the output classification.
Example: Charlottesville, VA

The Rivanna Trail that rings Charlottesville provides a bit of country in the city and a fun way to get around.
Aerial for Charlottesville VA where GIC just completed work…
Aerial

Gray Infrastructure Network
How do we turn the base map of land cover into a green network?
GREEN INFRASTRUCTURE CENTER

Aerial

Gray Infrastructure Network

Base Green Infrastructure Assets
GREEN INFRASTRUCTURE CENTER

Aerial

Gray Infrastructure Network

Base Green Infrastructure Assets

Key Open Space/Protected Assets (nodes)
GREEN INFRASTRUCTURE CENTER

Aerial
Gray Infrastructure Network

Base Green Infrastructure Assets
Key Open Space/Protected Assets (nodes)
Trail Network
Aerial

Gray Infrastructure Network

Base Green Infrastructure Assets

Key Open Space/Protected Assets (nodes)

Trail Network

Large Supporting Tree Canopy Patches
Aerial Gray Infrastructure Network

Base Green Infrastructure Assets

Key Open Space/Protected Assets (nodes)

Trail Network

Large Supporting Tree Canopy Patches

Creating “Green Threads” throughout City
Aerial
Gray Infrastructure Network

Base Green Infrastructure Assets
Key Open Space/Protected Assets (nodes)
Trail Network
Large Supporting Tree Canopy Patches
Creating “Green Threads” throughout City
Green Infrastructure = traffic calming = slower speeds, rainfall capture, beauty and economic benefits

Trees work as traffic calming elements because they create visual stimuli causing people to drive slower. Treed islands and bump outs tighten the footprint so lanes are narrowed, which slows traffic and shortens crossing distance for pedestrians.

The Belmont Neighborhood in Charlottesville – I worked with neighbors and the city to design these traffic calming projects.
This Charlottesville developer asked for (and got) a one-way road to reduce pavement, which is ringed by a bioswale. It also conserves 15 acres of forests and wetlands and allows public use.

http://www.riverbluffcommunity.com/Home.html
The GIC partnered with 6 states to demonstrate the role of trees as green infrastructure. The goal is to reduce flooding and to clean the water! Road flooding is a major issue.

There is a report for each city and a guide to replicating the work in any city (guide by early 2019)

SC, NC, GA, FL, AL, VA = 12 cities large to small, from mountains to coast!

For more visit:
http://www.gicinc.org/trees_stormwater.htm
Trees: the original – and best – green stormwater infrastructure!

Trees give us cleaner air, shade, beauty and stormwater benefits at a cost that is far cheaper than engineered systems!

*Estimates for the amount of water a typical street tree can intercept in its crown, range from 760 gallons to 4000 gallons per tree per year, depending on species.*
Accommodate Street Trees

Larger trees offer greater benefits – so think carefully when setting planting goals for streets! Allow 1000 cubic feet soil.

Consider using suspended pavement systems, rather than just choosing small trees! Trees will pay back your investment!
First, Map Urban Canopy!

Image classification is the process of breaking an image into discrete ‘classes’, with one of the most common applications being to identify land use classes (urban, agriculture, forest, etc.)
We account for the complexities of urban forests – what is the setting?

- Tree Over Lawn
- Tree Over Parking Lot
- Tree Over Street
- Tree Over Natural Forest Cover
Where Can We Fit More Trees?
Possible Planting Areas
Analysis:
Canopy varies greatly. So even if it is good citywide, it may be deficient in certain zoning types or neighborhoods.
Urban Tree Canopy

20% of annual rainfall or > retained in crown (Xiao et al., 2000)

Delays runoff up to 3.7 hours

↑ infiltration capacity of soils
GIC Developed a Stormwater Calculator

<table>
<thead>
<tr>
<th>Event (pick)</th>
<th>P (in)</th>
<th>Source</th>
<th>Existing Landcover</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual / 24 hour</td>
<td>4.5</td>
<td>Orange County 24 hour Rainfall Distribution</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Landcover</th>
<th>acres</th>
<th>%</th>
<th>Ci</th>
<th>Q Runoff (in)</th>
<th>Runoff / acre (cf)</th>
<th>Capture M gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare Earth</td>
<td>2,603</td>
<td>2.4%</td>
<td>3.80</td>
<td>334</td>
<td>1,192</td>
<td>750</td>
</tr>
<tr>
<td>Forested open space</td>
<td>13,991</td>
<td>13.0%</td>
<td>2.53</td>
<td>1,192</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td>Forested wetland</td>
<td>24,851</td>
<td>23.1%</td>
<td>2.65</td>
<td>2,225</td>
<td>1,245</td>
<td></td>
</tr>
<tr>
<td>Impervious</td>
<td>1,177</td>
<td>1.1%</td>
<td>4.30</td>
<td>171</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pervious</td>
<td>31,433</td>
<td>29.2%</td>
<td>2.65</td>
<td>2,808</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trees over pervious</td>
<td>18,134</td>
<td>16.8%</td>
<td>0.000</td>
<td>2.71</td>
<td>1,660</td>
<td>880</td>
</tr>
<tr>
<td>Trees over Impervious</td>
<td>15</td>
<td>0.0%</td>
<td>0.000</td>
<td>4.30</td>
<td>2</td>
<td>0.08</td>
</tr>
<tr>
<td>Water</td>
<td>4,383</td>
<td>4.1%</td>
<td>4.50</td>
<td>665</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetlands</td>
<td>11,048</td>
<td>10.3%</td>
<td>4.50</td>
<td>1,677</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>totals</strong></td>
<td>107,635</td>
<td></td>
<td></td>
<td></td>
<td>10,732</td>
<td>2,875</td>
</tr>
</tbody>
</table>

- Percent tree canopy: 61.8%
- Percent Impervious: 1.3%

- 0.000 Set Ci term
- Increased stormwater (million gallons): 842
- 10% <= Set loss %
- 60% <= Set % impervious

Hydrologic Soil Group acres
# Stormwater Calculator Example

## Potential Landcover - Increased Tree Cover

<table>
<thead>
<tr>
<th>Landcover Type</th>
<th>Acres</th>
<th>%</th>
<th>Runoff / acre (cf)</th>
<th>Capture M gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare Earth</td>
<td>1,314</td>
<td>1.2%</td>
<td>168</td>
<td></td>
</tr>
<tr>
<td>Forested open space</td>
<td>36,467</td>
<td>33.9%</td>
<td>3,106</td>
<td>4,121</td>
</tr>
<tr>
<td>Forested wetland</td>
<td>24,902</td>
<td>23.1%</td>
<td>2,229</td>
<td>2,886</td>
</tr>
<tr>
<td>Impervious</td>
<td>1,177</td>
<td>1.1%</td>
<td>171</td>
<td></td>
</tr>
<tr>
<td>Pervious</td>
<td>4,726</td>
<td>4.4%</td>
<td>422</td>
<td></td>
</tr>
<tr>
<td>Trees over pervious</td>
<td>23,603</td>
<td>21.9%</td>
<td>2,160</td>
<td>2,744</td>
</tr>
<tr>
<td>Trees over Impervious</td>
<td>15</td>
<td>0.0%</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>4,383</td>
<td>4.1%</td>
<td></td>
<td>665</td>
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<td>11,048</td>
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<td></td>
<td>1,677</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>107,635</td>
<td></td>
<td>10,601</td>
<td>9,752</td>
</tr>
</tbody>
</table>

- **Percent tree canopy**: max 92.2%, Goal % 69%  
- **Percent Impervious**: 1.3%  

**Increased H2O Captured** 1,719 million gallons
Water Flow Strategies

How do we make this... function like this?
Policy and Planning Tools
a large spreadsheet is used to track each city!

Codes and Policy Audits answer two questions:

Do city policies allow too much impervious area?
For example does the city mandate excessive parking area?
How wide are roads? Are curb and gutter required?
Are there incentives to reduce impervious area?

Can the city manage and expand the urban forest?
For example, are tree care and management well funded and implemented?
Does the city have a strategy for planting trees in areas most in need?
A large spreadsheet is used to track each city. Examples of recommended codes and practices...

<table>
<thead>
<tr>
<th>Tree Protection</th>
<th>Present?</th>
<th>Municipality Comments</th>
<th>Reviewer Comments</th>
<th>Source</th>
<th>What to Look For</th>
<th>Score</th>
<th>Potential Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter or less</td>
<td>Yes</td>
<td>A tree survey is required for all development sites and includes hardwood trees 18” caliper and over in the RCA and on buffers on-site. The inventory must also be completed 50’ offsite and include all trees 18” caliper and over. It is recommended to extend this requirement to softwoods as well and to all areas, not only those in RCA and buffer areas.</td>
<td>UDO 8.1.3.C2d</td>
<td>Include hardwoods 18” and oves, softwoods 24” and oves, and understory species 8” and oves in tree inventories of proposed development properties. Require inventories of the entirety of the property including 100’ offsite from all property boundaries. Require correct species identification, DBH size, and general condition description. Municipalities which include the above requirements, scores one point.</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Is tree protection fencing required (TPF)?</td>
<td>Yes</td>
<td>Tree protection fencing is required within the RCA and in areas designated as tree care areas. Fencing is to be placed at 1 foot away from the truck per inch in caliper radius. Add tree protection signage to better communicate with the public.</td>
<td>UDO 8.1.2.G</td>
<td>Require tree protection fencing on public and private property. Municipalities which require tree protection fence on both public and private property score two points. Municipalities which require tree protection fence on public property score one point. Municipalities which do not require tree protection fence at all score zero points.</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Are other kinds of tree protection allowed/enforced (e.g. root pruning, staking, vertical mulching)?</td>
<td>Not specified</td>
<td>The UDO states that “protection measures must adhere to generally accepted good design standards and practices.”</td>
<td>UDO 8.1.3(G)/(2)/(e)</td>
<td>Create root pruning, mulch matting, and staking matting details. Require the inclusion of these details on development plans. Inspect the site for adequate tree protection, and the mechanism installation before the first week is permitted on-site. If all details are required and construction may proceed on-site until tree protection device inspections have been completed, apply one point. If details are required but inspections are not required or details are not required and inspections are not required, apply zero points.</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Changing Codes Example: Reduce Imperviousness in Parking Lots

How?

- Match parking requirements to demand and sizing requirements
- Add trees to parking lots – shaded pavement lasts longer!
Example: Accommodate Large Trees

Larger trees offer greater benefits – so think carefully when setting planting goals for streets!

Consider using suspended pavement systems, rather than just choosing small trees! Trees will pay back your investment!
In conclusion ...
Map the most important habitats and assets first – plan for roads to avoid them to enjoy them.

Consider ways to reduce pavement (shrink footprints, reduce parking) to reduce runoff, keep cities cooler and save money.

Map and then plan to plant trees in cities to add shade, clean the air, improve the economy and calm traffic!

Be a multi-modal planner – transportation is for everyone – move people, animals and pollinators in creative ways!

Resource:
End

Want us to map your city? Just ask.
As a non-profit, we are affordable.

Karen Firehock, University of Virginia and the Green Infrastructure Center
Exec. Director, GIC
www.gicinc.org firehock@gicinc.org