Trees, Water and Health ::
Green Infrastructure Co-Design for Co-Benefits

Kathleen Wolf, Ph.D.
Research Social Scientist
University of Washington (Seattle)
School of Environmental and Forest Sciences
US Forest Service, Pacific NW Research Station

ASCA Annual Conference
Skamania, WA :: November 2017
Outline

trees & stormwater attenuation
the evolution
green infrastructure spaces & places
human health - performance
co-design examples
economic value
credit: EPA: Stormwater to Street Trees
measure the canopy of a city
Grey Infrastructure

Drain, direct, dispatch

Green Infrastructure

Slow, spread, soak

Source: Low Impact Development: A Design Manual for Urban Areas, 2010
1. Water flows from paved surface into Arborflow collector.
2. Large debris is filtered by grille top and internal leaf guard.
3. Water flows into the reservoir and is vented through panel walls and base.
4. Then into the StrataCell or RootSpace system, percolating into the tree root zone.

credit: Shane Carpani, LinkedIn
credit: Raise the Balloon
Stormwater Trees
Technical Memorandum

September 2016

Tree in decline as a result of poor root health and water deficit

Stormwater pools, then runs off site carrying sediments and pollutants

Impervious pavement prevents infiltration

Roots lift and crack pavement in search of moisture and air

Traditional sidewalk construction over compacted sub-base

Soil under sidewalk contains little pore space for either stormwater storage or healthy root growth

Typical street tree challenges (image from EPA 2013)
credit: Low Impact Development: A Design Manual for Urban Areas, 2010
Gray to Green

Decision support tool for transitioning to vegetation-based stormwater management

Rob Northrop
Andrew Koeser, PhD.
Green Stormwater Infrastructure :: Hermosillo, Mexico (6 inch rainfall)
SYSTEMS THINKING

AI QUALITY

STORMWATER

ENERGY

COMMUNITY IDENTITY

SOCIAL CAPITAL

ACTIVE MOBILITY

NOISE

EXERCISE & FITNESS

BIOTA

CARBON

BMP'S

PUBLIC ART

CULTURAL HERITAGE

CONNECTIVITY

WASTE WATER

SOLID WASTE

HEAT ISLAND

ALLERGENS

WASTE WATER

credit: American Planning Association
stormwater retention
<table>
<thead>
<tr>
<th>GSI Tool</th>
<th>GSI Tool</th>
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</thead>
<tbody>
<tr>
<td>Bioretention</td>
<td>Permeable Paving</td>
</tr>
<tr>
<td>Rain Gardens</td>
<td>Green Roofs</td>
</tr>
<tr>
<td>Stormwater Cisterns</td>
<td>Depaving</td>
</tr>
<tr>
<td>Dispersion</td>
<td>Tree Canopy</td>
</tr>
<tr>
<td>Dry Well/Infiltration Trench</td>
<td>Compost &amp; Mulch</td>
</tr>
<tr>
<td>Biofiltration</td>
<td></td>
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</tbody>
</table>

Green infrastructure tools & strategies = mini parks?

Credit: Seattle Public Utilities
stormwater management
management for co-benefits - retail
credit: SvR | MIG  Winslow Way, Bainbridge Island, WA
Stormwater Management

Thornton Creek Water Quality Channel (Seattle, SvR Design)
1 hectare, treats runoff from 275 hectares (1 hectare = 2.47 acres)
Tanner Springs Park
Portland OR
linked to active living network
neighborhood social cohesion

environmental education & social learning
Historic Fourth Ward, Atlanta

Clear Creek Basin, 2 acre stormwater detention lake, 17 acres of greenspace & parks amenities
Outline

trees & stormwater attenuation
the evolution

precipitation dynamics
single trees
green stormwater infrastructure
novel ecosystems
place and identity
Outline

trees & stormwater attenuation
the evolution
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human health - performance
co-design examples
economic value
WHO Health Definition

A state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (1946)
Determinants of Health

- Social and community networks
  - Individual lifestyle factors
    - Age, sex & hereditary factors
  - General socio-economic, cultural and environmental conditions
    - Work environment
    - Living and working conditions
    - Unemployment
    - Water sanitation
    - Health care services
    - Agriculture and food production
    - Housing
Green Cities: Good Health
www.greenhealth.washington.edu

Sponsors:
USDA Forest Service, U&CF Program
University of Washington
NGO partners

Thanks!
to U of WA students:
Katrina Flora
Mary Ann Rozance
Sarah Krueger

Research Reviews & Summaries
Local Economics

Trees in cities are not grown and managed for products that can be bought and sold on markets, but they do provide many intangible services and functions! This article serves two purposes. First, it introduces valuation methods that are used to convert intangible benefits to dollar sums. Then, it shows how nonmarket valuations can support local decision-making.

Fast Facts

- The presence of larger trees in yards and as street trees can add from 3% to 15% to home values throughout neighborhoods.

- Averaging the market effect of street trees on all house values across Portland, Oregon yields a total value of $1.35 billion, potentially increasing annual property tax revenues $15.3 million.

- A study found 7% higher rental rates for commercial offices having high quality landscapes.

- Shoppers claim that they will spend 9% to 12% more for goods and services in central business districts having high quality tree canopy.

- Shoppers indicate that they will travel greater distance and a longer time to visit a district having high quality trees, and spend more time there once they arrive.
design: milepost

coa-author

coa-author & printing:

Outside Our Doors
The benefits of cities where people and nature thrive.
strength of evidence; causal mechanisms?

Figure 2. A proposed framework for studying the health benefits of nature contact (adapted from Shanahan et al. 2015b).

Outline

trees & stormwater attenuation
the evolution
green infrastructure spaces & places
human health - performance
co-design examples
economic value
Stormwater Report, online April 2014 (search health)
place making: vertical + horizontal surfaces
design concept

bring people in!
design concept
orient seating to nature!
design concept

enable biodiversity & soft fascination
spatial linkages: the city becomes a park

TKF Foundation :: Nature Sacred initiative
Outline

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Forest Economics 101
Economic Value of City Nature
Methods Challenges

Forest Products
= market goods
excludable
identifiable ownership
expenses-revenues
= profits

Trees/Green in Cities
= public goods
non-excludable
multiple “owners”
expenses-returns?
-profits?
<table>
<thead>
<tr>
<th>Increase</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>2%</td>
<td>mature yard trees (greater than 9-inch dbh)</td>
</tr>
<tr>
<td>3%</td>
<td>larger street trees (up to 100’ away)</td>
</tr>
<tr>
<td>3-5%</td>
<td>trees in front yard landscaping</td>
</tr>
<tr>
<td>6-9%</td>
<td>good tree cover in a neighborhood</td>
</tr>
<tr>
<td>10-15%</td>
<td>mature trees in high-income neighborhoods</td>
</tr>
</tbody>
</table>

multiple studies:
Green Cities: Good Health > Local Economics
### Tree Retention In Development

<table>
<thead>
<tr>
<th>Increase</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>18%</td>
<td>building lots with substantial mature tree cover</td>
</tr>
<tr>
<td>22%</td>
<td>tree-covered undeveloped acreage</td>
</tr>
<tr>
<td>19-35%</td>
<td>lots bordering suburban wooded preserves</td>
</tr>
<tr>
<td>37%</td>
<td>open land that is two-thirds wooded</td>
</tr>
<tr>
<td>Increase</td>
<td>Condition</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td>10%</td>
<td>inner city home located within 1/4 mile of a park</td>
</tr>
<tr>
<td>17%</td>
<td>home near cleaned-up vacant lot</td>
</tr>
<tr>
<td>20%</td>
<td>home adjacent to or fronting a passive park area</td>
</tr>
<tr>
<td>32%</td>
<td>residential development adjacent to greenbelts</td>
</tr>
</tbody>
</table>
Local Government Benefits

Civic Investment – Public Goods
like schools, emergency response, roads

- street trees average positive effect on house values
- added up across Portland, Oregon
- yields a total value of $1.35 billion USD
- potentially increasing annual property tax revenues
  $15.3 million USD

Donovan & Butry. 2010
Landscape and Urban Planning
1. Place Perceptions
   • Place Character
   • Interaction with Merchants
   • Quality of Products

2. Patronage Behavior
   • travel time, travel distance
   • duration & frequency of visits
   • willingness to pay for parking

3. Product Pricing
   • higher willingness to pay for all types of goods
   • higher in districts with trees – 9-12%
the Chenoggye freeway in Seoul
~ 1970-2005
Cheonoggyecheon Stream Restoration

8.4 km, $900 M
1.45-mile-long (2.33 km) elevated linear park, greenway and rail trail

former New York Central Railroad spur, Manhattan

credit: NY City Parks
Economic Impacts

- between 2003 and 2011
- nearby property values increased 103% (despite deep recession)
- $2 billion USD was invested in nearby properties development
hedonic analysis of properties

studies of trees in business districts

urban open space conversions

economic value

urban forests =
human habitat

deeperoot.com
What are the economic values of nature and human health benefits?
Elements of Economic Valuation

• What are the benefits?
• Who experiences nature and gets benefits?
• What is the green condition or situation that provides benefits?
• Scale of value question (i.e., community, province/state, nation)
• What are the costs/income gained/lost associated with these benefits?
Analysis Process

- Scale of individual to community
  - Screen for benefits

- Green condition
  - Urban forestry, parks, gardens, etc.

- Market & non-market valuation strategy
process #1: screen for benefits
Local Economics

Trees in cities are not grown and managed for products that can be bought and sold on markets, but they do provide many intangible services and functions! This article serves two purposes. First, it introduces valuation methods that are used to convert intangible benefits to dollar sums.\(^1\)\(^,\)\(^2\)

Then, it shows how nonmarket valuations can support local decision-making.

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- A study found 7% higher rental rates for commercial offices having high quality landscapes.\(^3\)\(^4\)

- Shoppers claim that they will spend 9% to 12% more for goods and services in central business districts having high quality tree canopy.\(^3\)\(^4\)

- Shoppers indicate that they will travel greater distance and a longer time to visit a district having high quality trees, and spend more time there once they arrive.\(^3\)\(^4\)
Urban Forests and Newborns

the natural environment may affect pregnancy outcomes . . .

10% increase in tree-canopy cover within 50m of a house

= lower number of low weight births

(1.42 per 1000 births)

Donovan et al., Health & Place 2011; Hystad et al., Env Health Perspectives 2014
Hygiene Hypothesis

- presence of soil bacteria in body, *Mycobacterium vaccae* = increased serotonin
- boost immune function
- may alleviate depression (dirt or Prozac?)

Lowry et al. 2007. Neuroscience
Eat Dirt!
ADHD and nature contact

• 17 children aged 7-12 with diagnosed ADHD
• 20-minute guided walks
  • Park
  • Neighborhood
  • Downtown
• Pre-walk puzzles
• Post-walk cognitive test

Faber Taylor & Kuo. 2009. *Journal of Attention Disorders*
% of Americans Ages 20-44 on ADHD Meds
2001 - 2010

America’s State of Mind, Medco Health Solutions, Inc
parks, active living, active transit

CDC moderate activity recommendations
Parks Prescription

Date: ______________________
Dr: ______________________
Name: ______________________
I recommend:  
☐ Walking  ☐ Other: _____________
_______________ minutes a day
_______________ days per week

* Health Canada suggests moderate activity of 30 minutes per day | 5 days a week

Benefits of daily activity
• Improve overall physical and mental health
• Maintain a healthy weight
• Reduce the risk of diabetes and other chronic conditions
• Lower cholesterol levels
• Manage stress and anxiety

Signature: ____________________
Parks Prescription

Dr. Robert Zarr  ‘walk with a doc’

This information is provided for educational purposes and is not to be considered medical advice.
Shinrin yoku (forest bathing)

- extensive research
- restorative experiences
- workers retirees
- networked system, 52 bases in Japan
Improving Depression

20 adults with major depression walk in a park setting and an urban setting

- 50-minute walks one week apart
- before-after testing:
  - Mood: Positive and Negative Affect (PANAS)
  - Cognition: Backward Digit Span (BDS)

cognitive and affective improvements after walking in a nature setting
% of U.S. Population Using Mental Health Medications
2001 vs 2010

America’s State of Mind, Medco Health Solutions, Inc
Alzheimer’s Disease & Dementia
Provide wander gardens & horticulture therapy

- 10.5% reduction in amount of medications used in dementia facility
- 30% fewer falls, accompanied by a reduction in fall severity

Detweiler et al. 2009. American Journal of Alzheimer’s Disease and Other Dementias

www.rph.org/eden.html
process #2: understand green condition
Diversity in Metro Nature

NEARBY NATURE INCLUDES A VARIETY OF SPACES AND PLACES

- **Urban Forest Canopy**
- **Biophilic Design**
- **Parks and Gardens**
- **Green Stormwater Infrastructure**

*Image by MIG/SvR*
Prison Inmates :: nature videos
solitary confinement, video room/exercise option

- felt significantly calmer, less irritable, more empathetic
- committed 26% fewer violent infractions

process #3: apply valuation strategy
Valuation Strategies

Benefits Transfer approaches

• factor income
• avoided or replacement cost
• burden of illness
• hedonic pricing
• stated preference/contingent valuation
• revealed preference (e.g., travel cost)
• quality adjusted life years
• benefit/cost
Natural Resources Valuation

- travel cost
- income loss
- hedonic margin
- willingness to pay
Valuation Sources

Benefit x Nature x Health Outcome

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Metro Nature</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn Birth Weight</td>
<td>increased tree canopy cover near mothers' homes</td>
<td>fewer small for gestational age babies</td>
</tr>
<tr>
<td>Attention Deficit Hyperactivity Disorder</td>
<td>greener play areas vs built outdoor or indoor settings</td>
<td>reduced symptoms potentially reducing medication</td>
</tr>
<tr>
<td>School Performance</td>
<td>green views from classrooms and cafeteria</td>
<td>reduced dropout rate - average annual income</td>
</tr>
<tr>
<td>Crime Reduction</td>
<td>trees and lawn in outdoor common areas</td>
<td>reduced violent and non-violent incidence and costs</td>
</tr>
<tr>
<td>Cardiovascular Disease</td>
<td>presence of residential tree canopy</td>
<td>reduced incidence or severity of cardiovascular disease</td>
</tr>
<tr>
<td>Alzheimer’s Disease</td>
<td>wander garden in care facility</td>
<td>reduced medications for patients</td>
</tr>
</tbody>
</table>

common values: avoided costs & burden of illness
What is the Value?
Analysis Process

- scale of individual to community
- urban forestry, parks, gardens, etc.
- market & non-market valuation strategy

screen for benefits

green condition
Summary Table  Millions of U.S. Dollars (2012)

<table>
<thead>
<tr>
<th>Benefit (geographic scope)</th>
<th>Minimum ($)</th>
<th>Maximum ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn Health (U.S.)</td>
<td>5.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Attention Deficit Hyperactivity Disorder (U.S.)</td>
<td>383.5</td>
<td>1,917.7</td>
</tr>
<tr>
<td>Schools (U.S.)</td>
<td>20.4</td>
<td>1,262.9</td>
</tr>
<tr>
<td>Crime (U.S.)</td>
<td>340.6</td>
<td>899.4</td>
</tr>
<tr>
<td>Cardiovascular Disease (U.K., U.S.)</td>
<td>1,220.0</td>
<td>1,220.0</td>
</tr>
<tr>
<td>Alzheimer’s Disease (U.S.)</td>
<td>724.6</td>
<td>1,449.2</td>
</tr>
<tr>
<td>Totals</td>
<td>2,694.4</td>
<td>6,754.5</td>
</tr>
</tbody>
</table>

Nearby nature experiences are important across the entire life cycle, from cradle to grave.

Research about nature benefits and economic value is fairly new. Some of the quantified health benefits of nature in cities are easier to convert to economic value than others. Here are some preliminary valuations—estimated for the entire US, on an annual basis.

### INFANTS

**Birth Weight**

- **Potential Economic Value:** $6.84 billion savings on annual health care costs.
- Birth weight influences long-term childhood health and development, and has been linked to some adult diseases. Low birth weight is associated with both short- and long-term health care costs, as well as hospital stays and increased illness. Pregnant women who have more tree canopy and green space near their homes generally have babies with healthier birth weights.

**Immune Function**

- *Ecosystem Interaction:* Stronger immune system leads to reduced illness and chronic disease across a lifetime.
- We are most vulnerable in the early months of our life, when the body and mind are growing and developing at an astonishing rate. The “hygiene hypothesis” suggests that early contact with outdoor microorganisms stimulates the development of a healthy immune response.

**Family Dynamics**

- *IMPROVED FAMILY DYNAMICS:* Perhaps reducing mental health treatment and counseling services.
- An infant’s parents and siblings adjust their lives after a baby arrives, and the changes can bring on stress and anxiety. Nature spaces and walkable parks help reduce these conditions and improve interactions between people within the household.

Note: All economic values are in 2018 U.S. dollars, and are present annual savings across the entire US.

### CHILDREN & TEENS

**Overall Health and Well-Being**

- **Economic Impact:** Increased physical activity, reduced asthma, and reduced risk of childhood obesity.
- Nature exposure reduces childhood obesity and improves overall health and well-being.

**ADHD**

- **Economic Impact:** $1.08 billion in medication savings per year.
- Millions of children ages 4-17 are treated for Attention Deficit Hyperactivity Disorder (ADHD) in the U.S. Nature exposure is a potential alternative treatment, studies show that activity within nature or green spaces, such as play or just 20 minutes of walking, can reduce symptoms.

**Cardiovascular Disease**

- **Economic Impact:** $1.39 billion in treatment cost savings annually.
- Cardiovascular disease is the leading cause of premature death in the U.S. People show slightly reduced risk of CVD if their neighborhoods have greater nature coverage (particularly tree canopy), but it is worth noting that the majority of studies have focused on trees.

**Cognitive Disorders**

- **Economic Impact:** $1.59 billion in savings on medical services, not counting the value of home care services.
- About one in five older adults experience mental and cognitive disorders, with age being the greatest risk factor. In 2018, about 11% of people aged 65 or older were affected with Alzheimer’s disease. Those with dementia have three times as many hospital stays per year as other older adults. Encounters with nature improve symptoms related to cognitive disorders, such as agitation, depression, and reduced mobility.

### ADULTS

**Depression and Stress**

- **Economic Impact:** Reduced stress, reduced need for antidepressants, and improved body image, self-esteem, and life satisfaction.
- Busy, highly scheduled lifestyles take their toll. Nature experiences reduce stress. Nearly 1 billion adults experience major depression each year in the U.S., and mental, behavioral, and neurodevelopmental disorders are a leading cause of disability. Nature experiences support people for improved mental health, mood, and life function. Improved mental health and function reduces disease treatment costs, and improves overall productivity.

### OLDER ADULTS

**Mobility & Quality of Life**

- **Economic Impact:** $3.54 billion in savings on health care costs from falls per year.
- One in three older adults falls each year, giving rise to fatal and nonfatal injuries. Residents’ falls within senior care facilities are particularly expensive medical situations. Being in nature maintains personal mobility, leading to reduced falls and reduced need for medications. Further, those who are actively involved are more likely to be healthier, more independent, and nature walking activities promote social interactions and support positive lifestyles and quality of life.

**Hypertension**

- **Economic Impact:** $3.58 billion in savings on treatment costs annually.
- Hypertension, or high blood pressure, is one of the five most expensive conditions impacting older adults. Views of nature, particularly forests, and “forest bathing” (nature walks in naturalistic forest settings) decreases diastolic rates.

### Contributing Analysts

Dr. Stephen Grado & Marcus Measells, MSU; Dr. Alicia Robbins, Weyerhaueser
Summary

- trees as a green infrastructure element
- co-design for co-benefits
- eco + human health performance
- health outcomes evidence
- economic consequences, return on investment
Avoided Costs Potential?

$3 trillion
17% of US GDP


$222 billion  $134 billion  $57 billion
Benefit-Based Tree Valuation

E. Gregory McPherson

Abstract. Benefit-based tree valuation provides alternative estimates of the fair and reasonable value of trees while illustrating the relative contribution of different benefit types. This study compared estimates of tree value obtained using cost- and benefit-based approaches. The cost-based approach used the Council of Landscape and Tree Appraisers trunk formula method, and the benefit-based approach calculated the net present value (NPV, total future benefits minus costs discounted to the present) of future benefits and costs using tree growth data and numerical models. In a hypothetical example, the value of a 40 year old green ash (Fraxinus pennsylvanica) was $5,807 using the cost-based approach and either $3,102 (for a tree growing in Fort Collins, CO, U.S.) or $5,022 (for a tree growing in Boulder, CO) using the benefit-based approach. This example, however, did not consider planting and management costs. In a multiteree example, 15 years after planting five pistache (Pistacia chinensis) street trees in Davis, California, the trunk formula (cost-based) value was $8,756, whereas the benefit-based value NPV of benefits was negative at discount rates ranging from 0% to 10%. Negative NPVs occurred because future sidewalk repair costs were projected to be in excess of benefits, a relationship not fully captured in the cost-based approach to valuation. Removing and replacing the five pistache street trees was not cost-effective at 7% and 10% discount rates, primarily because high future sidewalk repair costs associated with retaining the trees were heavily discounted. Planting the five pistache trees in their current location was not an economically sound decision, but planting
cost + market, income approaches
environmental/economic benefits
context (site use, heritage, location)
Urban Forests for Human Health: A Focused Economic Valuation

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Human Dimensions of Urban Forestry and Urban Greening

featuring research on people's perceptions and behaviors regarding nature in cities

Nature and Consumer Environments
Research about how the urban forest influences business district visitors.

Trees and Transportation
Studies on the value of having quality landscapes in urban roadsides.

Civic Ecology
Studies of human behaviors and benefits when people are active in the environment.

Policy and Planning
Integrating urban greening science with community change.

Green Cities: Good Health
Human health & well-being research

Projects Director
Kathleen L. Wolf, Ph.D.

www.naturewithin.info