APPENDIX B:
MEETING AGENDA AND TECHNICAL PRESENTATIONS

The meeting agenda material shared with participants is presented in the first section of this report. The technical presentations provided by the invited experts follow the agenda, in the order listed.

MEETING AGENDA

Estimating Greenspace Exposure and Benefits for Cumulative Risk Assessment Applications

4−5 May 2015

Room AG-30, U.S. Environmental Protection Agency
26 Martin Luther King Drive West, Cincinnati, OH 45220

Meeting Purpose

The role of ecosystem services, including access and exposure to greenspace, may have beneficial effects on population health. There is some uncertainty as to which mechanisms (e.g., social connectedness, psychological well-being from exposure to nature) associations between greenspace and health outcomes are acting through. Given that greenspace may be a marker of non-chemical stressors or an exposure modifier, it is a good candidate to examine in a cumulative risk context, which could help determine its use and effectiveness as an ecosystem service and potential risk management practice. To this end, EPA's National Center for Environmental Assessment in Cincinnati is hosting a technical meeting to evaluate various measures and roles of greenspace from a cumulative risk assessment (CRA) perspective. The technical group will review existing greenspace exposure measures and methods used across different fields of study, with a focus on which measures are useful for different health outcomes and cumulative risk applications. The meeting discussion and outputs will inform methods for evaluating environmental health risks and benefits associated with greenspace (GS).

Driving Questions

- How can existing cumulative risk assessment frameworks consider greenspace as it relates to exposure assessment for human health?
- How is greenspace conceptualized across disciplines?
- What health outcomes are relevant to greenspace prevalence and access?
- Which evidence-based measures of greenspace provide the most applicable, reliable, and replicable estimates for greenspace exposure in urban settings?
- What are the specific mechanisms for certain health benefits and can these be used to inform biologic plausibility of reported associations with greenspace?

Key Objective

Identify and qualify approaches and appropriate data sources for measuring greenspace and evaluating the distribution of health benefits (i.e., across socioeconomic status, sensitive populations), including risk reductions, from a cumulative risk assessment perspective, with attention to bias and uncertainty in reporting and measurement.

1. Evaluate key pathways and methods for estimating greenspace exposure.
2. Evaluate key health outcomes and/or benefits and related methods and data sources for quantifying health outcomes related to greenspace.
3. Determine appropriate applications for greenspace measures, outcomes, and benefits within existing cumulative risk assessment frameworks.

Technical Fields and Focus Areas

Urban tree cover	Air quality	Reproductive health
Parks and recreation	Physical activity	Respiratory health
Built environment/neighborhood planning	Socioeconomic disparities (environmental and/or health)	Cardiovascular disease
Regional planning	Exposure and risk assessment	Obesity and diabetes
Ecosystem services		Psychological health

Schedule at a Glance

Sun 3 May	**Optional Activities** *(meet in hotel lobby for each, at 2:45 pm for Greenspace Tour 1)*		
3:00–3:30 pm Greenspace Tour 1	*5:00–5:30 pm* Greenspace Tour 2	*6:00–7:00 pm* Social hour	*7:00 pm* Dinner option

Mon 4 May	**Greenspace Metrics and Exposure Assessment**	***Tues 5 May***	**Greenspace and Health**
9:00–9:15	Welcome and meeting overview	9:00–9:45	Respiratory effects
9:15–9:30	Group process; shared data sets for GS metrics	9:45–10:25	Reproductive effects
9:30–10:20	Exposure assessment approaches	*10:25–10:35*	*Break*
10:20–10:30	*Break*	10:35–11:15	Obesity and physical activity
10:30–11:10	Tree cover measurements	11:15–12:00	Cardiovascular disease and mortality
11:10–12:00	Access to greenness	*12:00–1:00*	*Lunch*
12:00–1:00	*Lunch*	1:00–1:40	Neurological/neurodevelopmental effects
1:00–1:40	Built environment	1:40–2:40	Psychosocial effects
1:40–2:30	Design and environmental psychology	2:40–3:20	Attention restoration/cognitive effects
2:30–3:20	Specific populations, exposure considerations	*3:20–3:30*	*Break*
3:20–3:30	*Break*	3:30–4:10	Economic and community benefits
3:30–4:20	Exposure metrics, links to health	4:10–4:40	Specific populations, health considerations
4:20–5:10	Key points for exposure	4:40–5:00	Refine conceptual diagrams of GS/CRA
5:10–5:30	Wrap-up of Day 1, review of plan for Day 2	5:00–5:30	Key points for health; meeting wrap-up

Mon 4 May	**Greenspace Metrics and Exposure Assessment**			
• *How is greenspace conceptualized across disciplines? What is being measured, and what needs to be measured for accurate assessments?* • *Which evidence-based measures of greenspace provide the most applicable, reliable, and replicable estimates for greenspace exposure in urban settings?* • *What are accepted methods for quantifying exposure to greenspace?* • *Considerations of multiple routes of greenspace exposure*				
8:30–9:00	*Arrival*			
9:00–9:15	**Welcome and meeting overview**	R. Gernes		
9:15–9:30	**Group process; shared data sets for greenspace metrics**	T. Miller		
9:30–10:20	**Exposure assessment approaches** *(U.S. and international)*	L. Jackson	M. Nieuwenhuijsen	M. A. van den Bosch
10:20–10:30	*Break*			
10:30–11:10	**Tree cover measurements** *(NDVI, regional-local UTC)*	G. Donovan	P. Hystad	
11:10–12:00	**Access to greenness**	R. Mitchell	M. Kondo	M. A. van den Bosch
12:00–1:00	*Lunch*			
1:00–1:40	**Built environment**	P. Hystad	Y. Michael	
1:40–2:30	**Design and environmental psychology**	J. Africa	R. Mitchell	W. Sullivan
2:30–3:20	**Specific populations, exposure considerations**	R. Mitchell	A. Hipp	Y. Michael
3:20–3:30	*Break*			
3:30–4:20	**Exposure metrics, links to health** *(attention restoration example)*	W. Sullivan	Y. Michael	
4:20–5:10	**Key points for exposure**	T. Miller		
5:10–5:30	**Wrap-up of Day 1, review plan for Day 2**	T. Miller	R. Gernes	

Tues 5 May	**Greenspace and Health**			
• *How can existing CRA frameworks consider greenspace as it relates to health?* • *What health outcomes are relevant to greenspace prevalence and access?* • *What are the specific mechanisms for certain health benefits, and can these be used to inform biologic plausibility of reported associations with greenspace?* • *Considerations of community and individual level outcomes.*				
8:30–9:00	*Arrival*			
9:00–9:45	**Respiratory effects**	P. Ryan	G. Donovan	
9:45–10:25	**Reproductive effects**	P. Hystad	G. Donovan	Y. Michael
10:25–10:35	*Break*			
10:35–11:15	**Obesity and physical activity**	M. A. van den Bosch	A. Hipp	
11:15–12:00	**Cardiovascular disease and mortality**	P. Hystad	M. Nieuwenhuijsen	
12:00–1:00	*Lunch*			
1:00–1:40	**Neurological/neurodevelopmental effects**	M. Nieuwenhuijsen	P. Ryan	
1:40–2:40	**Psychosocial effects**	M. Kondo	M. A. van den Bosch	J. Africa
2:40–3:20	**Attention restoration/cognition effects**	A. Hipp	L. Jackson	
3:20–3:30	*Break*			
3:30–4:10	**Economic and community benefits**	M. Kondo	G. Donovan	
4:10–4:40	**Specific populations, health considerations**	R. Mitchell	P. Ryan	
4:40–5:00	**Refine conceptual diagrams of greenspace/CRA**	T. Miller		
5:00–5:30	**Key points for health; meeting wrap-up**	T. Miller	R. Gernes	

Day 1−***Mon 4 May***

Greenspace Metrics and Exposure Assessment

EnviroAtlas is …

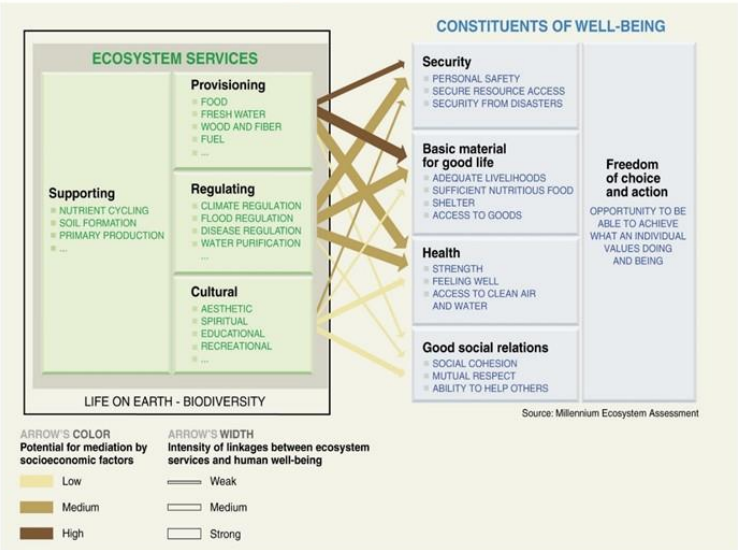
An online decision support tool for viewing, analysing, and downloading geospatial data related to ecosystem services

- **Maps, data, tools and information about the supply, demand, drivers, and social benefits of ecosystem services**
- **Population and climate scenarios**
- **Reference data (e.g., boundaries, land cover, soils, hydrography, impaired water bodies, wetlands, demographics)**
- **Analytic and interpretive tools**
- **Free & open access**

Version 1 Released May, 2014

Developed through cooperative effort among multiple Federal agencies, universities, and other organizations

International "Ecosystem Services" Framework



Related concepts:

"benefits from nature," "green infrastructure," "our life-support system," "positive environmental exposures"

Ecosystem Services & Health: Unrealized Assets = Unintended Consequences

Approach: Demonstrate Multiple Benefits of Green Infrastructure,

- Clean air
- Clean & plentiful water
- Natural hazard mitigation
- Climate stabilization
- Recreation, culture & aesthetics
- Food, fiber & materials
- Biodiversity conservation

...and How They Relate to Human Health & Well-Being

- *Air and water pollutants removed by neighborhood tree cover*
- *Homes and schools near busy roadways*
- *Extreme heat events*
- *Opportunities for physical exercise, social engagement, outdoor experience, and play*
- *Distributions of vulnerable populations*

How Does EnviroAtlas Conceptualize Green Space as Ecosystem Services? *(Goods not addressed today)*

Buffers for Natural and Anthropogenic Hazards

- Extreme heat mitigation
- Stormwater runoff absorption
- Polluted runoff filtration
- Storm energy dissipation
- Air pollutant reduction

Opportunities for Healthful Behaviors

- Engagement with nature
- Social interaction
- Physical activity

Supporting Functions

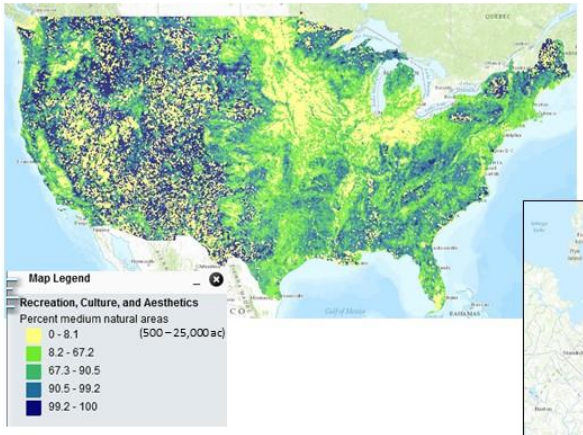
- Carbon sequestration and storage
- Soil retention
- Wildlife habitat provision

Ecosystem dis-services are not currently emphasized in EnviroAtlas

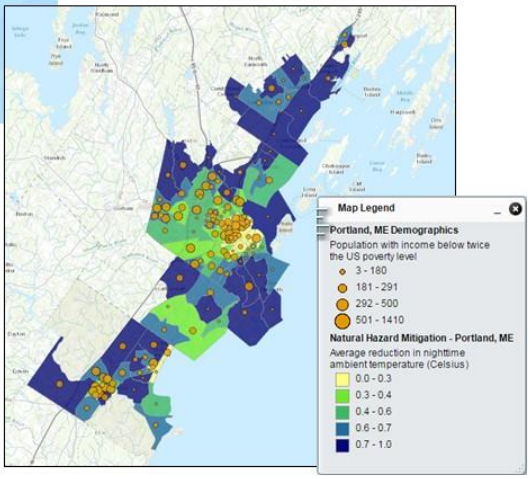
- *Pests*
- *Disease*
- *Physical dangers*
- *Pollen*

EnviroAtlas is Multi-Scaled

300+ map layers available online



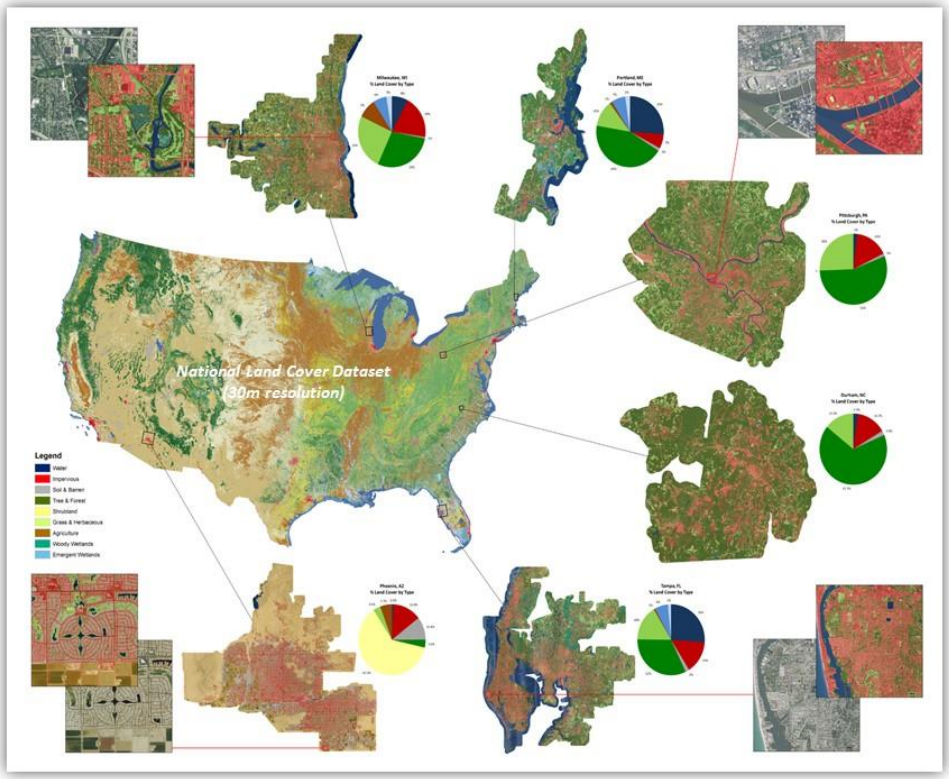
National: Wall-to-wall coverage for coterminous US; summarized by ~90,000 drainage basins (12-digit HUCs). 160+ data layers



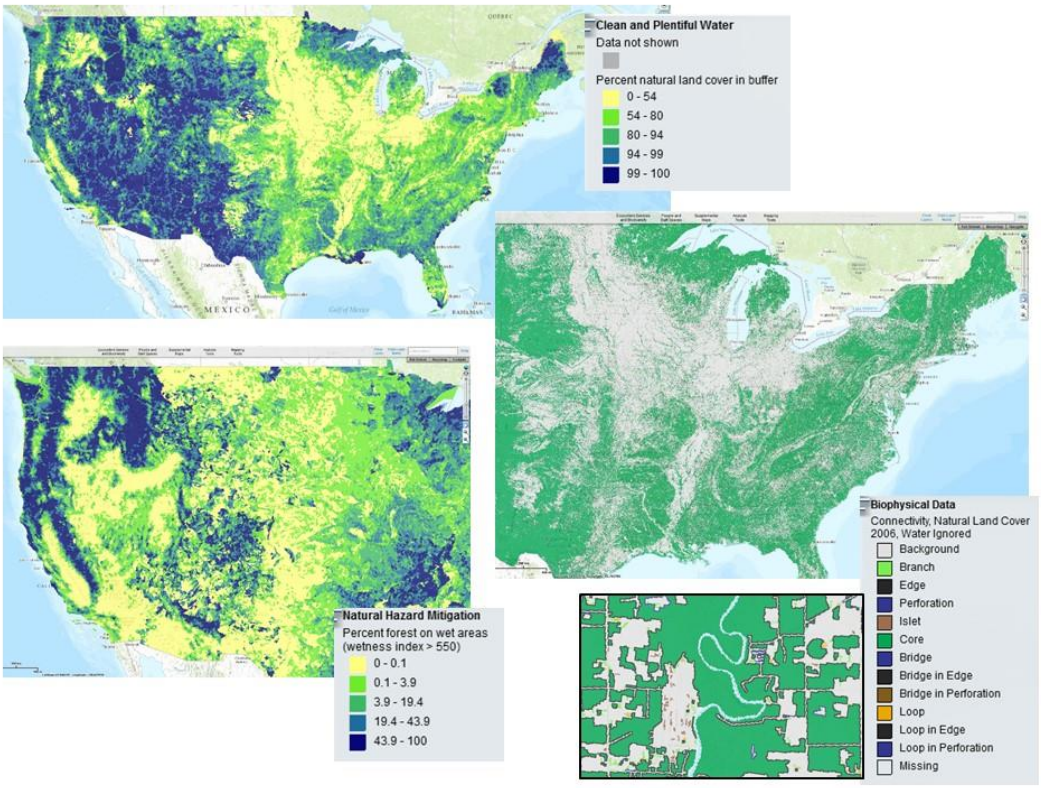
Community: High resolution component for 50 populated places; summarized by US census block group. 100+ data layers

Pictured: Greater Portland, ME

http://enviroatlas.epa.gov/

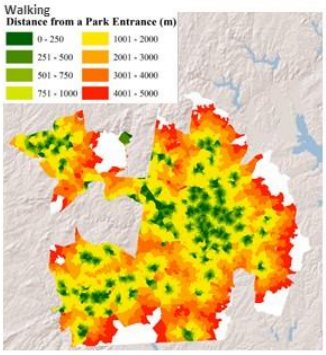


Day 1−Exposure assessment approaches *(U.S. and international)*

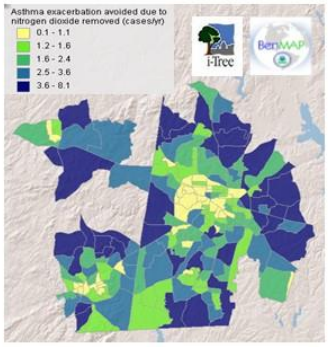


Community Information to Assist Decision-Making

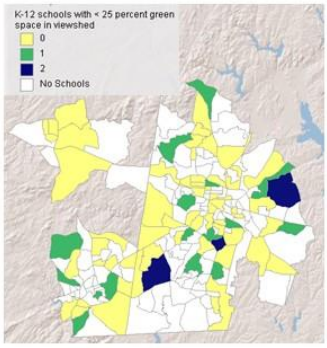
e.g., health interventions, public infrastructure, social equity



Opportunities for physical activity, engagement with nature, & social interaction



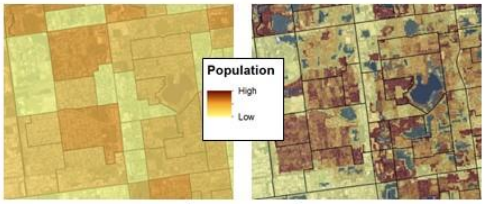
Estimated reductions in adverse respiratory health events due to ambient air filtration by trees



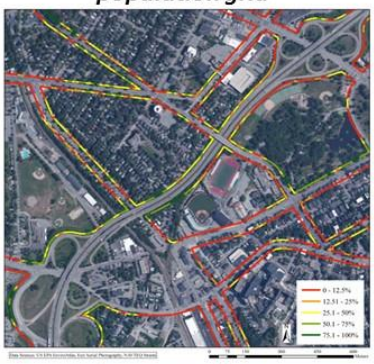
Potential to improve school performance through cognitive restoration & stress reduction

Pictured: Greater Durham-Chapel Hill, NC

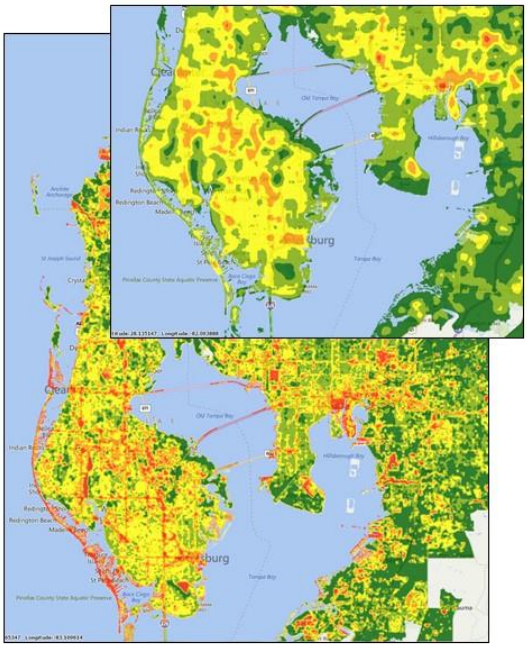
All Data are Downloadable & Accessible via Web Services
(incl. fact sheets for general users and technical metadata)



Downscaled (30-meter) U.S. Census population grid



Precise maps of tree cover along local roads & streams

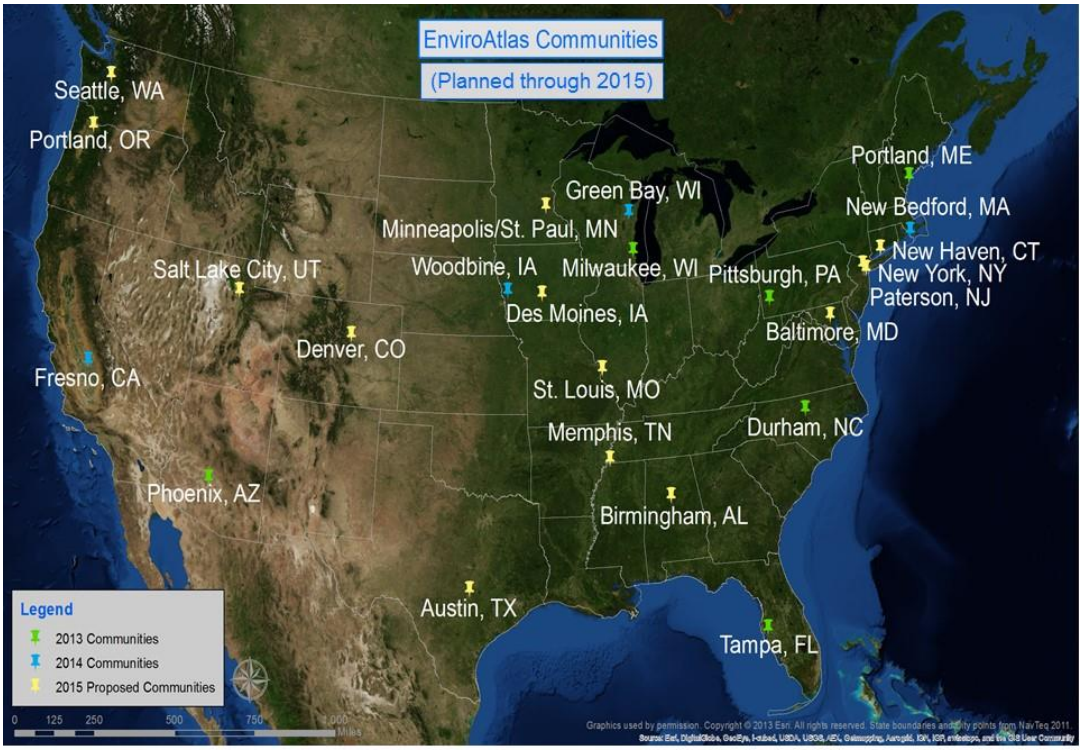


Heat maps

Indicators of Public Health and Well-Being
Types of EnviroAtlas-Community Metrics

- Green space, tree cover, & impervious surface measures
- Walking distance to park entrances
- Air pollutants removed by tree cover
- Health & economic benefits of air pollutants removed
- Reduced runoff, water pollution from tree cover
- Temperature reduction, carbon storage by tree cover
- Presence/absence of tree cover along walkable & major roads
- Population living along busy roads
- Residences with limited window views of trees
- Schools & day care centers with limited views of green space
- Intersection density, housing & employment metrics

Day 1−Exposure assessment approaches *(U.S. and international)*

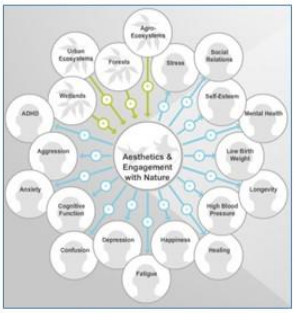


LandScope America NRCS USFS USGS

The Eco-Health Relationship Browser

4 ecosystems:

- Forests
- Urban Ecosystems
- Wetlands
- Agro-Ecosystems



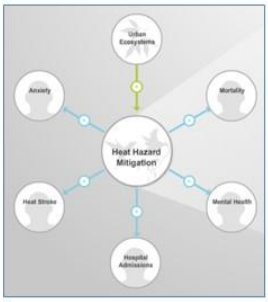
6 Ecosystem Services:

Health promotional services

- Aesthetics & Engagement with Nature
- Recreation & Physical Activity

Buffering services

- Clean Air
- Clean Water
- Heat Hazard Mitigation
- Water Hazard Mitigation



Incl. extensive bibliography (n ~ 300)

30+ health outcomes:

- Asthma
- ADHD
- Cancers
- Cardiovascular diseases
- Heat stroke
- Healing
- Low birth weight
- Obesity
- Social relations
- Stress

... many more

Landcover Composition in Residential Buffers as Indicators of Healthful Exposures		
Radius	**Indicates potential for**	**Mechanism(s)**
50m	Window views and peridomestic activities	Engagement w/ natural features; Social interaction
500m	Walkable neighborhood	Promotion of physical activity; Engagement w/ natural features; Social interaction
1-3 km	Local green destinations	Promotion of physical activity; Engagement w/ natural features; Social interaction

Landcover Composition by City Block		
50m moving windows along road centerlines	Green views along walkable roads	Promotion of physical activity; Engagement w/ natural features; Social interaction

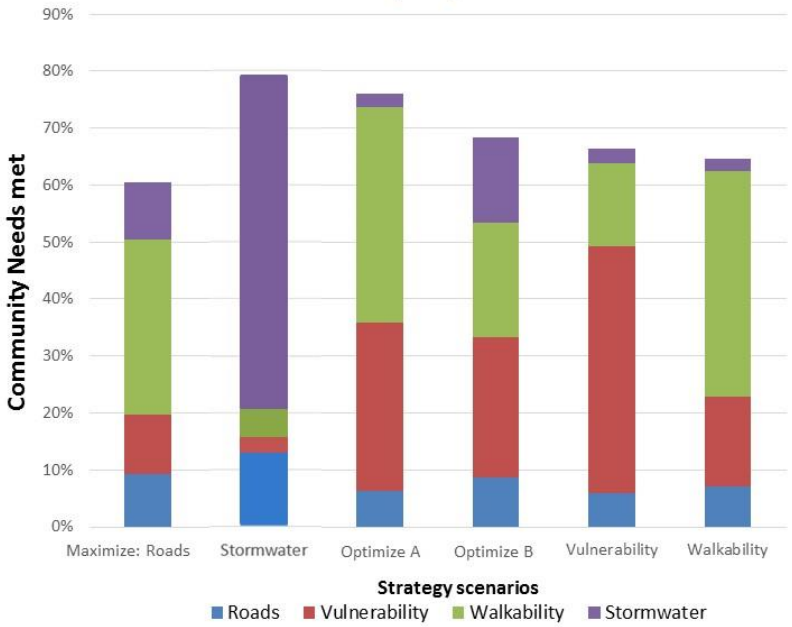
Landcover Composition in Residential Buffers as Indicators of Effect Modification		
Radius	**Indicates potential for**	**Mechanism(s)**
50m	Window views and peridomestic activities	Mitigation of extreme heat, air pollution, noise, night light
300m	Near-roadway buffers	Absorption / dilution of vehicular pollutants
400 - 1000m	Walkable neighborhood	Mitigation of extreme heat, air pollution

Landcover Composition by City Block		
8.5m width pedestrian zones along road edges	Shade along walkable roads	Mitigation of extreme heat

Ecosystem Services Deliver "Co-Benefits," Facilitate Systems-Level Solutions

Evaluating Cumulative Benefits under Alternate Tree-Planting Scenarios

Use Case by City of Durham, NC



The Parma Commitments, WHO 2010

"We aim to provide each child by 2020 with access to healthy and safe environments and settings of daily life in which they can *walk and cycle* to kindergartens and schools, and to ***green spaces*** in which to *play* and undertake *physical activity*."

1

Urban Green Space Indicator

- Define urban green spaces
- Identify GIS-definition
- Specify population distribution data in GIS and specificity requirements (census or individual data)
- GIS-analysis, software, script

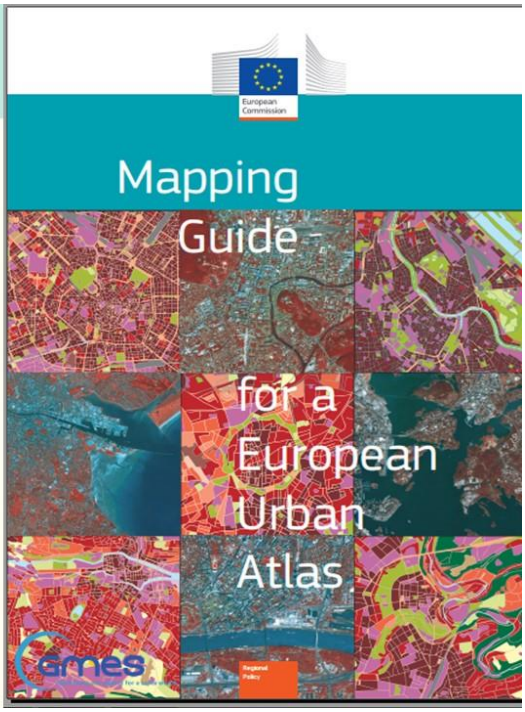
2

Urban Atlas

Satellite data
Navigation data
Topographic maps
Field observations
Soil sealing

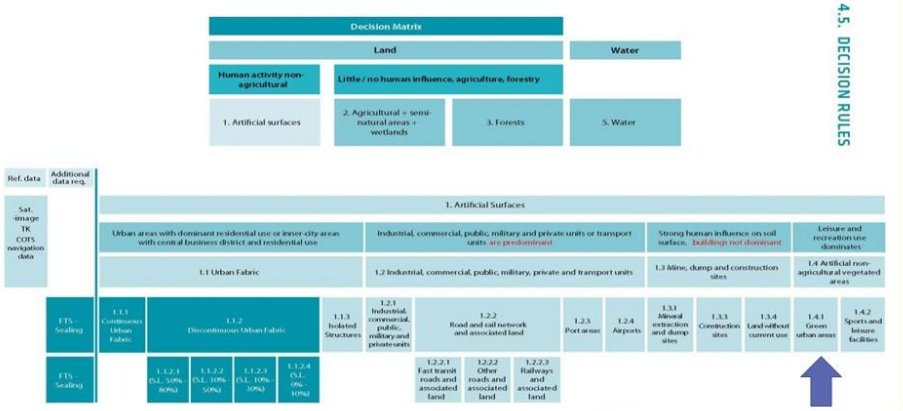
Coordinate system:
LAEA/ETRS89
(EU standard)

European Environment Agency (EEA):
http://www.eea.europa.eu/data-and-maps/data/urban-atlas



Land use data from Urban Atlas

http://www.eea.europa.eu/data-and-maps/data/urban-atlas



"Green Urban Areas":
Urban Atlas: 1.4.1.
Vector code: 14100

Definition of urban green in Urban Atlas

Included are:

- MinMU 0.25 ha, Minimum width: 10 m
- *Recreational use* such as gardens, zoos, parks, castle parks.
- Suburban natural areas that have become and are managed as *urban parks.*
- Forests or green areas extending from the surroundings into urban areas
- Urban areas when at least two sides are bordered by green urban areas and structures, and traces of recreational use are visible.

Not included are:

- Private gardens within housing areas →class 1.1;
- Cemeteries →class 1.2.1;
- Buildings within parks, such as castles or museums →class 1.2.1;
- Patches of natural vegetation or agricultural areas enclosed by built-up areas without being managed as green urban areas →class 1

Case study Malmö

Sweden's 3rd city (n= 306 074)
Green space unevenly distributed and availability below Swedish average

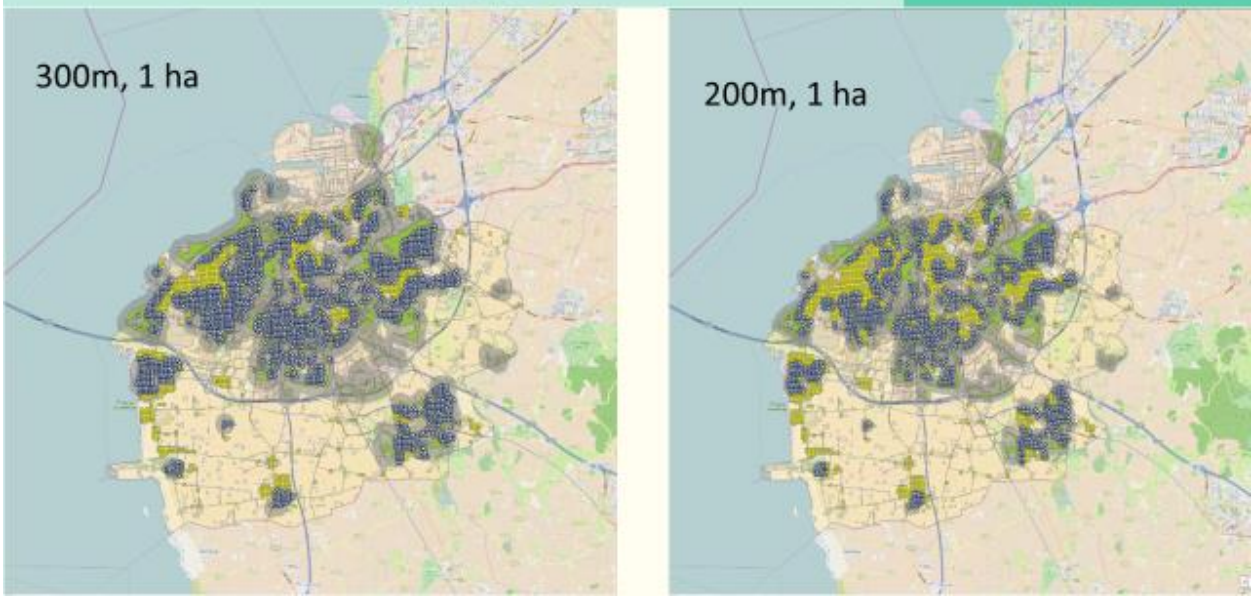
Population data

- Local, Malmö municipality
- Individual and aggregated (100x100m grids)

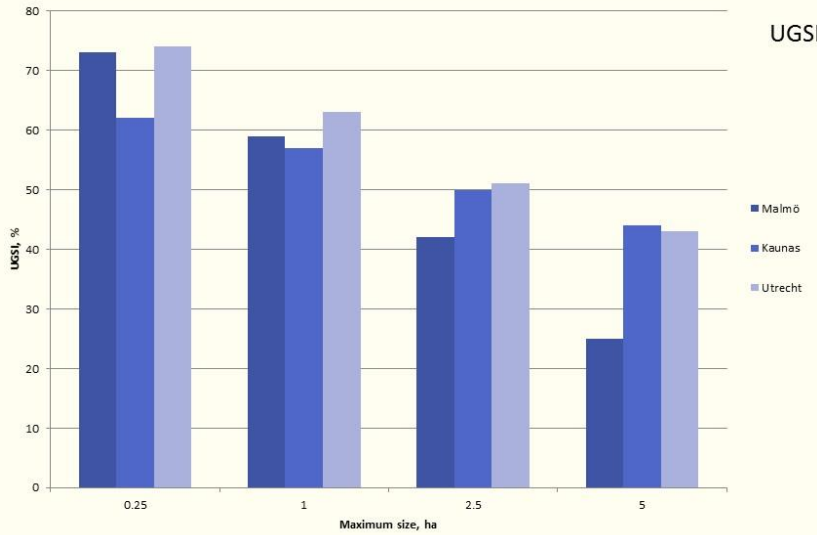
European population data:

Population density disaggregated dataset (EEA). Eurostat (2001) och CORINE (2000)

Buffer analysis, 300 & 200 m



UGSI, 200m, Malmö, Kaunas, Utrecht: various sizes



$UGSI = N_{ACC}/N_{TOTAL} \times 100$

UGSI

- < 300 m
- > 1 ha
- or suffix, e.g. UGSI (200, 2.5)
- full script for use by urban planners and municipality officers
- policies and guidelines

10

Issues

- Linear distance vs walking distance
- Optimal size
- Quality, amenities
- Comparability
- Non-EU countries

PHENOTYPE

- FP7 Theme ENV.2011.1.2.3-2; Positive effects of natural environment for human health and well-being. Grant Agreement 282996
- 1st January 2012 – 31st December 2015
- EC contribution: € 3.499.403
- Beneficiaries:
  - Fundació Centre de Recerca en Epidemiologia Ambiental – Spain (C)
  - Rijksinstituut voor Volksgezondheid en Milieu – Netherlands
  - Staffordshire University – United Kingdom
  - Vytauto Didziojo Universitetas – Lithuania
  - Université de Geneve – Switzerland
  - Vereniging voor Christelijk Hoger Onderwijs, Wetenschappelijk Onderzoek en Patientenzorg – Netherlands
  - Veiligheids- en Gezondheidsregio Gelderland Midden – Netherlands
  - University of California, Berkeley Campus – United States

Open Access Protocol

BMJ Open

*P*ositive *h*ealth *e*ffects of the *n*atural *o*utdoor environment in *ty*pical *p*opulations in different regions in *E*urope (*PHENOTYPE*): a study programme protocol

Mark J Nieuwenhuijsen,[1,2,3] Hanneke Kruize,[4] Christopher Gidlow,[5] Sandra Andrusaityte,[6] Josep Maria Antó,[1,2,3,7] Xavier Basagaña,[1,2,3] Marta Cirach,[1,2,3] Payam Dadvand,[1,2,3] Asta Danileviciute,[6] David Donaire-Gonzalez,[1,2,3] Judith Garcia,[1,2,3] Michael Jerrett,[8] Marc Jones,[5] Jordi Julvez,[1,2,3,7] Elise van Kempen,[4] Irene van Kamp,[4] Jolanda Maas,[9] Edmund Seto,[8] Graham Smith,[5] Margarita Triguero,[1,2,3] Wanda Wendel-Vos,[4] John Wright,[10] Joris Zufferey,[11] Peter Jan van den Hazel,[12] Roderick Lawrence,[11] Regina Grazuleviciene[6]

To cite: Nieuwenhuijsen MJ, Kruize H, Gidlow C, *et al*. *P*ositive *h*ealth *e*ffects of the *n*atural *o*utdoor environment in *ty*pical *p*opulations in different regions in *E*urope (*PHENOTYPE*): a study programme protocol. *BMJ Open* 2014;4:e004951. doi:10.1136/bmjopen-2014-004951

ABSTRACT

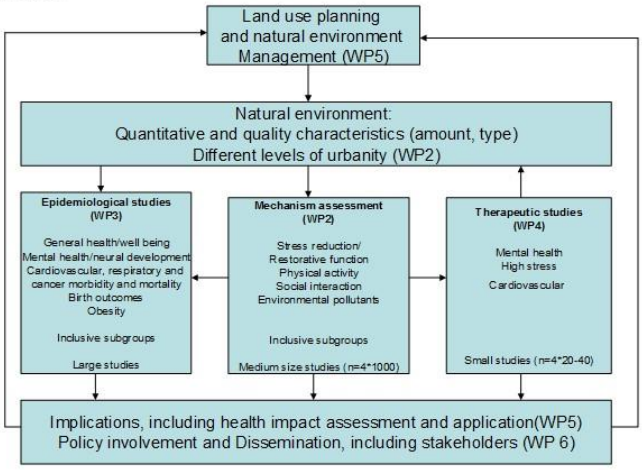
Introduction: Growing evidence suggests that close contact with nature brings benefits to human health and well-being, but the proposed mechanisms are still not well understood and the associations with health remain uncertain. The *P*ositive *H*ealth *E*ffects of the *N*atural *O*utdoor environment in *T*ypical *P*opulations in different regions in *E*urope (PHENOTYPE) project investigates the interconnections between natural outdoor environments and better human health and well-being.

Strengths and limitations of this study

- The *P*ositive *H*ealth *E*ffects of the *N*atural *O*utdoor environment in *T*ypical *P*opulations in different regions in *E*urope (PHENOTYPE) project is the largest European project on green space and health.
- The PHENOTYPE project examines simultaneously the possible underlying mechanisms (stress reduction/restorative function, physical

PHENOTYPE

Project Structure



PHENOTYPE – WP2

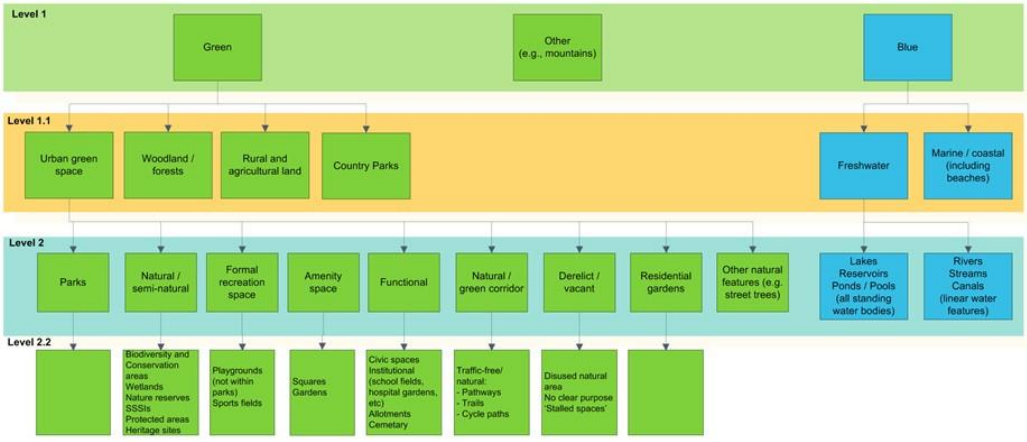
The characterisation of natural environments is reported at three levels:

LEVEL 1 >> **Basic Measures:** Using Europe-wide, secondary data (e.g., Urban Atlas; NDVI)

LEVEL 2 >> **Detailed Measures:** Using locally held secondary data (City Council, etc.) for a more detailed classification of environments

AUDITS >> **Environment Quality:** Primary data collection using a Streetscape Audit and Neighbourhood Green Space Tool to report environment quality data.

Classification of Natural Environments



LEVEL 1 >> Basic Measures (I)

This is the broad distinction between 'green' and 'blue' environments.

The basic indicators are being produced using routinely available data such as Urban Atlas and LandSat derived NDVI.

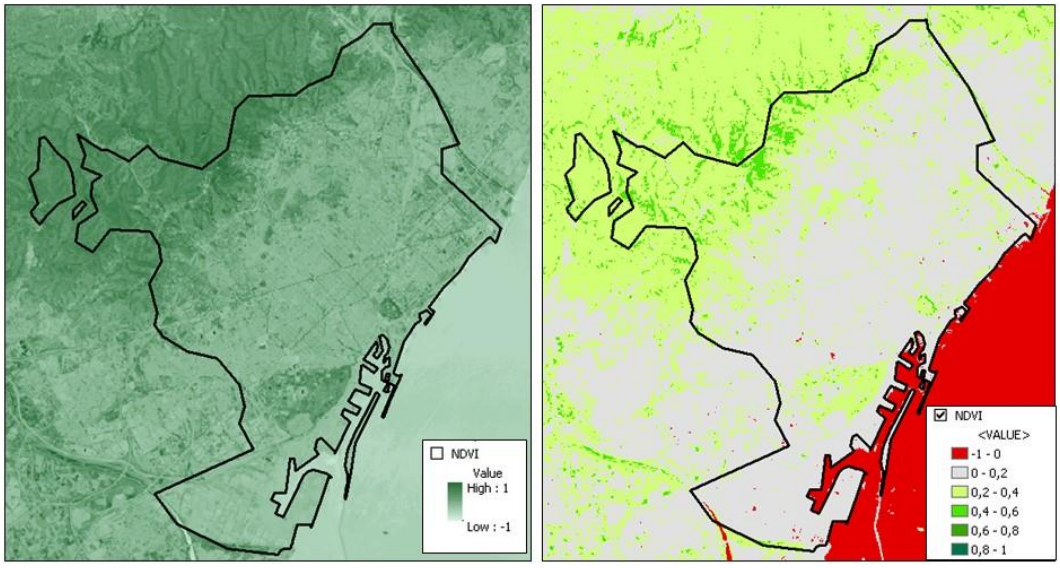
These are designed to be generally representative of the amount of natural environment available within a neighbourhood and can also be applied in other cities in Europe for comparability.

- **NDVI**

Source	Indicator	Distance
NDVI (Landsat 30m – representative of WP2 data collection period – best available data from April to August)	Average NDVI within exposure buffer.	100m, 300m, 500m
	Proportion of buffer area classified within 6 NDVI ranges	100m, 300m, 500m

LEVEL 1 >> Basic Measures (I)

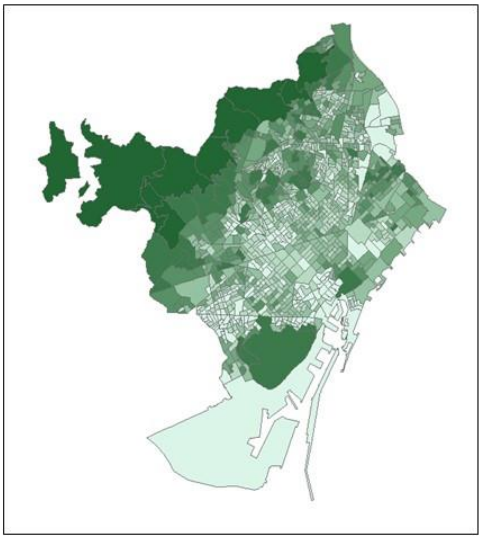
Barcelona NDVI map
Landsat 8 (2013)



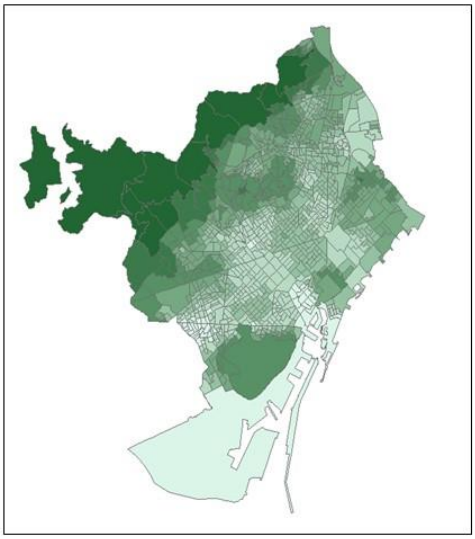
LEVEL 1 >> Basic Measures (I)

NDVI EXPOSURES WITHIN CENSUS AREAS IN BARCELONA

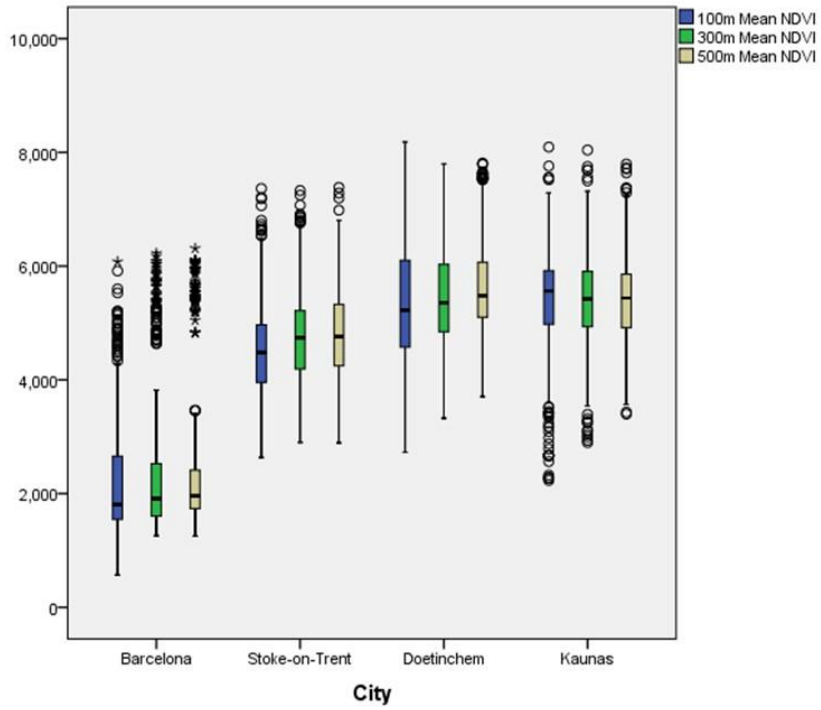
Within census area



Within census area + 300m buffer



LEVEL 1 >> Basic Measures (I)



LEVEL 1 >> Basic Measures (II)

- **URBAN ATLAS (green)**

Source	Indicator	Distance
Urban Atlas – green space	Straight line distance to nearest space > 5,000m²	Closest
	Street network distance to nearest space > 5,000m²	Closest
	Number of spaces within a street network distance	300m, 500m, 1000m
	Total area of spaces (all) within buffer (network distance)	300m, 500m, 1000m
	Network distance to nearest space by size - 0.5 to 2, 2 to 5, 5 to 20, 20 plus hectares	300m, 500m, 1000m 3000m, 5000m (5 to 20, 20 plus only)
	Number of spaces with street network distance by size - 0.5 to 2, 2 to 5, 5 to 20, 20 plus hectares	300m, 500m, 1000m 3000m, 5000m (5 to 20, 20 plus only)

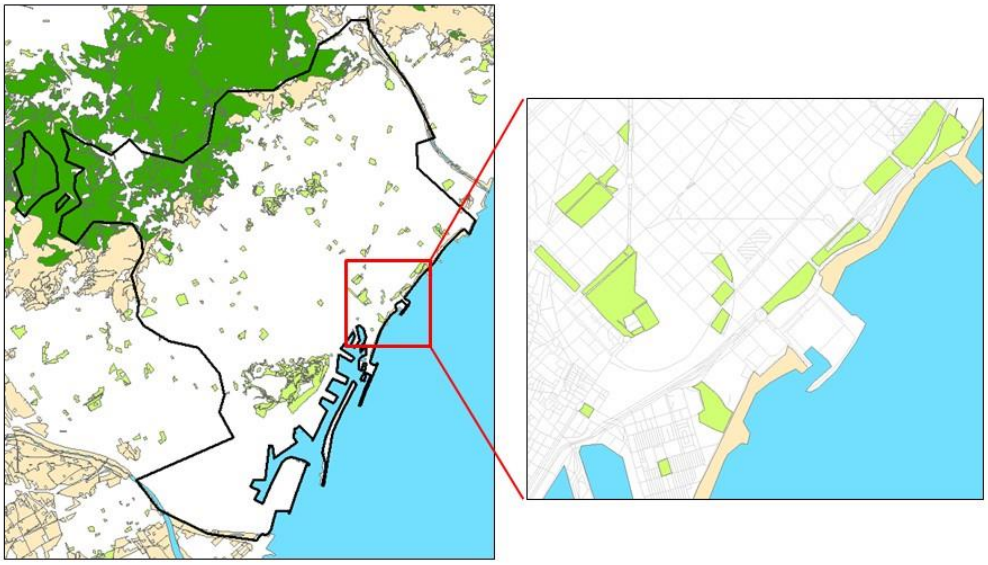
LEVEL 1 >> Basic Measures (III)

- **URBAN ATLAS (blue)**

Source	Indicator	Distance
Urban Atlas – blue space	Straight line distance to nearest space > 5,000m²	Closest
	Street network distance to nearest space > 5,000m²	Closest
	Number of spaces within a street network distance	300m, 500m, 1000m
	Total area of spaces (all) within a (network distance)	300m, 500m, 1000m
	Presence of Blue (Y/N)	300m, 500m, 1000m

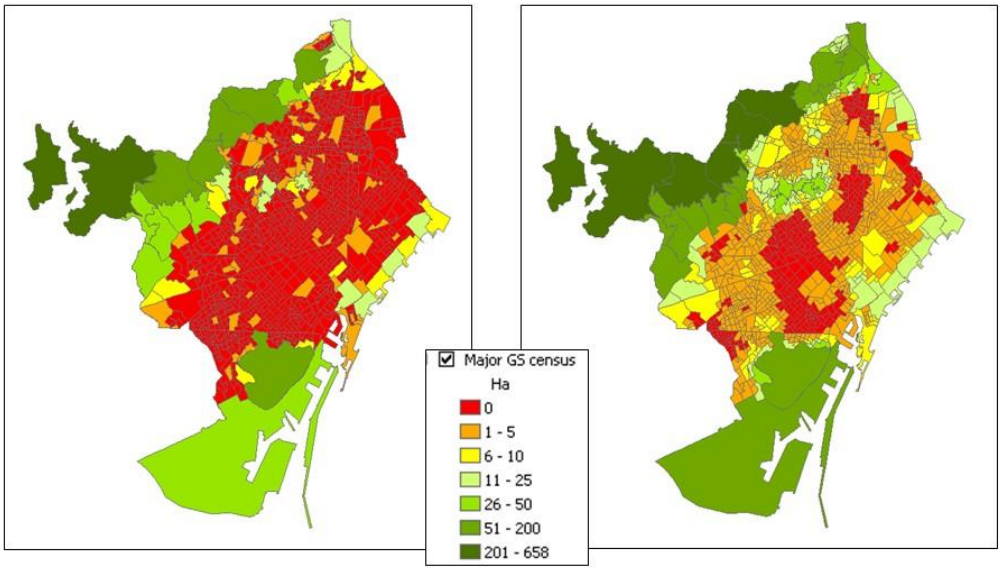
LEVEL 1 >> Basic Measures (III)

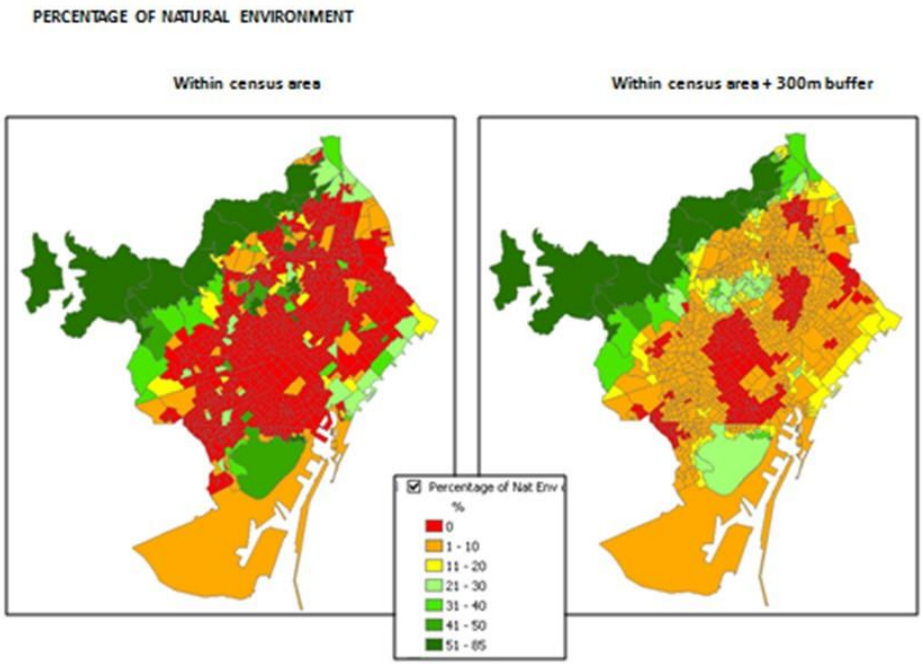
Barcelona Major Green and Blue space (> 0.5ha)
Urban Atlas



AMOUNT OF MAJOR GREEN SPACES

Within census area **Within census area + 300m buffer**





LEVEL 2 >> Detailed Measures

The detailed indicators are produced using locally held secondary data (City Council, etc.).

This data represents the best available data for each study area.

To make the data comparable a common classification of environments is applied to the local data in each study area.

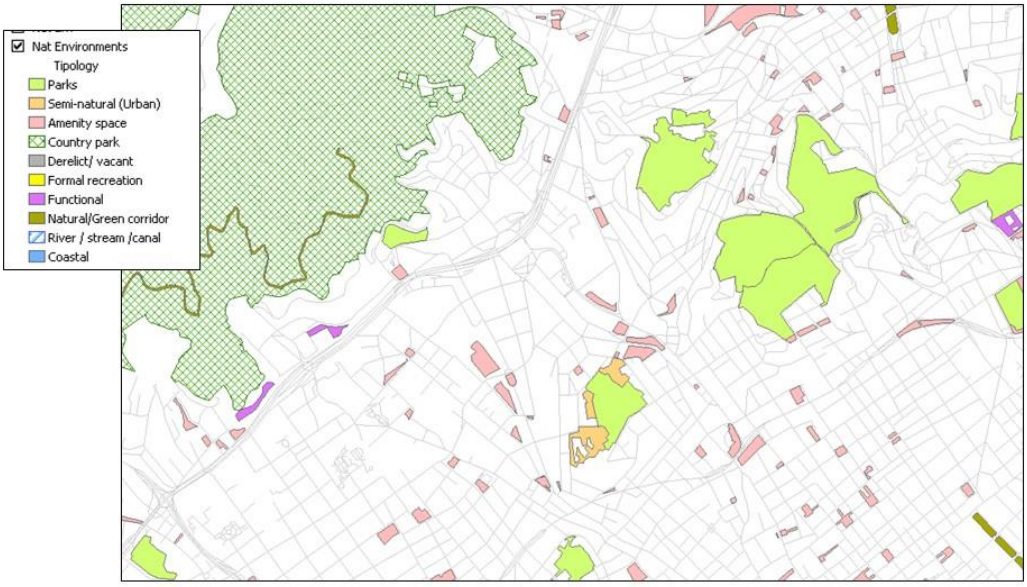
This classification is used to assign spaces to subsets of environments that will be used to produce the indicators associated with a particular mechanism.

This is the level required to conduct the mechanism assessment in WP2. However, indicators are not produced for individual categories but are grouped together to form sub-groups appropriate to the mechanism being assessed:

- **Stress reduction & restorative** – All natural environments are included apart from agricultural land not associated with urban areas and derelict urban space which is assumed not to be providing a 'pleasant' environment for people to access or to view.
- **Physical Activity** – All natural environments that can be accessed and are large enough to support some level of physical activity. The minimum size required is 0.5 hectares unless the space provides a dedicated physical activity opportunity such as a playground or sports field.
- **Social Interaction / Cohesion** – All natural environments that can be accessed are included. Size is not seen as important.
- **Exposure to Environmental Hazards** – All natural spaces are important. There is insufficient data to attempt to match spaces to particular types of environmental hazard that they mitigate.

LEVEL 2 >> Detailed Measures

Barcelona Natural Environments map for Level 2



LEVEL 2 >> Detailed Measures

Barcelona Natural Environments map for Level 2 (II)

LEVEL 2 >> Detailed Measures

Level 1	Level 1.1	Level 2	Level 2.2	Mechanism subset			
				1. Stress reduction & restorative	2. Physical Activity	3. Social Interaction Cohesion	4. Exposure to Environmental Hazards
Green	Urban Green Space	Parks	Urban parks	Y	Y	Y	Y
		Semi-natural / natural	Biodiversity areas, conservation areas, nature reserves, protected areas, heritage sites?	Y	Y - access	Y - access	Y
		Formal Recreation	Playgrounds and sports fields (not within parks)	Y	Y	Y	Y
		Amenity space	Squares, Gardens,	Y	Y - size >0.5ha	Y	Y
		Functional	Allotment, Cemetery, Civic Spaces, Institutional (school, hospital grounds etc.)	Y	Y	Y	Y
		Natural / green corridor	Traffic free / natural: Pathways, Trails and cycle paths	Y	Y - access	Y - access	Y
		Derelict / vacant	Disused natural areas, no				

LEVEL 2 >> Detailed Measures

Mechanism Subset	Indicator	Distance
1. Stress reduction & restorative - Green	Straight line distance to nearest space	Closest
	Street network distance to nearest space	Closest
	Number of spaces within a street network distance	300m, 500m, 1000m
	Total area of spaces (all) within buffer (network distance)	300m, 500m, 1000m
	Network distance to nearest space by size - <0.5, 0.5 to 2, 2 to 5, 5 to 20, 20 plus hectares	300m, 500m, 1000m 3000m, 5000m (5 to 20, 20 plus only)
1. Stress reduction & restorative - Blue	Straight line distance to nearest space	Closest
	Street network distance to nearest space	Closest
	Number of spaces within a street network distance	300m, 500m, 1000m
	Total area of spaces (all) within a (network distance)	300m, 500m, 1000m
	Presence of Blue (Y/N)	300m, 500m, 1000m

LEVEL 2 >> Detailed Measures

2. Physical Activity - Green	Street network distance to nearest space	Closest
	Number of spaces within a street network distance	300m, 500m, 1000m
	Total area of spaces (all) within buffer (network distance)	300m, 500m, 1000m
	Network distance to nearest space by size - 0.5 to 2, 2 to 5, 5 to 20, 20 plus hectares	300m, 500m, 1000m 3000m, 5000m (5 to 20, 20 plus only)
2. Physical Activity - Blue	Street network distance to nearest space	Closest
	Number of spaces within a street network distance	300m, 500m, 1000m
	Total area of spaces (all) within a (network distance)	300m, 500m, 1000m
	Presence of Blue (Y/N)	300m, 500m, 1000m

LEVEL 2 >> Detailed Measures

Mechanism Subset	Indicator	Distance
3. Social Interaction Cohesion - Green	Street network distance to nearest space	Closest
	Number of spaces within a street network distance	300m, 500m, 1000m
	Total area of spaces (all) within buffer (network distance)	300m, 500m, 1000m
	Network distance to nearest space by size - <0.5, 0.5 to 2, 2 to 5, 5 to 20, 20 plus hectares	300m, 500m, 1000m 3000m, 5000m (5 to 20, 20 plus only)
3. Social Interaction Cohesion - Blue	Street network distance to nearest space	Closest
	Number of spaces within a street network distance	300m, 500m, 1000m
	Total area of spaces (all) within a (network distance)	300m, 500m, 1000m
	Presence of Blue (Y/N)	300m, 500m, 1000m

LEVEL 2 >> Detailed Measures

Mechanism Subset	Indicator	Distance
4. Exposure to Environmental Hazards - Green	Straight line distance to nearest space	Closest
	Number of spaces within a straight distance	300m, 500m, 1000m
	Total area of spaces (all) within straight-line buffer	300m, 500m, 1000m
4. Exposure to Environmental Hazards - Blue	Straight line distance to nearest space	Closest
	Number of spaces within a straight-line distance	300m, 500m, 1000m
	Total area of spaces (all) within a straight-line distance	300m, 500m, 1000m

AUDITS >> Environment Quality

In PHENOTYPE, for every selected neighborhood, we have audited:
- the streets/streetscape, and
-natural outdoor spaces in these neighborhood

Nat Env audit tool was comprised of 59 items grouped into eight main domains:

Domains	Items (summarised)	Items
1. Access	Entrance points; busy/minor surrounding roads; pedestrian crossings; links areas; walking paths (amount and quality); car parking	7
2. Recreational Facilities	Playground equipment; Grass pitches; Courts; Skateboard ramp(s); Other sports or fitness facilities	7
3. Amenities	Seating/benches; Litter bins; Dog mess bins (or equivalent); Public toilets; Cafe / kiosk; Shelter/shade - man-made; Shelter/shade - from trees; Barbeques; Picnic tables; Drinking fountains	10
4a. Aesthetics (Natural features)	Area on the foreshore of a beach, river or large lake; OTHER water features WITHIN area; % area occupied by the water feature(s); Good view points, vistas, scenic views; %of area occupied by trees; Primary surface quality; Flower beds / planters / wild flowers; Other planted trees / shrubs / plants	8
4b. Aesthetics (Non-natural)	Water fountain (decorative); Other public art; Historic/attractive buildings/structures; Public attractions (e.g., zoo, other)	4
5. Incivilities	General litter; Evidence of alcohol use' Evidence of drug taking; Graffiti; Broken glass; Vandalism; Noise (e.g., traffic, industry); Unpleasant smells	9
6. Safety (social)	Lighting within area; Visibility of surrounding roads (from centre of area); Visibility of surrounding houses (from centre of area)	3
7. Useage (suitability for…)	Sport; Informal games; Walking/running; Children's play; Conservation/biodiversity; Enjoying landscape/visual qualities; Meeting, socialising; Relaxing/unwinding; Cycling; Water sport; Fishing	11
	TOTAL	**59**

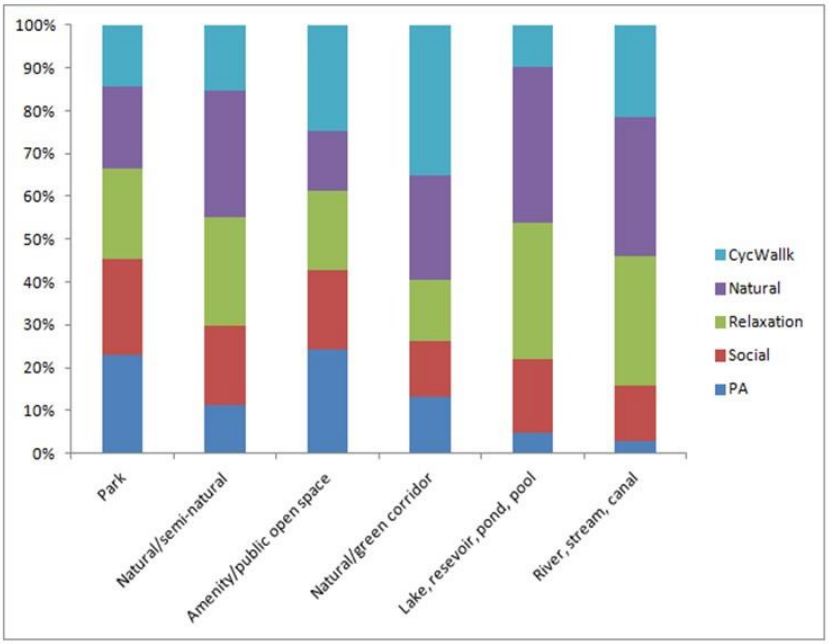
AUDITS >> Environment Quality

Distribution of Natural Environment tipology audited by city

Typology*		City				Total
		Barcelona	Doetinchem	Stoke-on-Trent	Kaunas	
	Park	37	63	56	4	160
	Natural/semi-natural	14	15	10	12	51
	Amenity/public open space	8	4	6	1	19
	Natural/green corridor	0	0	10	0	10
	Lake, reservoir, pond, pool	0	0	2	0	2
	River, stream, canal	0	2	6	0	8
Total		**59**	**84**	**90**	**17**	**250**

AUDITS >> Environment Quality

Bar graph showing the relative contribution of Mechanism scores to each Typology



AUDITS >> Environment Quality

Next steps:

Derive final scores for all audited spaces and

- Calculate neighbourhood-level aggregate scores

- Link individual space scores to relevant survey items about specific spaces visited

Initial results WP3

PHENOTYPE
Health from outside in

Birth outcomes

Articles	Population and outcome	NDVI	Access (Distance)	Use
Dadvand et al 2012	2393 4 Spanish birth cohorts Birth weight Gestational age	500 m IQR 44.2 (20.2-68.2)* 0.0 (–0.9, 0.9)	nd	nd
Dadvand et al 2012	8246 births Barcelona Birth weight g Gestational age d.	100 m in low SES: 436.3 (43.1, 829.5)* –19.8 (–67.6, 28.1) –0.3 (–1.9, 1.4)	500 m in low SES: 189.8 (23.9, 355.7)* –15.8 (–36.3, 4.8) –0.4 (–1.1, 0.3)	nd
Dadvand et al 2014	10780 births Bradford Birth weight g	250 m IQR in white British 26.2 (3.1- 49.3)* Pakistani 6.5 (-16.4- 29.5)	300 m 4.8 (–12.5, 22.1)	nd
Grazuleviciene et al 2015	3292 births Kaunas Birth weight, g Gestational age d.	100 m 13.2 (–3.7–30.2) –0.2 (–0.77–0.35)*	1000 m park -6.43 (-45.2–32.4) -0.21 (-0.39–-0.04)	nd

30

PHENOTYPE
Health from outside in

Children health

Articles	Population and outcome	NDVI	Access (Distance)	Use
Dadvand et al 2014	3178 9-12 yrs Sabadell Sedentary behaviour Obesity Asthma	100 m IQR 0.85 (0.77, .93)** 0.83 (0.75, .93)** 1.00 (0.82, 1.21)	Parks 300m 0.91 (0.76, 1.09) 0.90 (0.74, 1.09) 1.60 (1.09, 2.36)** Forest 0.61 (0.45, 0.83)** 0.75 (0.54, 1.03)* 1.02 (0.56, 1.87)	Nd
Amoly et al 2014	2,111 7-10 years Barcelona Total difficulties Emotional symptoms Peer relationship problems Hyperactivity	NDVI 100m −3.6 (−6.6–0.6)** −1.4 (−5.9-3.2) −2.4 (−8.7-4.3) −6.0 (−11.3- −0.2)**	Distance 300 m −1.3 (−8.2-6.2) 1.9 (−8.7-13.8) −5.1 (−19.1-1.3) 1.8 (−11.6-17.3)	Playing time Green/Blue spaces −4.8 (−8.6 −.9)** /−3.9 (−7.2, −0.4)** −8.2 (−13.9 −2.2)** /−3.9 (−9.1, 1.6) −15.4 (−22.7−.4)** /−16.8 (−23.4–9.7)** −1.6 (−9.0-6.4) /−0.1 (−6.7-6.9)
Balseviciene et al 2014	1468 4- 6 years Kaunas (Low SES 296) SDQ	300m (beta coefficient) in high SES	Parks (beta coefficient) in low SES	nd
	Total Difficulties		0.069*	
	Peer problems		0.023*	
	Conditional problems	0.901*	0.026*	
	Hyperactivity		0.026*	
	Prosocial behavior	-1.104*	-0.029	

31

PHENOTYPE
Health from outside in

Adults mental health

Articles	Population and outcome	NDVI	Access (Distance)	Use
Reklaitiene et al 2014	6944 45-72 yrs Kaunas Depressive symptoms	Nd	>300 m parks 1.04 (0.91–1.19)	Use <4 h/week 1.17 (1.01–1.37)
Triguero-Mas et al 2015	8793 adults Catalonia Perceived depression General health	300 m 0.79 (0.71, 0.88)* 0.80 (0.71, 0.91)*	300 m 0.86 (0.76, 0.98)* 0.87 (0.72, 1.05)	nd

32

PHENOTYPE
Health from outside in

Cardiovascular health

Articles	Population and outcome	NDVI	Access (Distance)	Use
Grazuleviciene et al 2014	3416 women Kaunas, blood pressure mmHg High normal <139/89 Hypertension ≥140 or ≥ 90	nd	>1000 m park 1.74 (1.14-2.66)* 1.18 (0.79-1.77)	nd
Tamosiunas et al 2014	5112 45-72 yrs Kaunas Cardiovascular morbidity and mortality	nd	Distance 3rd tertile Total CVD 1.36 (1.03-1.80)*	Total sample Non- fatal CVD 1.66 (1.01-2.73)*

33

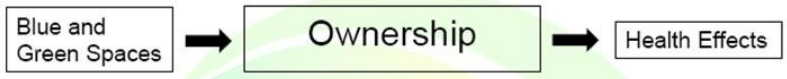
GREEN SPACE MANAGEMENT INDICATORS

Indicators

-Quantitative

-Qualitative

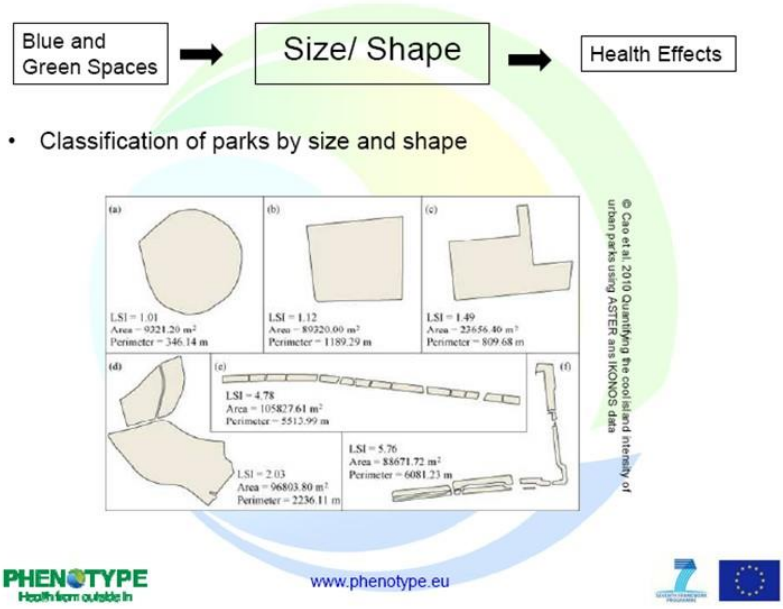
1. **Ownership**



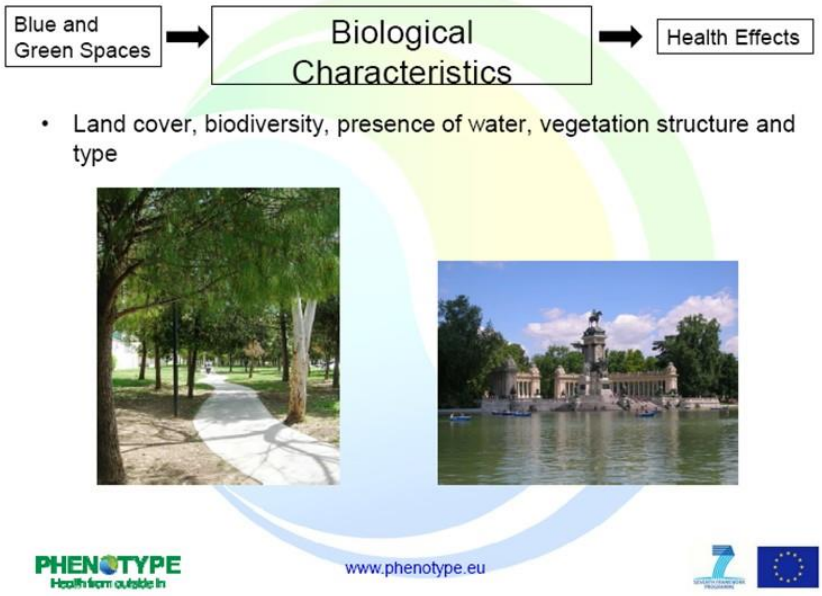
- Distinction public vs. private (hinterland, region, city, neighbourhood)
- Communal/collective/ shared vs. private or public

PHENOTYPE Health from outside in www.phenotype.eu

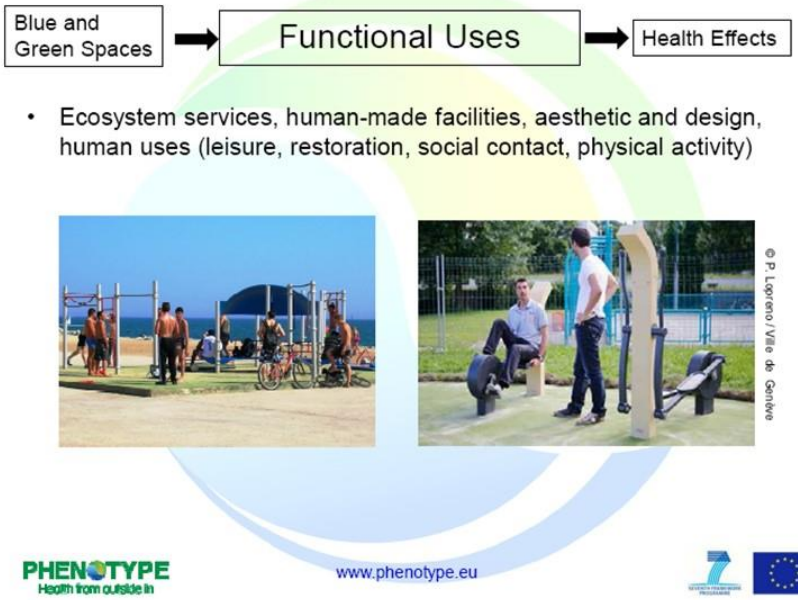
2. Size/shape



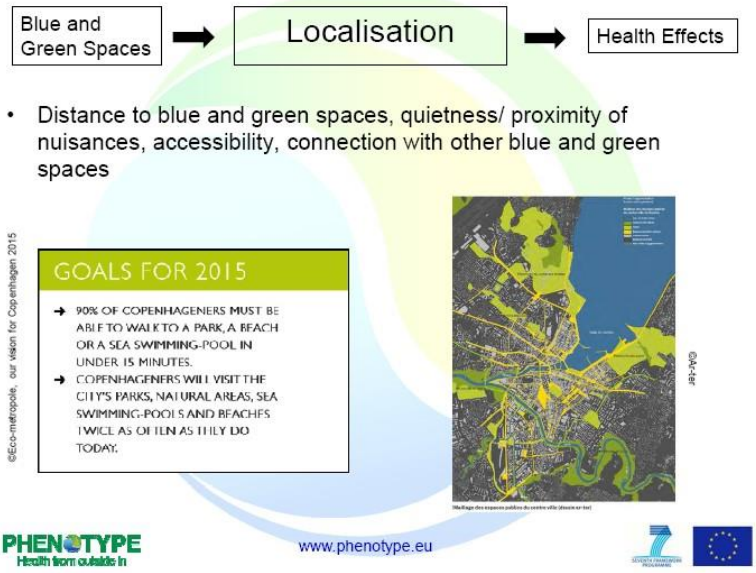
3. Biological characteristics



4. Functional uses



5. Localisation



6. Management

Blue and Green Spaces → Management → Health Effects

- Maintenance (cleanliness, horticultural and landscape management), sense of security, time of opening/closing, entrance fees, codes of conduct (rules)

PHENOTYPE Health from outside in www.phenotype.eu

7. Community identity

Blue and Green Spaces → Community Identity → Health Effects

- Identity, history, culture, presence of local people/ethnic communities, artistic, educational, sporting and tourist interests

Park life! Boating, music, art, dancing and dining in London's green spaces. *Time Out London July 2013*

PHENOTYPE Health from outside in www.phenotype.eu

8. Climate/Weather

Blue and Green Spaces → Climate/ Weather → Health Effects

- Climate, weather conditions, seasonal change

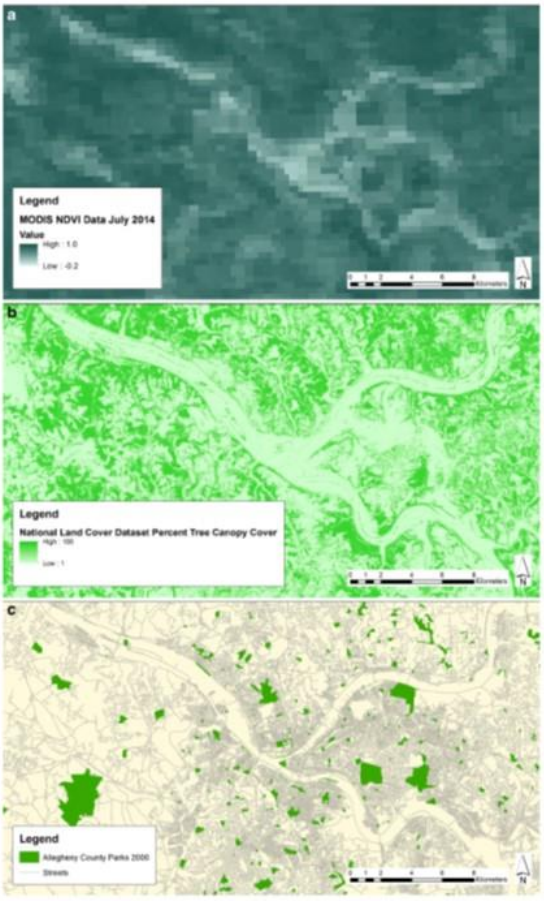
©Wikimedia Commons

PHENOTYPE Health from outside in

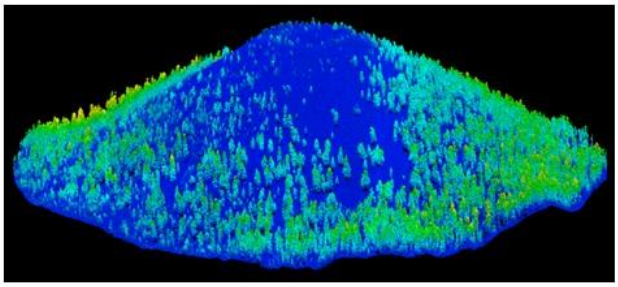
www.phenotype.eu

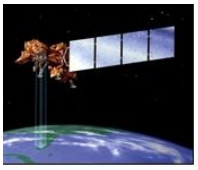
NDVI and Tree Cover Measurements

Geoff Donovan and Perry Hystad



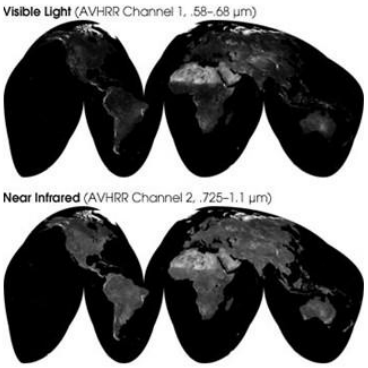
A number of different GIS methods can be used to assess NDVI and tree cover for large populations/areas





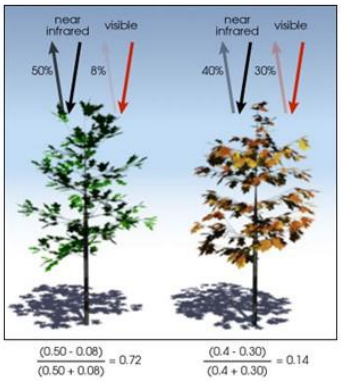
Satellite Vegetation Indices

- Chlorophyll strongly absorbs visible light (from 0.4 to 0.7 µm) for use in photosynthesis.
- The cell structure of the leaves strongly reflects near-infrared light (from 0.7 to 1.1 µm).
- The more leaves a plant has, the more these wavelengths of light are affected.



NDVI

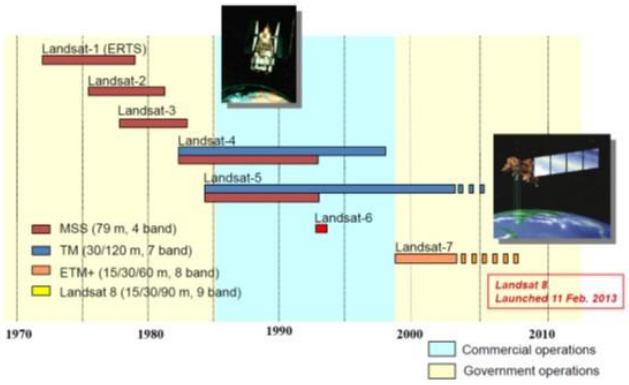
- Most common index using in health research is the Normalized Difference Vegetation Index (NDVI).
- NDVI ranges from -1 to 1 (however, no green leaves gives a value close to zero).



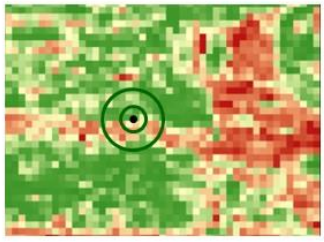
NDVI = (NIR — VIS)/(NIR + VIS)

Landsat NDVI

- Landsat NDVI (1972 onwards)
  - Daily measurements
  - Some processing/calculations of NDVI needed



Landsat NDVI



Day 1−Tree cover measurements *(NDVI, regional-local UTC)*

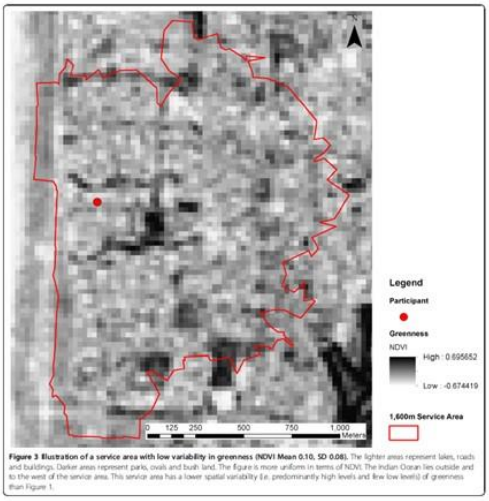


Figure 3 Illustration of a service area with low variability in greenness (NDVI Mean 0.10, SD 0.06). The lighter areas represent lakes, roads and buildings. Darker areas represent parks, ovals and bush land. The figure is more uniform in terms of NDVI. The Indian Ocean lies outside and to the west of the service area. This service area has a lower spatial variability (i.e. predominantly high levels and few low level(s) of greenness than Figure 1.

- **Walkable network area rather than circular buffer**
- **Mean or Variation in Greenness?**

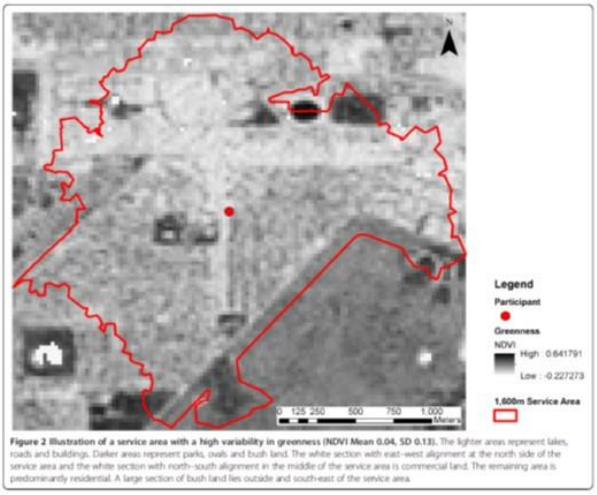
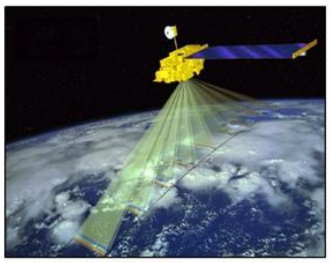


Figure 2 Illustration of a service area with a high variability in greenness (NDVI Mean 0.04, SD 0.13). The lighter areas represent lakes, roads and buildings. Darker areas represent parks, ovals and bush land. The white section with east-west alignment at the north side of the service area and the white section with north-south alignment in the middle of the service area is commercial land. The remaining area is predominantly residential. A large section of bush land lies outside and south-east of the service area.

Pereira et al. (2012). The association between neighborhood greenness and cardiovascular disease: an observational study

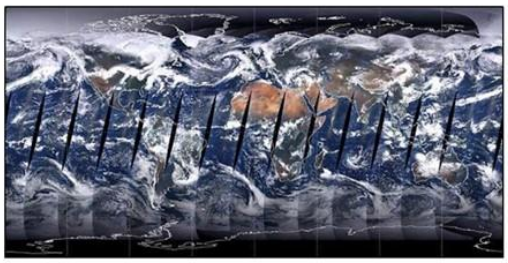
MODIS NDVI or EVI



Spatial Resolution
250m, 500m, 1km

Temporal Resolution
Daily, 8-day, 16-day, monthly, quarterly, yearly (2000-present)

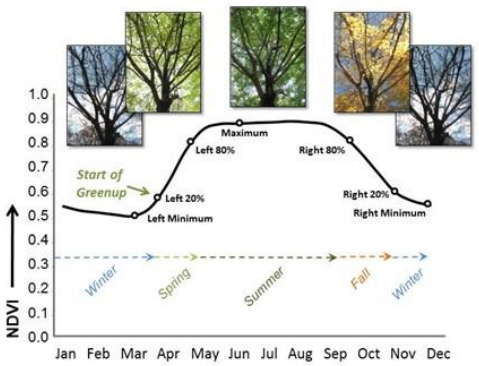
Data Format
Hierarchal Data Format - Earth Observing System Format (HDF-EOS)

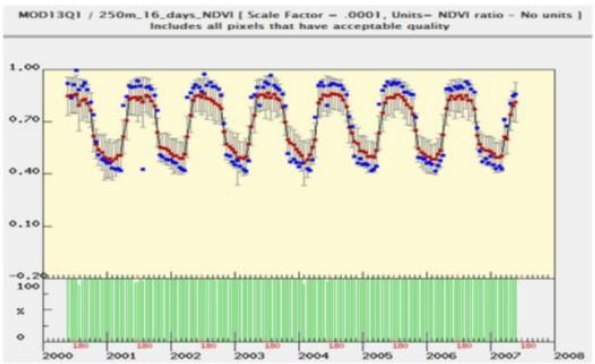


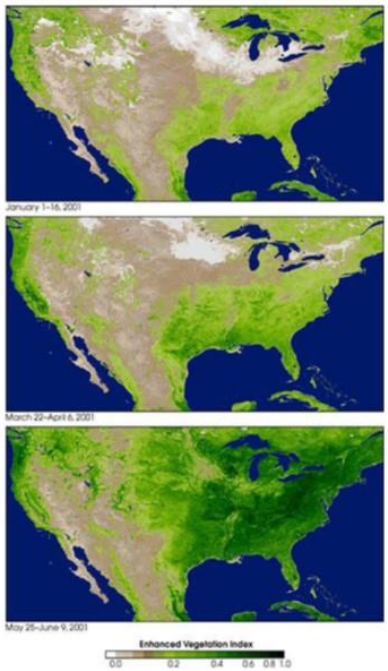
Spectral Coverage
36 bands (major bands include Red, Blue, IR, NIR, MIR)
Bands 1-2: 250m
Bands 3-7: 500m
Bands 8-36: 1000m

EVI

- Enhanced Vegetation Index (EVI) was designed to improve upon the quality of the NDVI product (available from the MODIS sensor).
- Corrects for some distortions in the reflected light caused by the particles in the air as well as the ground cover below the vegetation.
- Improves on the saturation of NDVI at very high greenness levels.





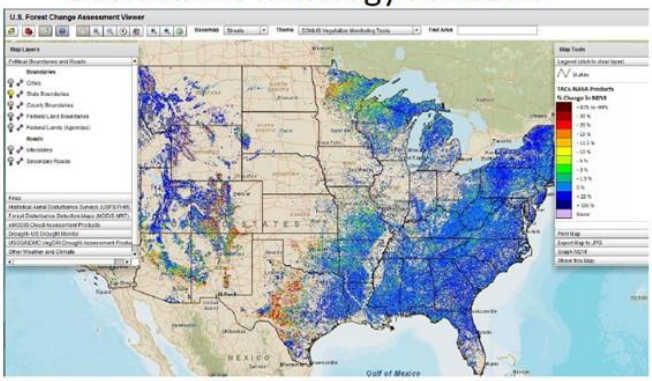


Day 1−Tree cover measurements *(NDVI, regional-local UTC)*

U.S. Forest Change Assessment Viewer (ForWarn)

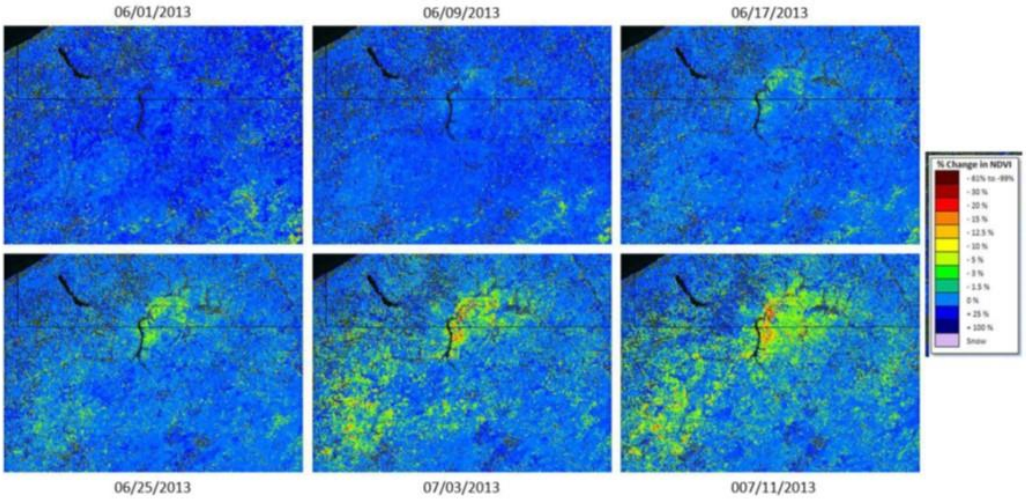
Three types of products:

- Forest Change Products
- Basic Phenology Products
- Derivative Phenology Products



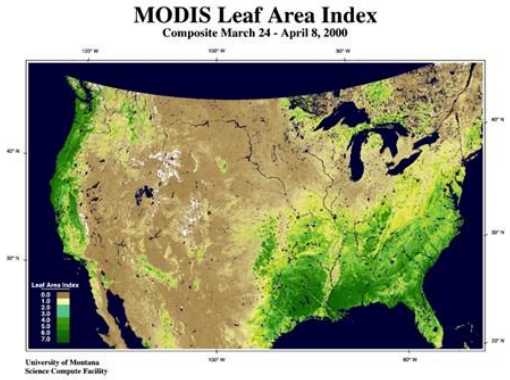
http://forwarn.forestthreats.org

Use of ForWarn: 2013 Gypsy Moth Defoliation in New York and Pennsylvania

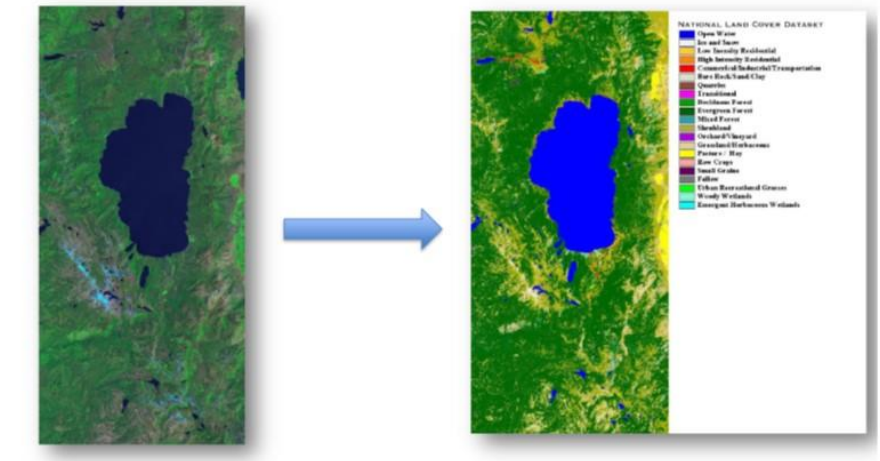


Leaf Area Index

- Ratio of leaf area to ground area.
- Computed daily at 1km from MODIS spectral reflectance's for all vegetated land surface globally.



Land Cover Maps

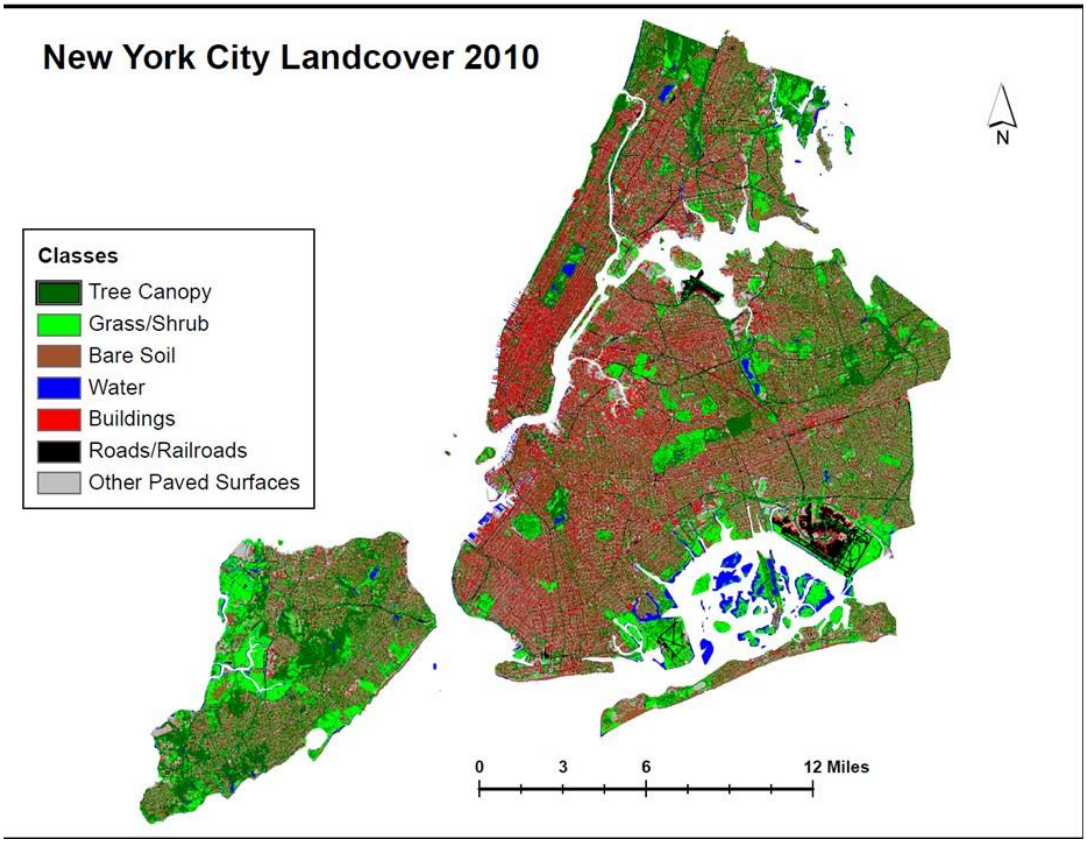


Landsat Image of Lake Tahoe

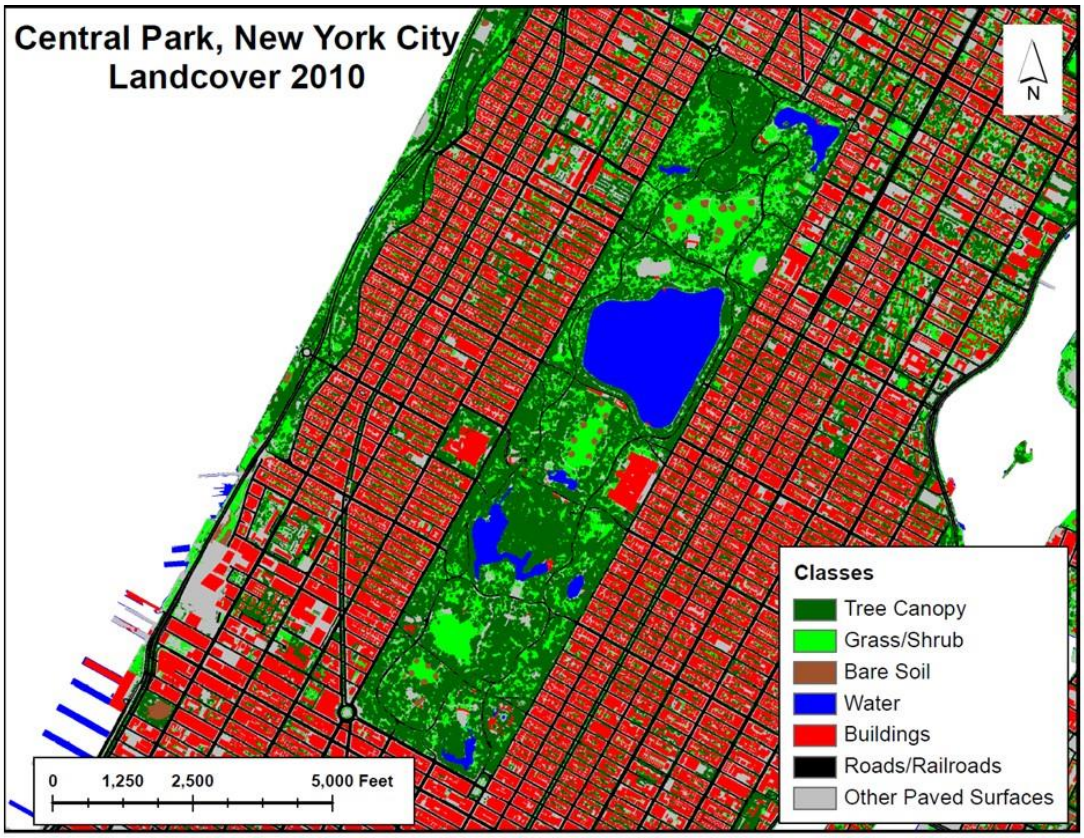
Landcover map of Lake Tahoe

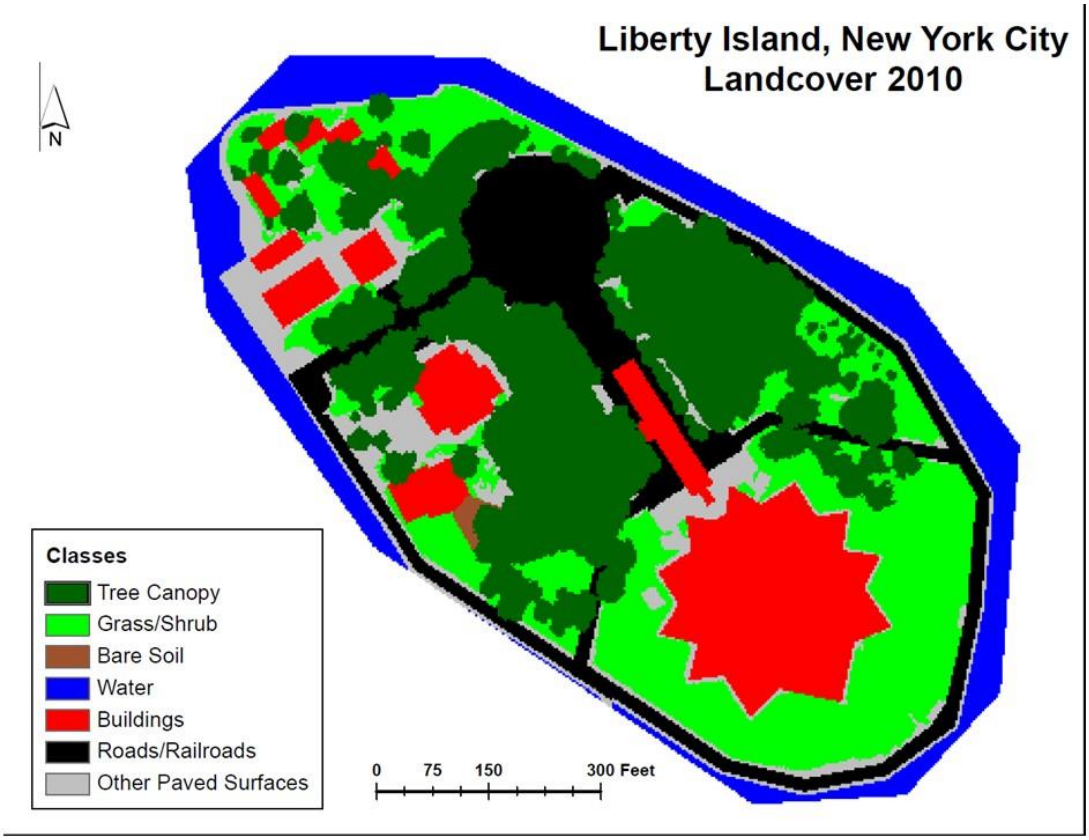
Landsat Derived Land Cover Products

- **United States**
  - National Land Cover Database (NLCD)
  - GAP Analysis
  - LANDFIRE
- **Global**
  - Global Land Cover Network (FAO)
  - Forest Change Products (Amazon Basin, Central Africa, Paraguay) and Landsat Tree Cover (GLCF)



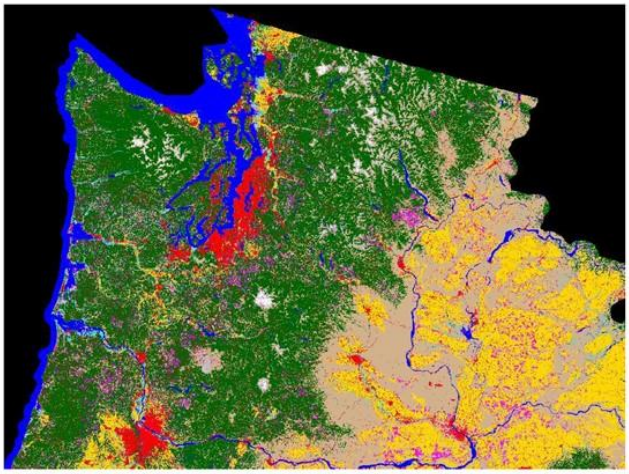
Day 1−Tree cover measurements *(NDVI, regional-local UTC)*



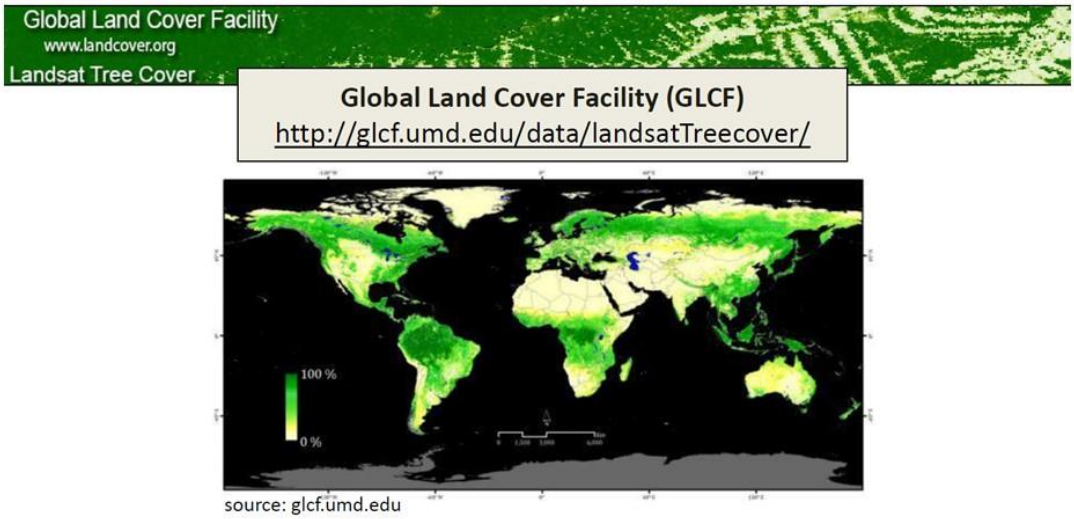


Assessing Change

- Land cover change from 1992 to 2010 in the Pacific Northwest.



Landsat Tree Cover

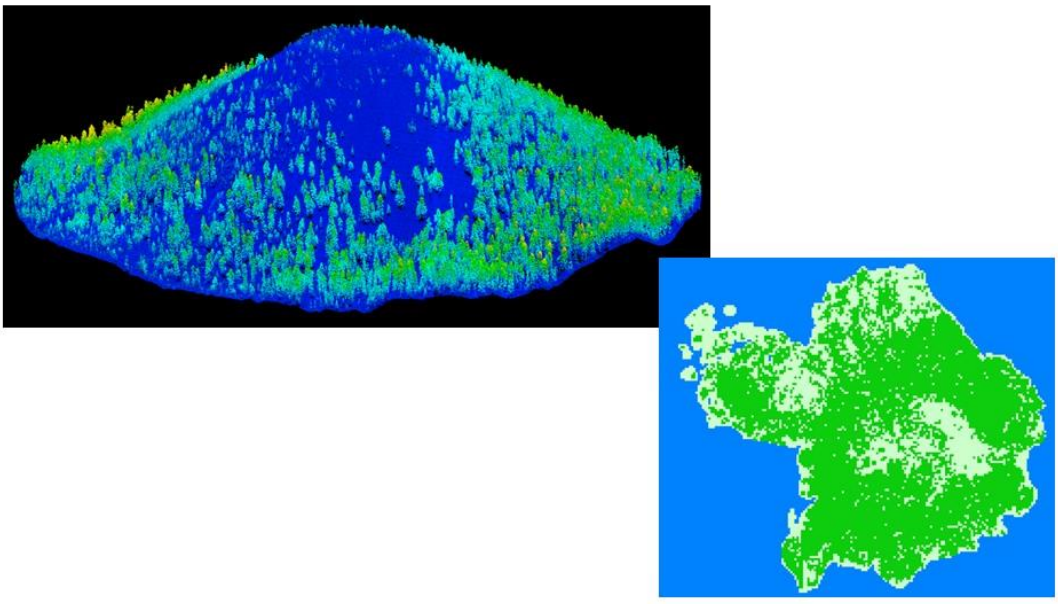


- Landsat Tree Cover layers estimate the percent of tree cover per 30m pixel area (includes stems, branches, leaves greater than 5 meters in height)
- Derived from all seven bands of Landsat 5-TM and Landsat ETM
- Landsat Tree Cover product represents 2000, 2005

LiDAR

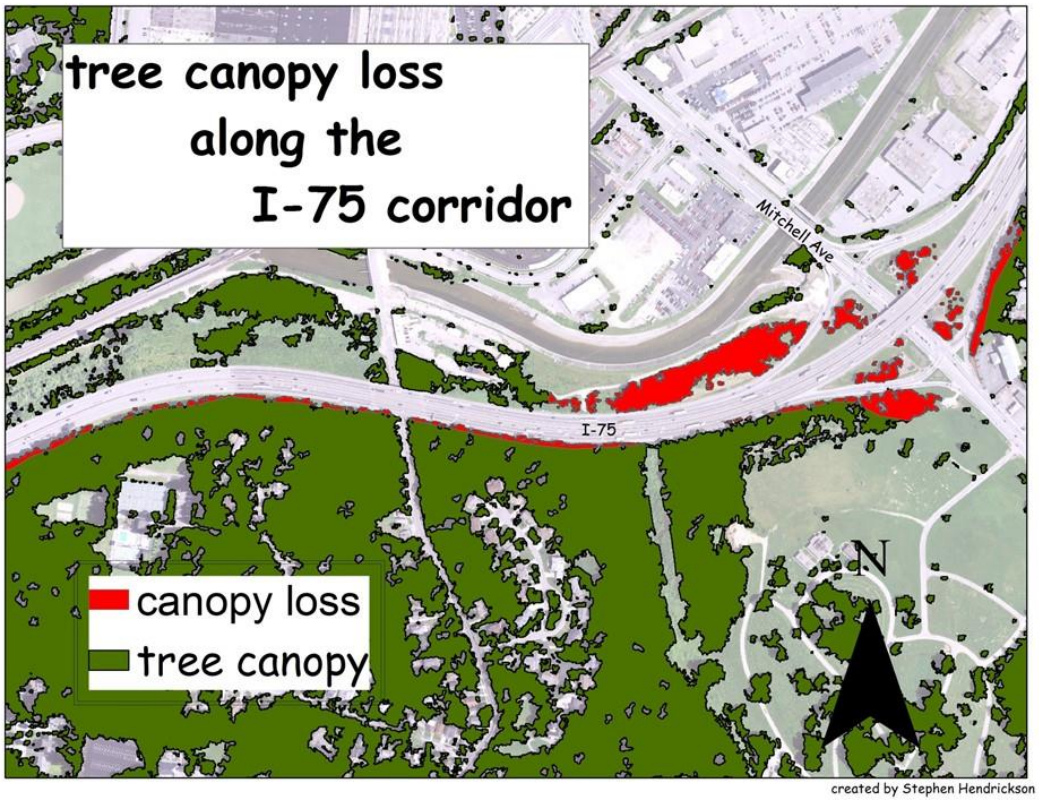
- LIDAR (Light Detection and Ranging) is a remote sensing method that uses light in the form of a pulsed laser to measure distances to the Earth.
- Generates precise, three-dimensional information about the shape of the Earth and its surface characteristics.

Example of LiDAR data – Canopy Cover

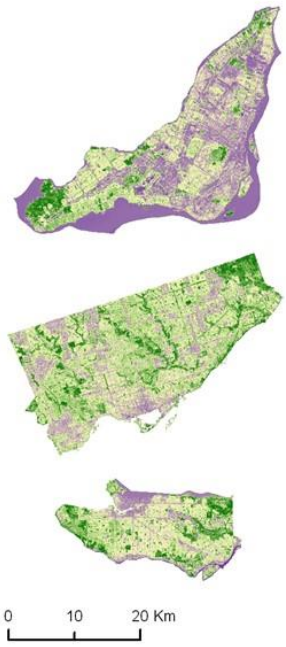


Day 1−Tree cover measurements *(NDVI, regional-local UTC)*

Figure 2.2.2: A city block in study area that displays a) resulting building polygons from the LiDAR extraction technique, and b) resulting building polygons after post-processing to simplify polygon shapes, remove secondary structures, and separate buildings by land parcel boundaries.

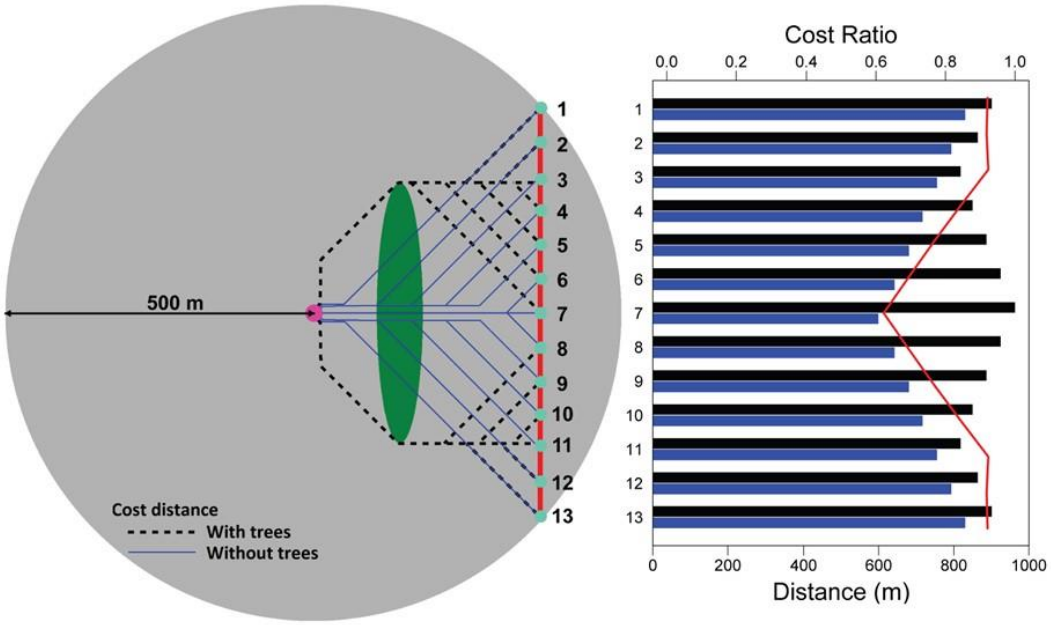


Other Applications Applications



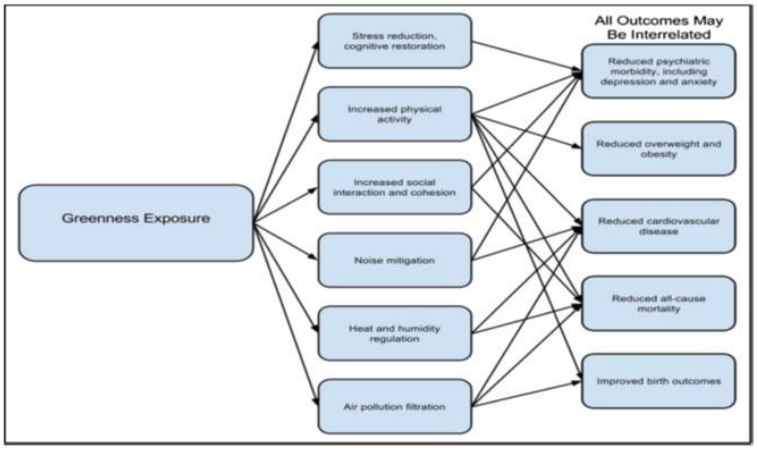
- Separate vegetation index by trees and grass using LIDAR.
- Integrate cooling impacts of vegetation.
- Cost distance.

Cost Distance



Enhancing NDVI and Tree Cover "Exposure" Assessment

- Start with the specific exposure construct in which we want to examine:



Enhancing NDVI and Tree Cover "Exposure" Assessment

- Include both objective and subjective measurements.
- Collect information on use of greenspace.
- Assess greenspace using GPS and accelerometer data with momentary assessments of greenspace?
- Greenspace and tree exposure assessment from a human view (rather than birds eye view).
- Etc…

Access to greenness

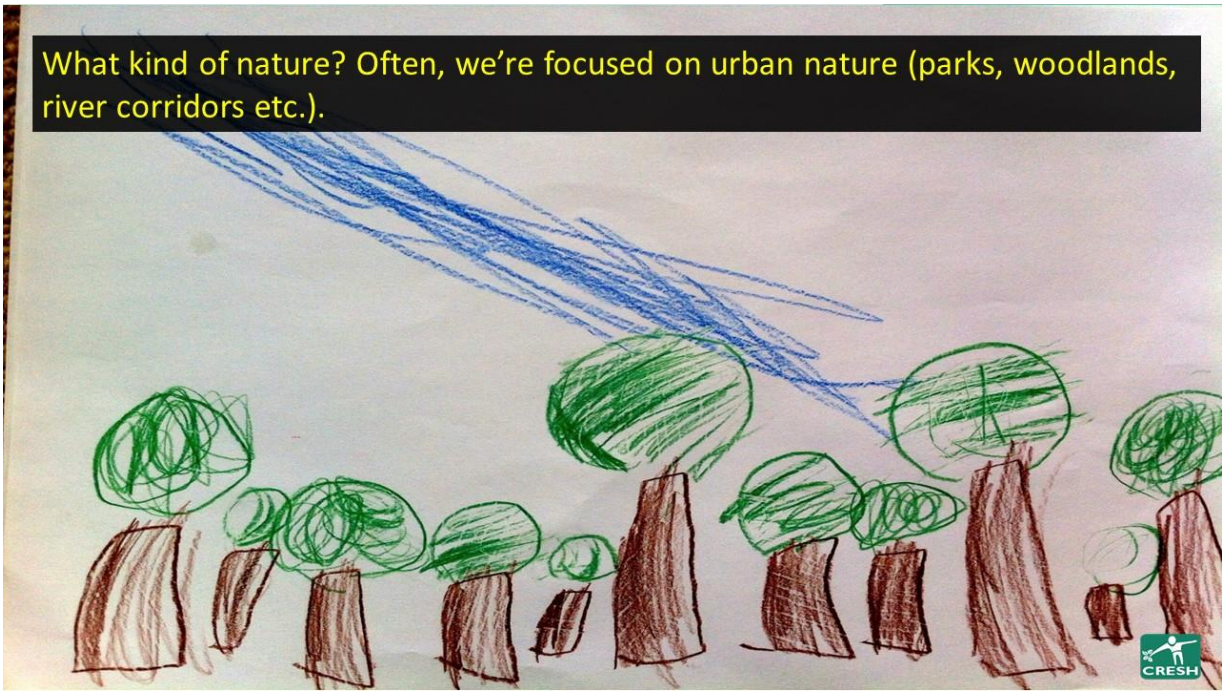
Rich Mitchell, Michelle Kondo, Matilda Van Den Bosch

Day 1

Estimating Greenspace Exposure & Benefits for Cumulative Risk Assessment Applications
Technical Working Group Meeting
May 4-5, 2015

U.S. Environmental Protection Agency
26 Martin Luther King Drive West, Cincinnati, OH 45220

1



An example of very detailed landcover mapping

Glasgow: Kelvinbridge and Botanical Gardens

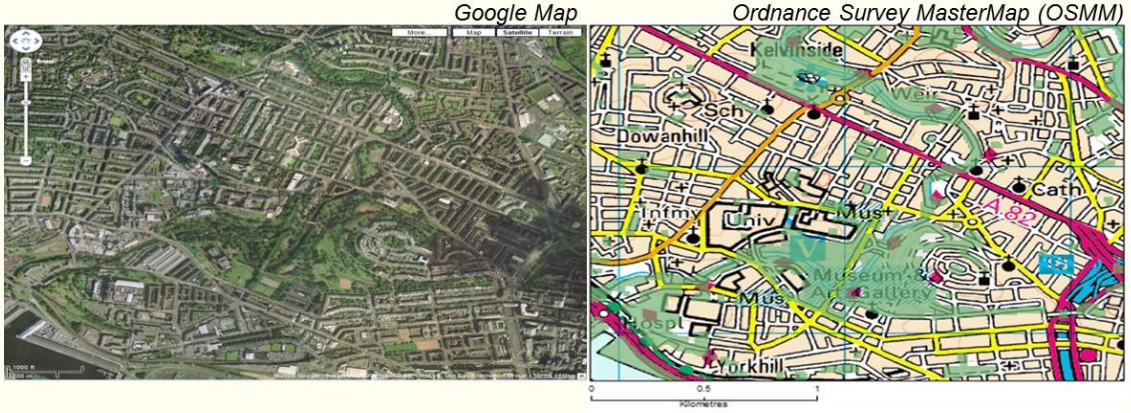
Google Map *Ordnance Survey MasterMap (OSMM)*

Master Map ©Crown Copyright/database right 2009. An Ordnance Survey/EDINA supplied service. Google imagery © Google

We extract 'green' areas based on land cover

Glasgow: Kelvinbridge and Botanical Gardens

Google Map *Ordnance Survey MasterMap (OSMM)*

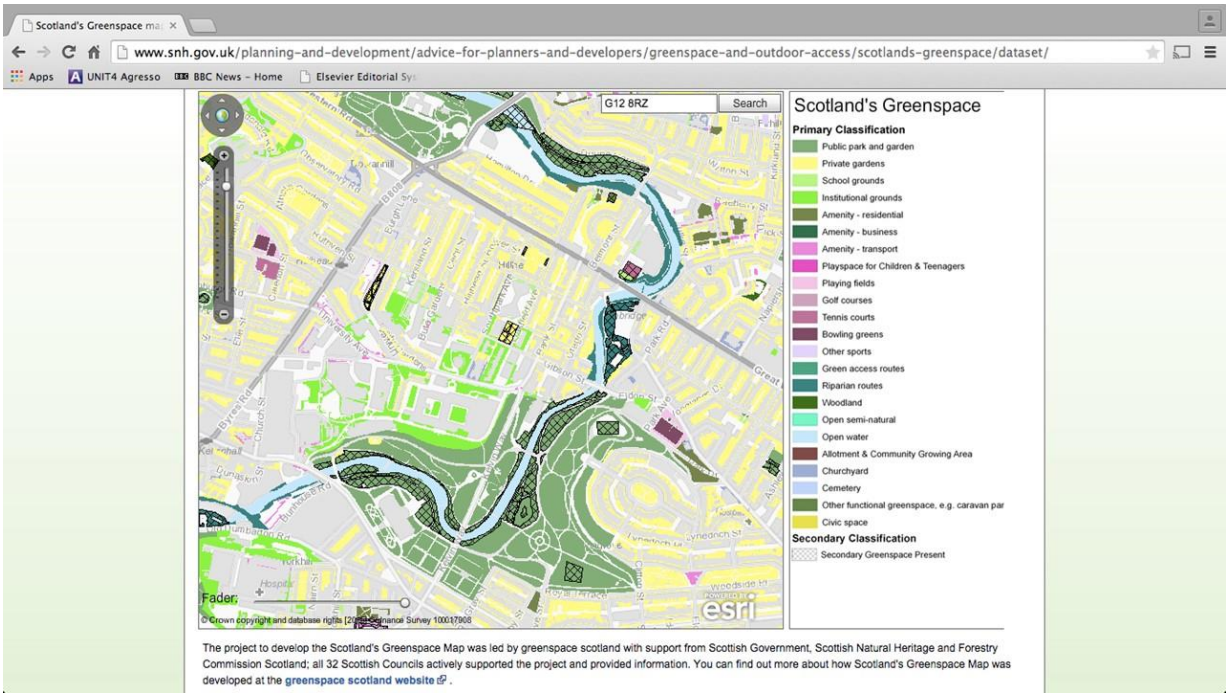


Master Map & 150000 Map ©Crown Copyright 2009. An Ordnance Survey/EDINA supplied service. Google imagery © Googlec

Scotland's greenspace map

- The Map was compiled in 2011 from greenspace data provided by all 32 Scottish Councils.
- The local datasets were produced using greenspace mapping characterisation.
- This involved using GIS maps and aerial photography to categorise greenspaces into 23 different open space types; these include public parks, play areas, allotments, amenity greenspace, private gardens. Primary and secondary codes are used to capture multi-functional greenspaces, for example, play areas or woodland within larger public parks

5



These can then be buffered to give a ‘distance to green space’ measure

Google Map

Distance buffer

Or the proportion of land cover within an areal unit that is green can be calculated

Google Map

Hybrid

Some remotely sensed data sets capture only larger green spaces

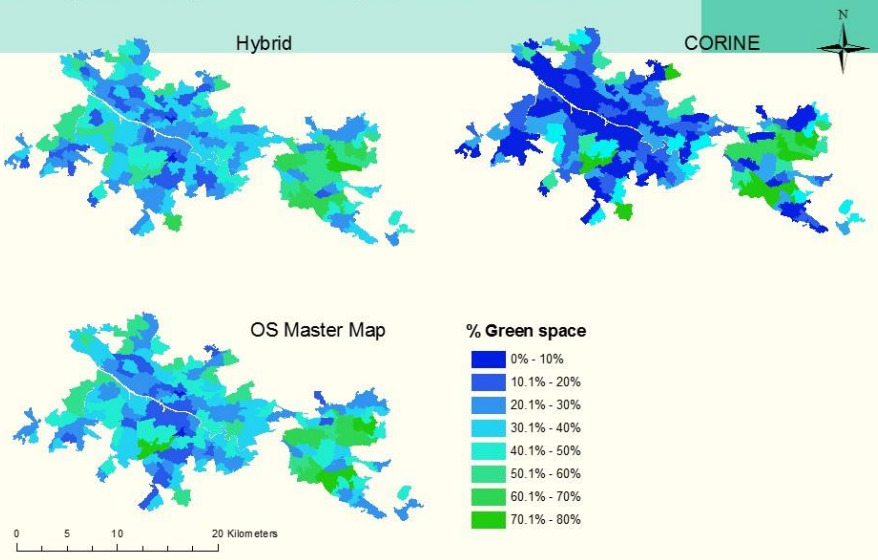
Glasgow: Kelvinbridge and Botanical Gardens

Google Map

EEA CORINE

CORINE data © **EEA**, Copenhagen, (2001). Google imagery © Google. OS 150000 map, © Crown Copyright. An Ordnance Survey / EDINA supplied service

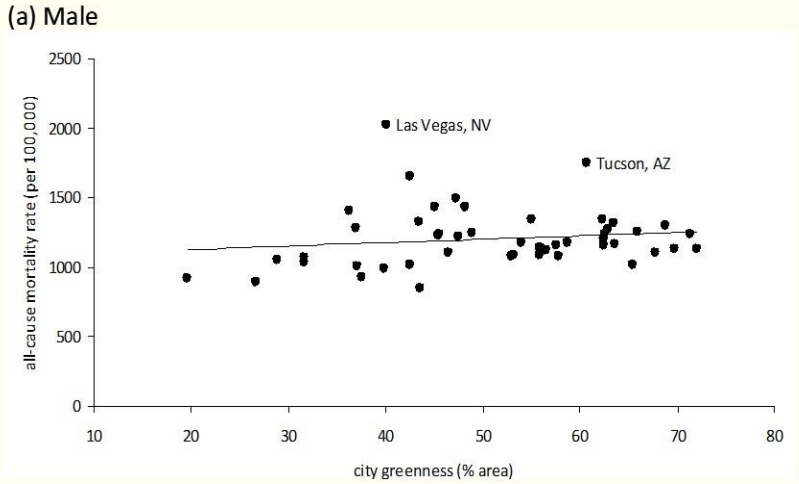
Comparison of 'neighbourhood greenness' in Glasgow, from different data sets



This work is based on data provided through EDINA UKBORDERS with the support of the ESRC and JISC and uses boundary material which is copyright of the Crown and the Post Office. Master Map ©Crown Copyright/database right 2009. An Ordnance Survey/EDINA supplied service. CORINE (c) EEA, Copenhagen, (2001)

Day 1−Access to greenness

Scale matters here – these are 'city level' greenness measures, from National Land Cover Database for 2001, in the US.



Richardson EA, Mitchell R, Hartig T, de Vries S, Astell-Burt T, Frumkin H. Green cities and health: a question of scale? Journal of Epidemiology and Community Health. 2011 doi:10.1136/jech.2011.137240

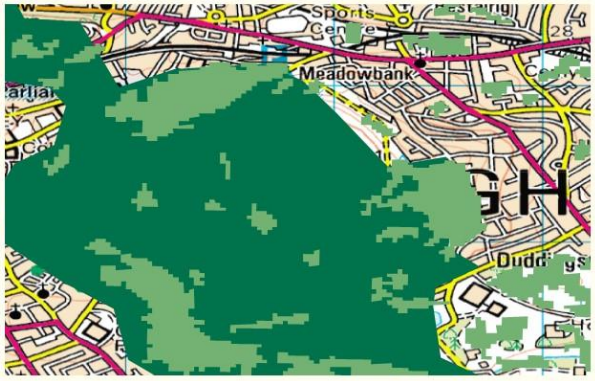
Day 1−Access to greenness

But if you look at how 'green' that part of the city is, different data sets tell you different things

Edinburgh: Holyrood Park

EEA's Green Urban Areas (GUA) data

EEA's GUA data, with CORINE



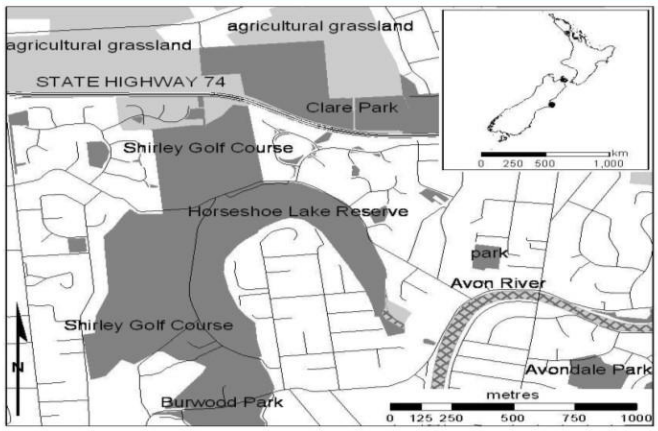
CORINE & GUA data © EEA, Copenhagen, (2001).150000 OS map © Crown Copyright. An Ordnance Survey / EDINA supplied service

More problems

- Distance/walking time or % coverage are not the same as exposure in at least two more important ways
- We don't know if the space is *accessible* to our population of interest
- We don't know if the space is *accessed* by our population of interest
- *Co-location or spatial proximity ≠ exposure*

This lovely park in Dowanhill is private

Google Imagery © Google

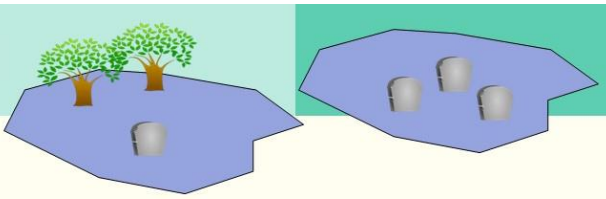


In our work in New Zealand, we were able to use land registry data to distinguish public and private, or accessible and non accessible space. We found different levels of access, of different kinds of space, for different social groups

Richardson E, Pearce J, Mitchell R, Day P, Kingham S. The association between green space and cause-specific mortality in urban New Zealand: an ecological analysis of green space utility. Bmc Public Health. 2010;10(1):240.

How do we do this?

Estimates of the % land area in a neighbourhood that is green space
www.cresh.org.uk

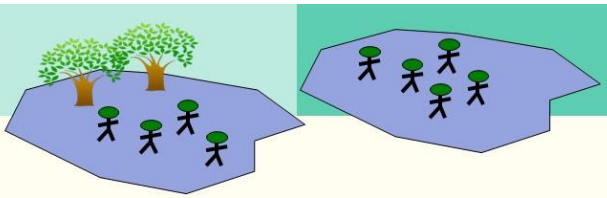


(1) Relate the health of everyone in a neighbourhood to how much green space there is (comparing neighbourhoods)

Mortality data from GROS & ONS (2001-2005)

How do we do this?

Estimates of the % land area in a neighbourhood that is green space
www.cresh.org.uk



(2) Relate the health of individuals to how much green space they have in their neighbourhood &/or whether they visit green spaces (comparing individuals in different neighbourhoods)

Scottish Health Survey 2008

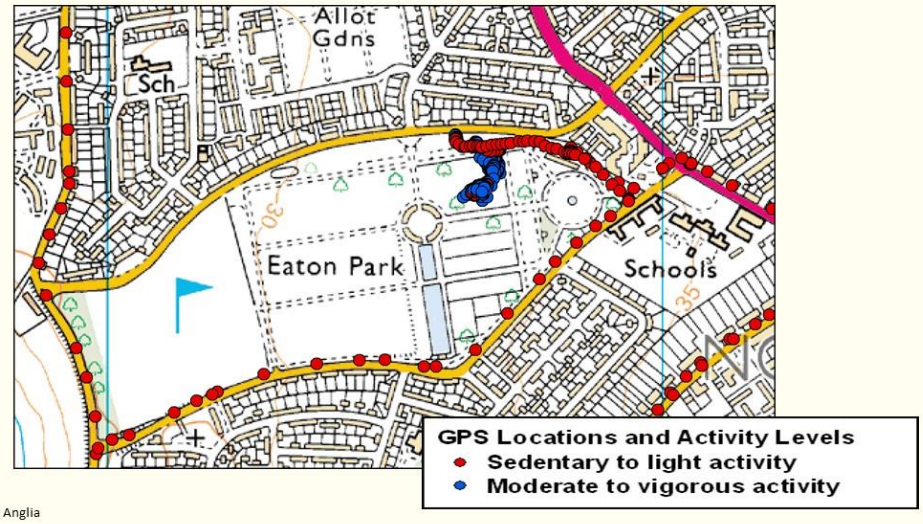
How do we do this?

(3) Relate the health of individuals to whether they visit green spaces or not and what they do there (comparing individuals)

Scottish Health Survey 2008, Scottish Social Attitudes Survey 2009, European Quality of Life Survey, MENE, SPANS… the list goes on

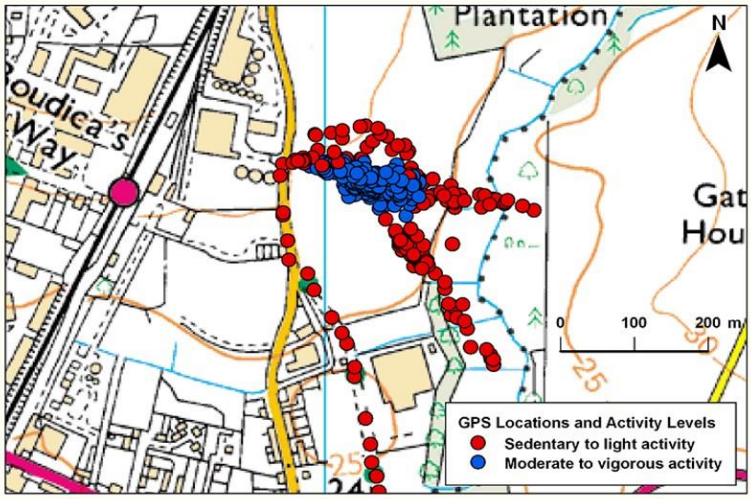
PROBLEM! We rarely also have good health data…

Using GPS to capture environmental exposure



Source: Andy Jones, Uni of East Anglia

Time + environment = exposure



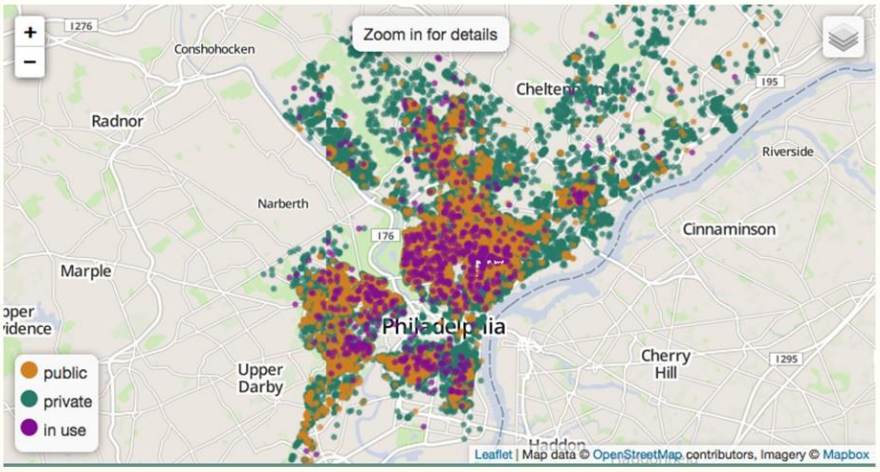
Source: Andy Jones, Uni of East Anglia

Ambient greenness, house plants, etc

- Much research is focused on natural spaces, outside.
- Good evidence that indoor nature, pictures of nature, viewing nature in other ways has health benefits (esp mental health)
- We are very bad at capturing this kind of exposure at a population level.

23

Vacant spaces



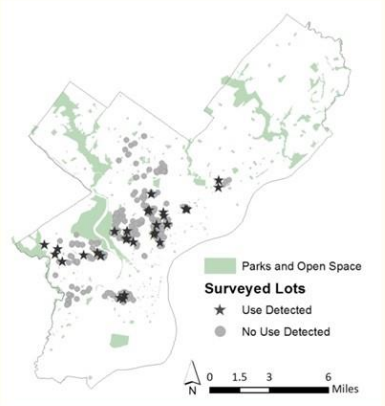
Vacant lot greening

- 2003: Pennsylvania Horticultural Society & City of Philadelphia launched **Philadelphia LandCare**
- 2015: PLC has "cleaned and greened" ~7,600 of Philadelphia's approximately 40,000 vacant parcels
- Studies document influence of vacant lot greening on physiology (heart rate; South et al 2015) & social life (violent crimes; Branas et al. 2011; Kondo et al in review) in neighborhoods

25

Vacant lot survey: Do residents access greened lots?

- Physical survey of random 300 lots
- (Pre-greening) focus groups and (post-greening) interviews



Heckert, M., Kondo. M. Surveyed Uses and Perceptions of "Cleaned-and-Greened" Vacant Lots (under review)

26

Are greened lots used by residents?

- 10% of lots showed signs of use
- Few noticed the greening, or were not sure how to interact with the lots, remaining vacant lots remained problems
- Signs-of-use lots not statistically different in terms of density, playground proximity

Heckert, M., Kondo. M. Surveyed Uses and Perceptions of "Cleaned-and-Greened" Vacant Lots (under review)

27

Vacant lot greening & greenspace exposure

- Definition of greenspace:
  - Do overgrown lots count as green space?
- Exposure effects for who?
  - For nearby residents or outsiders?
- How should accessibility be measured and does it equate to health effect?
  - Can we have health benefits without accessibility?
- Does community involvement modify effect?

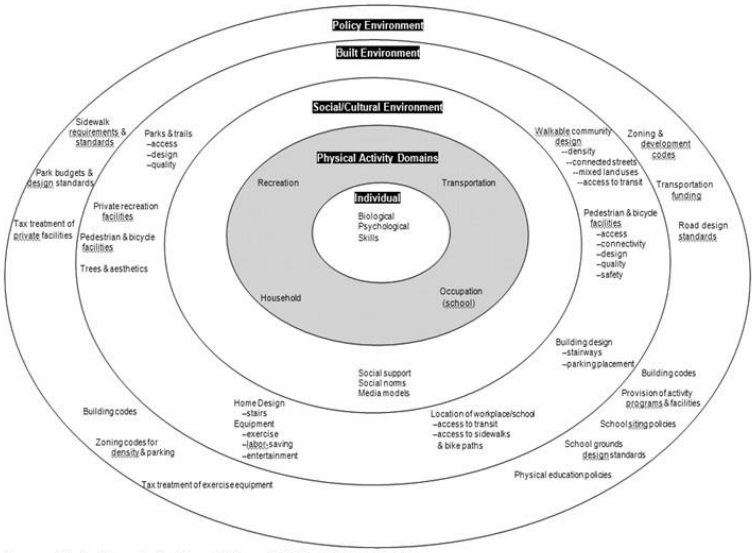
28

Built Environment and Open Space: Key Concepts and Metrics

Perry Hystad, Yvonne Michael

May 4, 2015

Built Environment and Health



James F. Sallis et al. Circulation. 2012;125:729-737

American Heart Association.

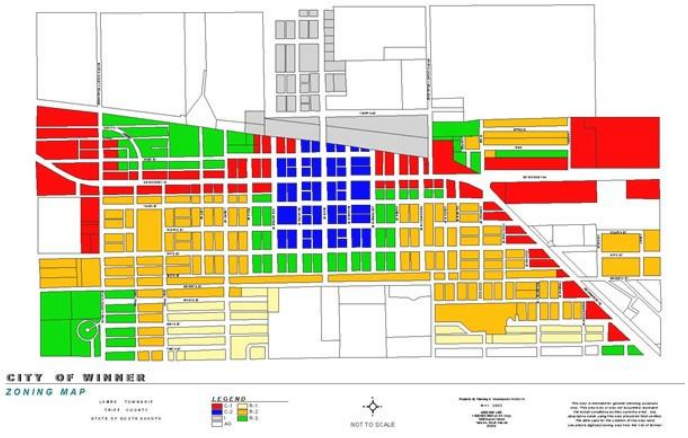
Built Environment and Natural Amenities

- Built environment determined by implementation of local land use plans through zoning and design guidelines.
- Increasing interest in policies to promote urban development that includes access to natural amenities and limits "grey space"
  - From parks, trails, and open space to green roofs and green storm water infrastructure

3

Zoning

- Zoning ordinances commonly include designations for:
  - *Public*
  - *Open Space*
  - *Agricultural*
  - *Residential*
  - *Commercial*
  - *Industrial*
  - *Mixed Use*



Courtesy of: public health law & policy

Urban Parks

Green roof

www.facilities.upenn.edu

Green Storm water infrastructure

http://www.uswaterallia
nce.org/

Urban Open Space

Blighted urban vacant land to be transformed into green space.

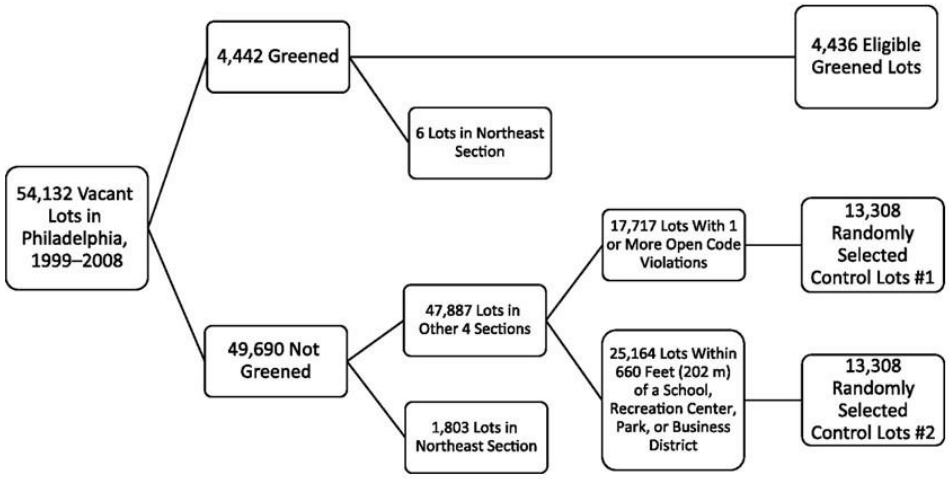
http://www.na.fs.fed.us/

http://axisphilly.org/

Health, Safety, and Greening Vacant Urban Space in Philadelphia

- Across 4 sections of Philadelphia, 4,436 vacant lots totaling over 7.8 million square feet (about 725,000 m^2) were greened from 1999 to 2008.
- "Before" and "after" outcome differences among treated vacant lots compared with matched groups of control vacant lots that were eligible but did not receive treatment.
- Outcomes assessed through Household Health Survey conducted 1998-2008.

Methods



Results

- Vacant lot greening was associated with:
  - Reductions in gun assaults across all 4 sections of the city
  - Consistent reductions in vandalism in 1 section of the city
  - Residents' reporting less stress and more exercise

Measurement of Green Space in Built Environment Studies

Objective measures

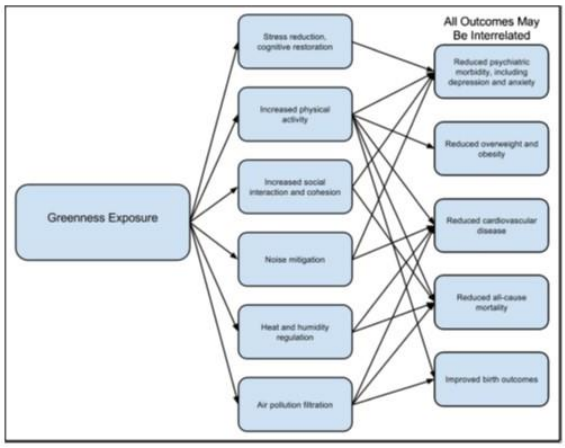
- Residential proximity to natural environment
  - Distance to closest open space, park
- Percent green space
  - Land use data
  - NDVI
  - Google Earth – may also be useful for evaluating quality with trained assessors
- Street-level audits, including tree audits

Perceived measures via survey

- Quality and presence of amenities including parks and other public/private recreation facilities

Complex Relationships!

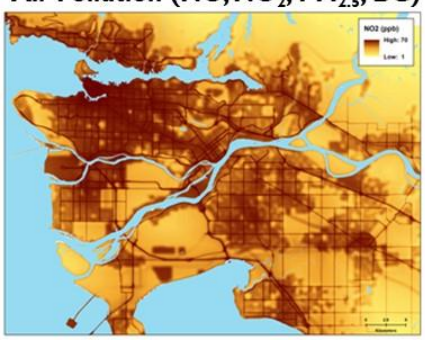
- Can we examine greenspace and health without controlling for other built environment factors?



James et al. (2015)

Greenness

Air Pollution ($NO, NO_2, PM_{2.5}, BC$)



Noise (Traffic and

Variable	NDVI 100 m	NO	NO_2	$PM_{2.5}$	BC	Traffic	All	Walk. index	Park proximity
Greenness									
NDVI 100m	1	-0.43	-0.42	-0.36	-0.31	-0.05	-0.20	-0.58	-0.05
Air pollution									
NO		1	0.49	0.29	0.55	0.18	0.37	0.41	-0.20
NO_2			1	0.53	0.29	0.05	0.18	0.37	-0.25
$PM_{2.5}$				1	0.17	0.09	0.16	0.26	-0.19
BC					1	0.29	0.37	0.18	-0.10
Noise									
Traffic						1	0.92	0.01	-0.08
All							1	0.15	-0.15
Physical activity									
Walkability index								1	-0.43
Park proximity									1

Urban trees and the risk of poor birth outcomes (Portland)

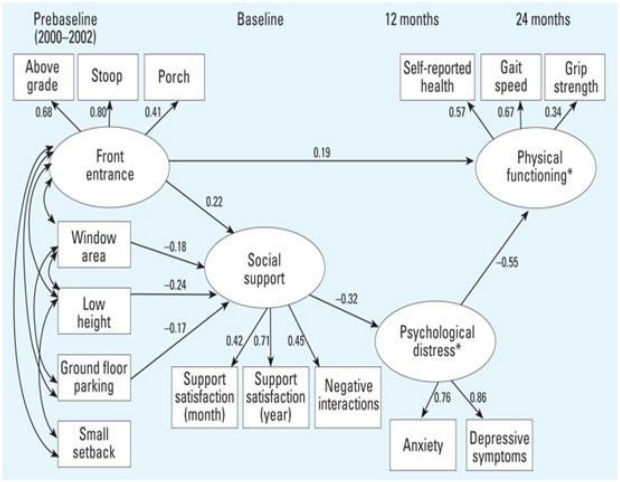
Table 1
Selected individual and neighborhood characteristics overall and by tree canopy within 50 m.

Variable	Overall	Tree canopy within 50 m below median	Tree canopy within 50 m above median
2007 real market value ($)	268 000	260 000*	276 000*
Mother did not graduate high school (%)	9.7	10.0	9.4
Mother non-Hispanic white (%)	71.1	73.3*	69.0*
Mother's age (years)	30.3	30.1*	30.6*
Married (%)	78.1	77.1	79.0
Total births	1.80	1.76*	1.83*
Gestational age (weeks)	39.0	39.0	39.1
Birth weight (g)	3425	3407	3443
Delivery cost paid by private insurance (%)	74.2	73.6	74.8
House age (years)	66.3	64.9*	67.7*
Distance to nearest private open space (m)	3008	2948*	3070*
Distance to nearest public transit stop (m)	679	682	676
Violent crimes within 200 m (2006 and 2007)	1.59	1.60	1.59

* Overall p-value < 0.05 comparing characteristics by level of tree canopy within 50 m of mother's residence.

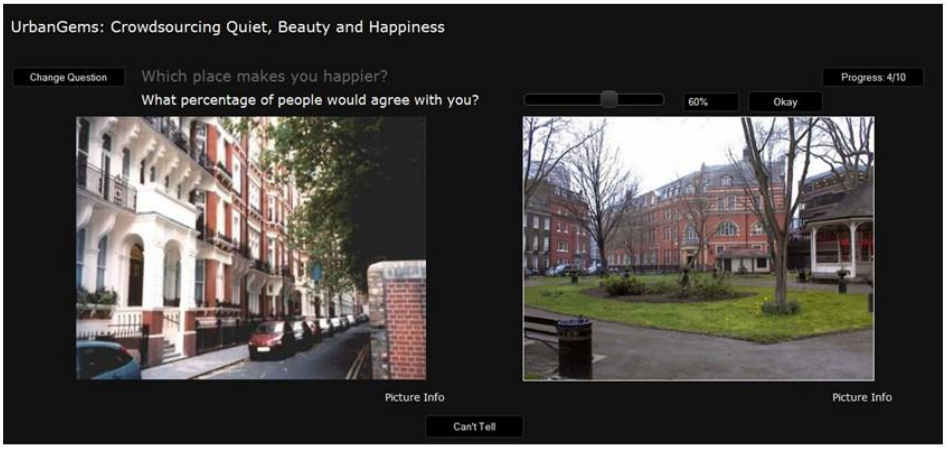
Miro-Features of the Built Environment

- Architectural features that facilitate visual and social contacts may be a protective factor for elders' physical functioning.



Brown et al. 2008 http://ehp.niehs.nih.gov/11160/

Objective vs. Subjective Measures



http://urbangems.org/

Findings

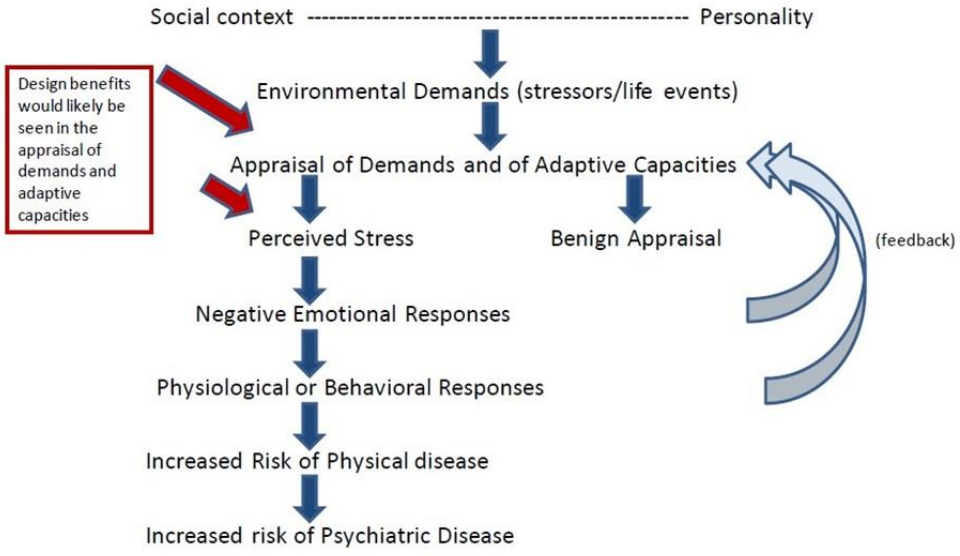
- Analyzed the scenes with ratings using image processing tools.
- Amount of greenery in any given scene is associated with all the three attributes.
- Urban design elements that increase human interactions were associated with all three attributes, especially happiness.

Key Questions

- *How is the built environment and open space conceptualized and evaluated across disciplines?*
- *How is greenspace characterized within the definition of the built environment?*
- *What is being measured, and what needs to be measured for accurate estimates of the quality of the built environment?*
- *What are accepted methods for quantifying exposures related to the built environment?*
- *Consideration of the intersection of socioeconomic context and social behavior with built environment features, quality and public use.*

Day 1−Design and environmental psychology

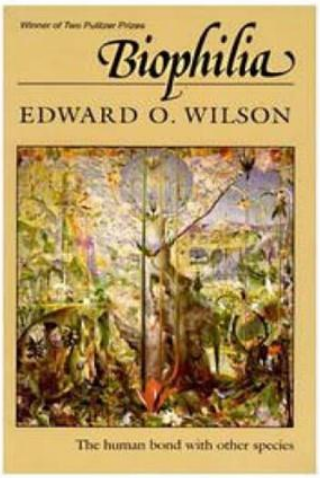
Context: etiology and pathology of stress

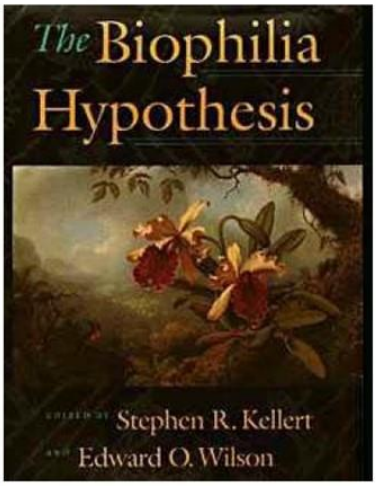


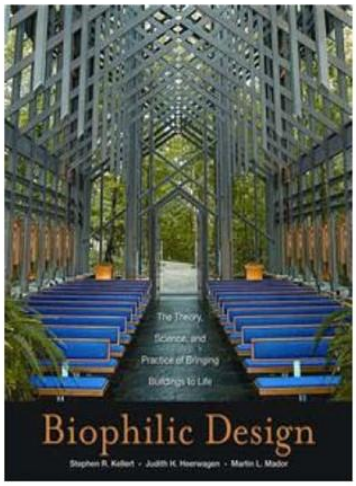
Cohen et al 1995

Day 1–Design and environmental psychology

Theory: Introducing Biophilia







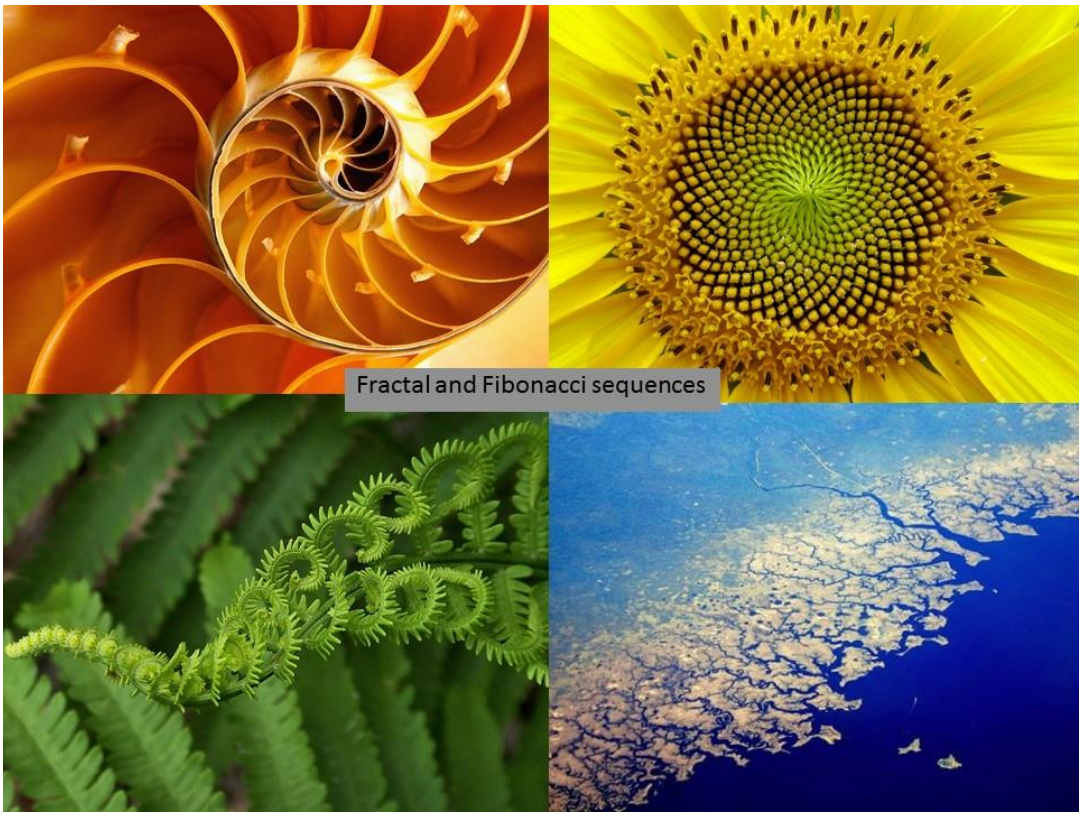
Biophilia was released in 1984, and has since generated a design ethos (including much of what underlies Biomimicry). E. O. Wilson defines *biophilia* as 'the innate tendency [in human beings] to focus on life and lifelike process. To an extent still undervalued in philosophy and religion, our existence depends on this propensity, our spirit is woven from it, hopes rise on its currents.'

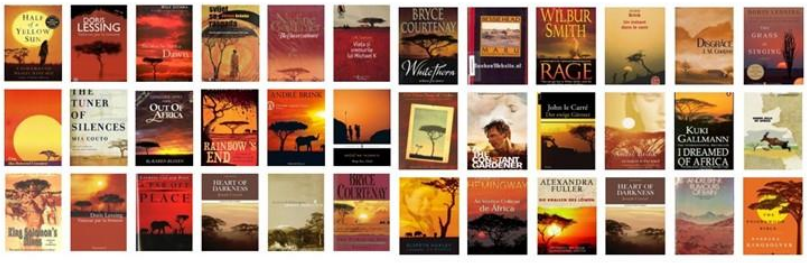
What does a restorative environment feel like?

movement, variability, periodicity, and stimuli for the five senses

Restorative landscapes rapidly evoke positive emotions and hold attention, displacing or restricting negative thoughts and allowing a reduction in arousal that had been heightened by stress.

Day 1−Design and environmental psychology



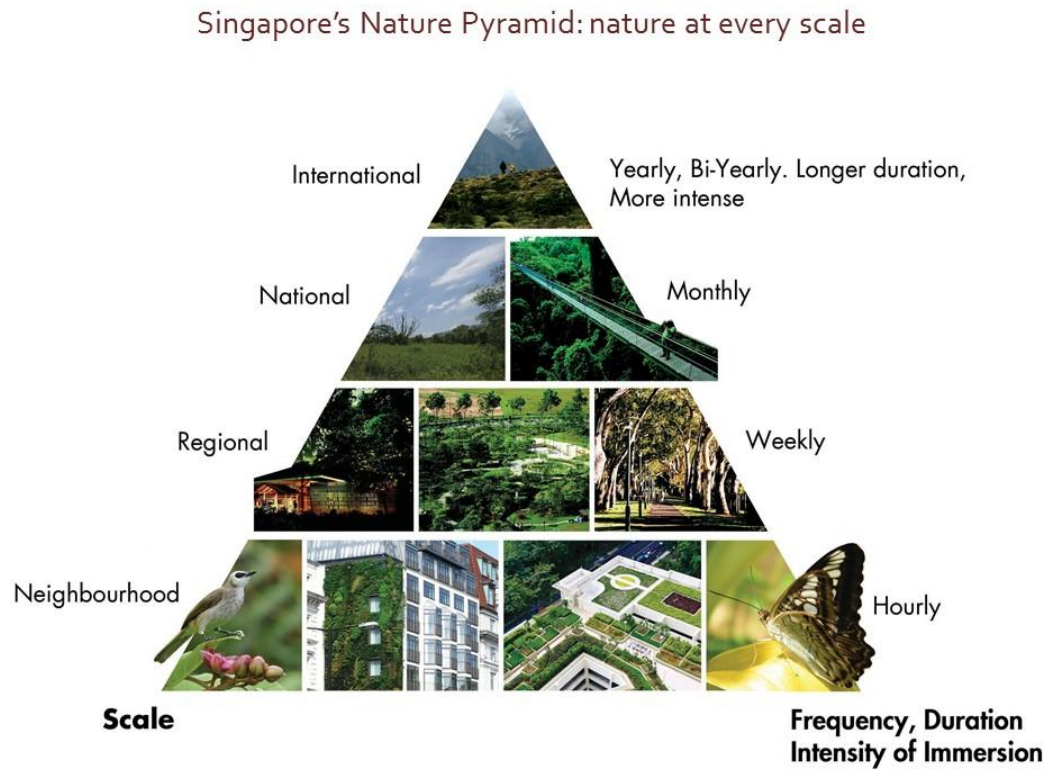


Why do we like what we like? Who says we like what we like?

Day 1−Design and environmental psychology

Natural Soundscapes

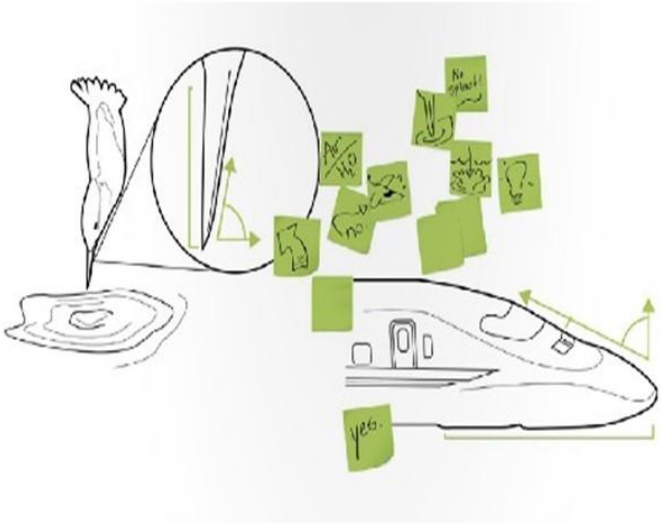
"The argument here is that the ambient sounds of an environment mimics a modern-day orchestra: the voice of each creature has its own frequency, amplitude, - mbre, and dura - on, and occupies a unique niche among the other musicians. This "animal orchestra" or biophony represents a unique sound grouping for any given biome and sends a clear acous- cal message". – Bernie Krause


Singapore's Nature Pyramid: nature at every scale
International
Yearly, Bi-Yearly. Longer duration, More intense
National
Monthly
Regional
Weekly
Neighbourhood
Hourly
Scale
Frequency, Duration
Intensity of Immersion


"Cultural evolution and the production of architecture co-evolve with the natural systems of the world: all the works of humans are "natural", and in making the artifacts of civilization over the last ten thousand years we have changed nature. The understanding of the natural world – the very conception of nature is culturally produced."
Michael Weinstock, *Hypernatural*

Day 1−Design and environmental psychology

HOK/Biomimicry Institute: Nature as mentor, model and measure



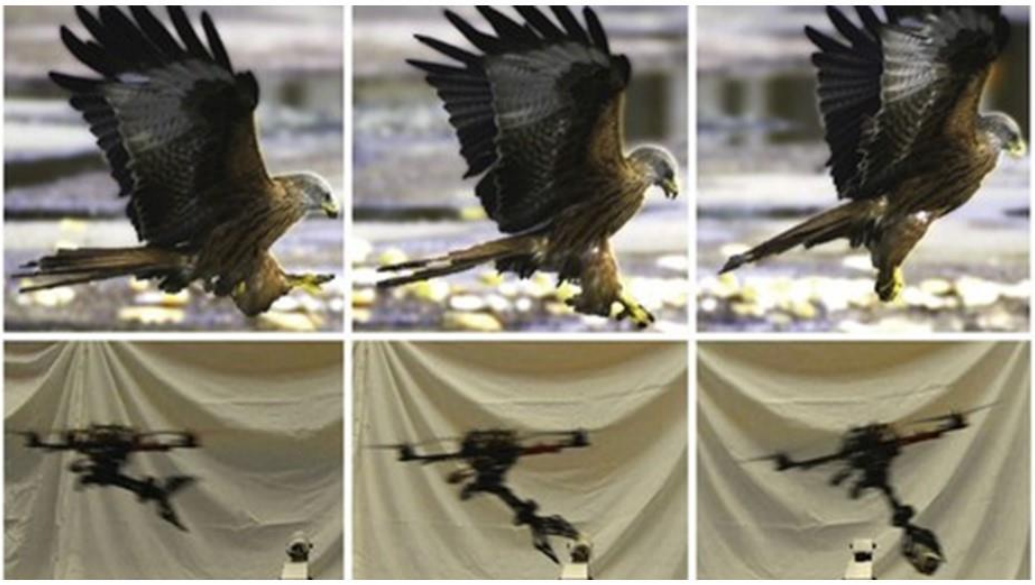
Recognizing that the fluid mechanics of a bird's bill in water and bullet train in air are similar

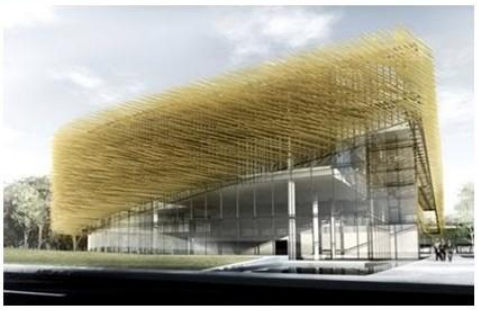
1. What is the function of the design?
2. In nature, whose survival depends on solving a similar problem?
3. Identify operating parameters of the biome:

-dimate conditions (wet, cold, hot, low/high pressure, high/low UV)
- Nutrient conditions (poor, rich)
- Social conditions (competitive, cooperative)
- Temporal conditions (dynamic, static, aging)

4. Through pattern recognition, emulate these relevant species-or biome-specific design principles for literal, abstracted or conceptual applications.

h8p://bit.ly/11W5h97





Day 1−Design and environmental psychology

Designing with nature and natural design cues

Specific populations, exposure considerations

Richard Mitchell, Yvonne Michael, Aaron Hipp

May 4

Estimating Greenspace Exposure & Benefits for Cumulative Risk Assessment Applications
Technical Working Group Meeting
May 4-5, 2015

U.S. Environmental Protection Agency
26 Martin Luther King Drive West, Cincinnati, OH 45220

1

Why specific populations?

- If access to nature is salutogenic (or pathogenic)
  - Potential to increase inequalities in health
  - Potential to decrease inequalities in health (equigenic)
- What would vary by population sub group?
  - Differential exposure or access
    - Environmental (in)justice determining proximity / quality
    - Culture / behaviour determining visits
    - Culture / behaviour determining activities and perceptions
  - Differential susceptibility
    - Particularly positive or adverse impacts
- Which populations should we care about and why?
  - Vulnerable groups, with particular health problems
  - Groups where we suspect social, cultural and environmental processes work very differently to the majority
  - We should never assume 'one size fits all' in our science. Often the exceptions are those which teach us most.

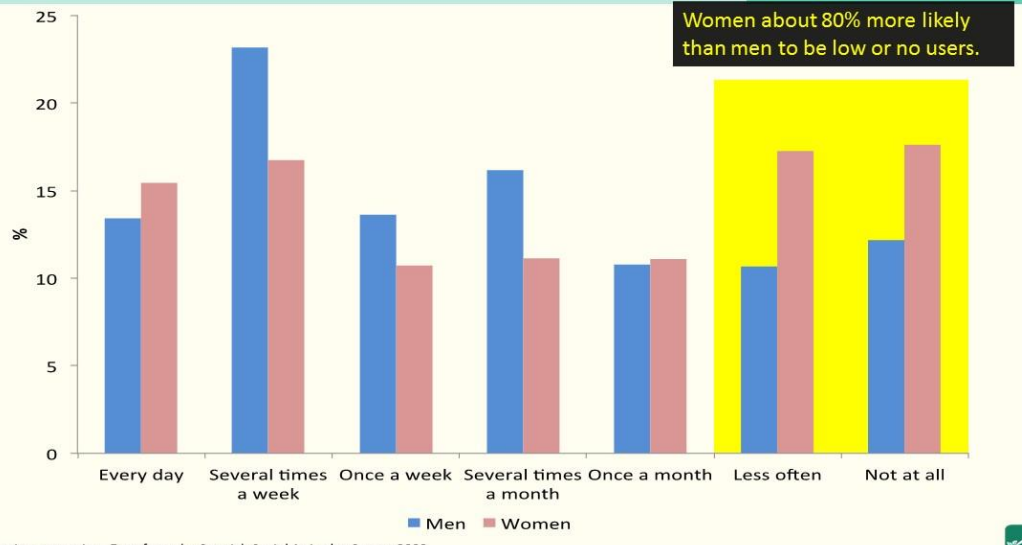
2

Gender

- It's unlikely that residential location for men and women is responsible for differential access to nature (residential segregation by sex is…rare)
- Yet, evidence suggests that women are less likely to access natural environments, where available, than men, particularly urban parks.
  - Some evidence that some aspects of quality are more important to women
- Evidence is mixed over whether women who *do* access green spaces use them in different ways or with different frequencies.
- Do we need to measure *exposure* differently for men and women?
  - Perhaps this is about being sensitive to different aspects of exposure; for example the proximity=exposure relationship may be very different from men and women, but once they are within a space, activity/interaction may be similar

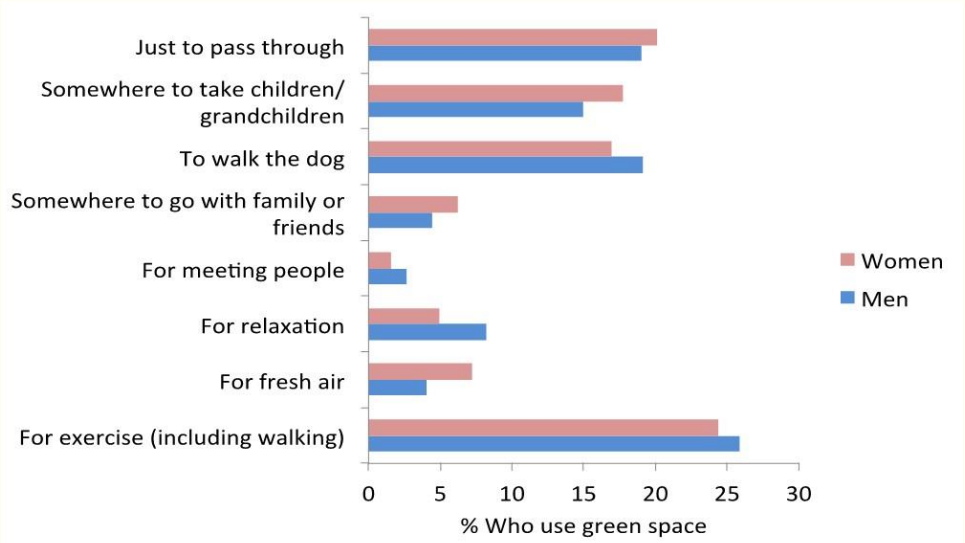
3

Who uses their green space? (data from Scotland n=c1000)



Mitchell R. Paper in preparation. Data from the Scottish Social Attitudes Survey 2009

Men and women who do use their green spaces, use them for similar things.

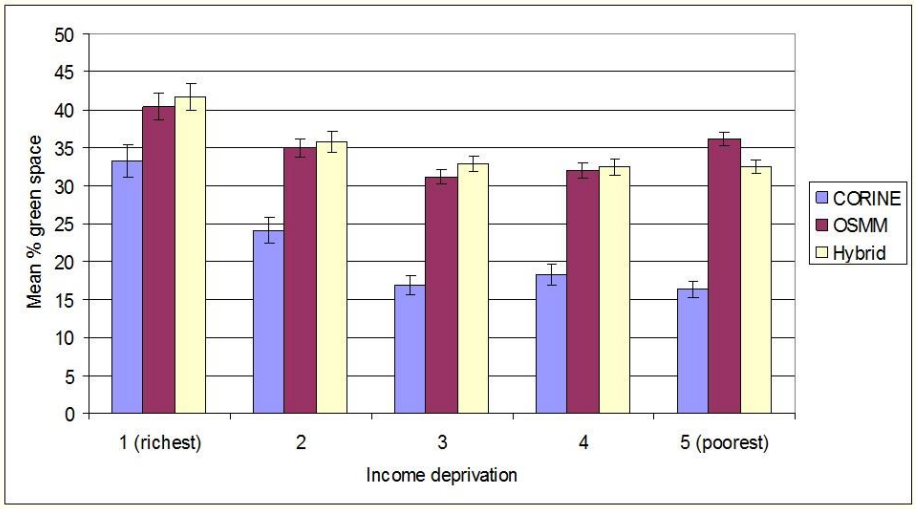


Socio-economic position / race

- Many studies looking at inequitable access to nature, where access is defined by proximity or landcover
- Dominated, numerically at least, by studies on race and nature from the USA. European and Australasian studies have tended to focus more on socio-economic position
- Typically use conventional measures of access / availability & then explore whether these vary by SEP / ethnic group (either at neighbourhood or individual level)
- Mixed results, but generally evidence for environmental injustice in terms of proximity & quality, some suggestion of differences in terms of biodiversity too
- Also evidence for lower levels of use among more deprived, vulnerable and non-white groups, even where green spaces are available
- Evidence that spaces are perceived differently (as being for white or dominant groups for example)
- Do we need to measure *exposure* differently for these groups?
  - Again, questions the 'proximity=exposure' relationship
  - We must better understand that proximity/exposure relationship!

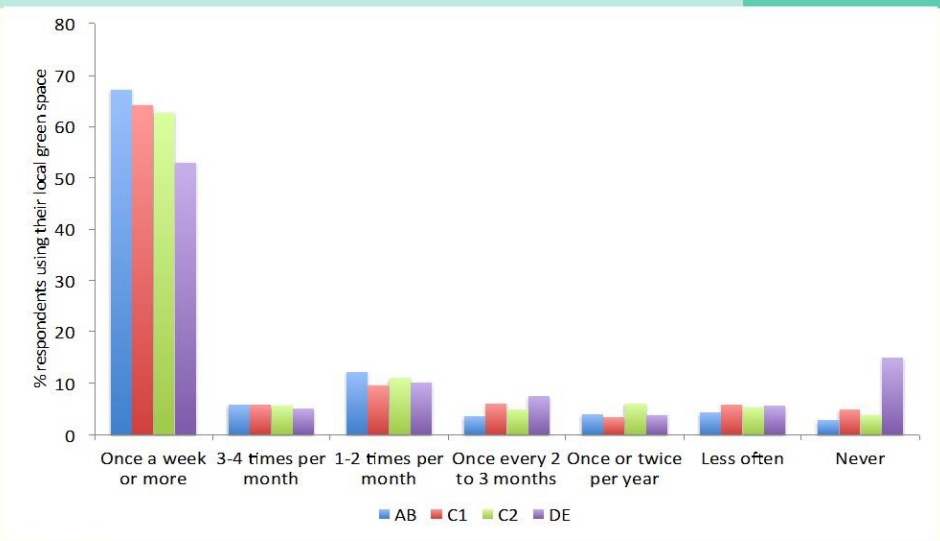
6

Socio-economic differences in 'access'



7

Who uses their green space?



Source: K Ord, PhD thesis 2014. *n*=1516

Does inequality in use of green space reduce when it is readily available?

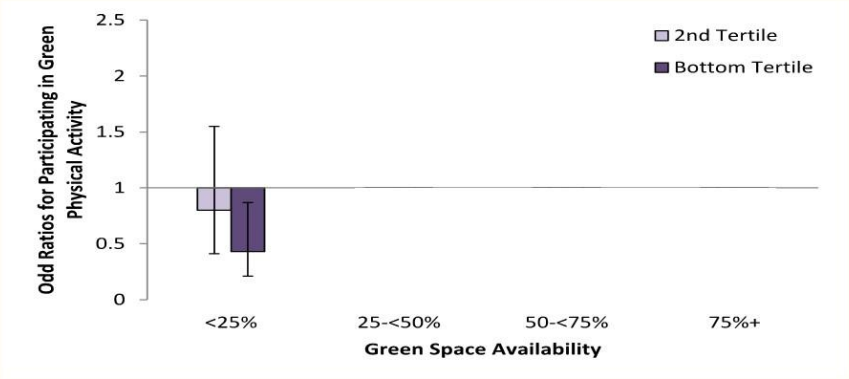


Figure 7.12 Income related inequality in participating in green physical activity by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1209). The interaction effect did not reach significance (x2 = 6.76, P = 0.3437) [1] adjusted for age, sex and income

Source: K Ord, PhD thesis 2014

Does inequality in use of green space reduce when it is readily available?

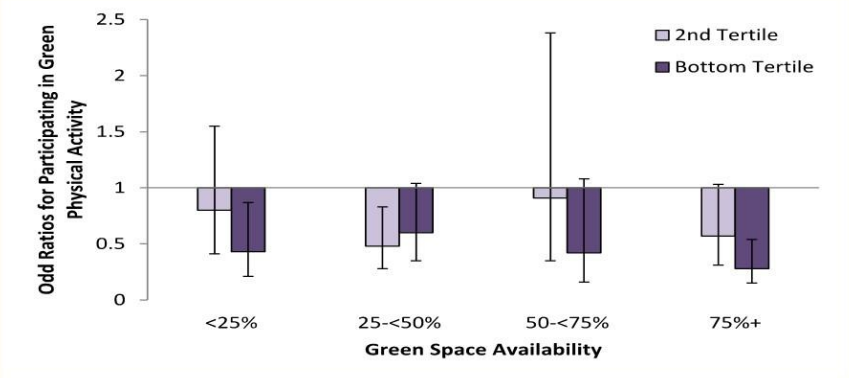
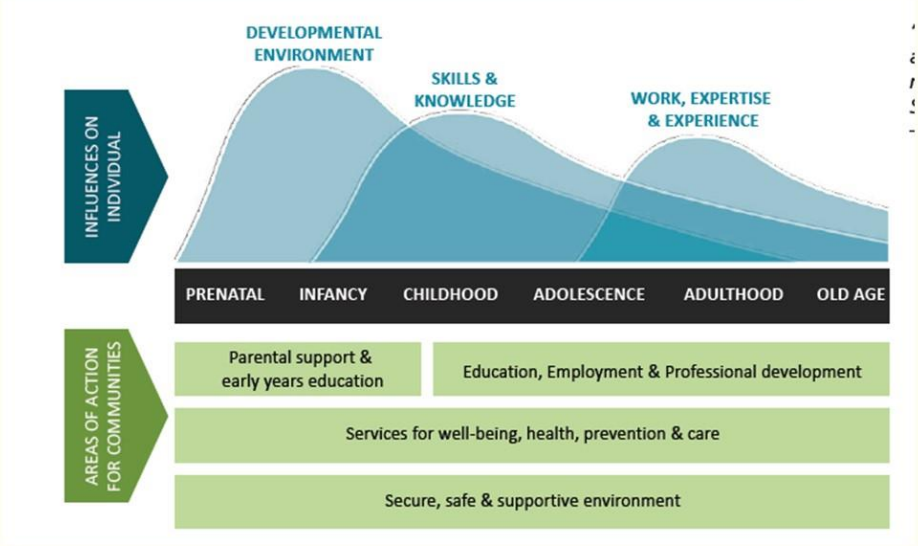


Figure 7.12 Income related inequality in participating in green physical activity by green space availability. Odds ratios given relative to the reference group (Top Income Tertile, Odds Ratio = 1.00) and bars indicate 95% confidence interval (n=1209). The interaction effect did not reach significance (x2 = 6.76, P = 0.3437) [1] adjusted for age, sex and income

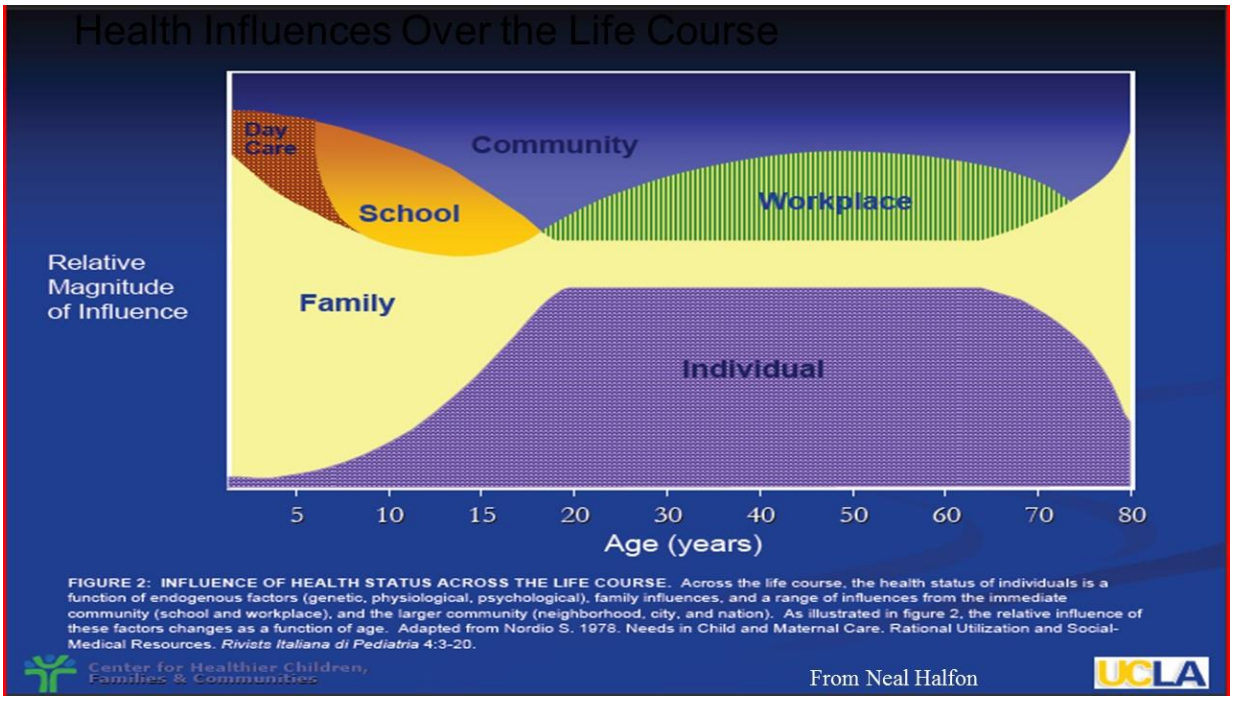
Source: K Ord, PhD thesis 2014

Life Course Approach



Influences and Actions along the Life Course. Model developed as part of the Fair Society, Healthy Lives report (2011)

11



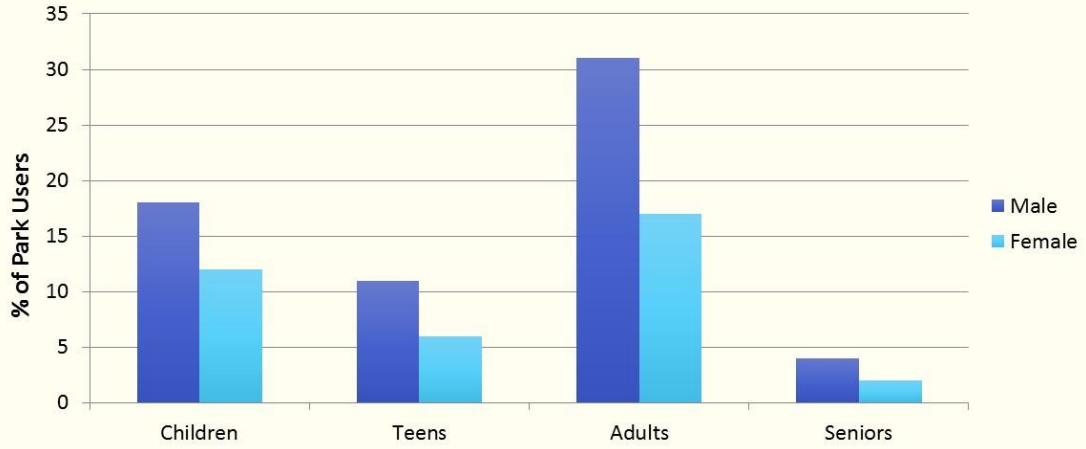
Age Cohort and Green space

- Differential exposure/access
  - Children's independent mobility to local urban green space is limited by distance to closest park, perceived safety, and parenting social norms
  - Mobility limitations may keep older adults homebound, with limited access to green space
  - Older adults and teens less frequent users of green space
- Differential susceptibility
  - Allergic sensitization may vary by age
  - Risk of chronic conditions and co-existing geriatric impairments increase with age

Christian et al, Journal of Physical Activity & Health, 2015; Rosso et al, Journal of Aging Research 2011

13

Relative to other age groups, seniors and teens use parks less

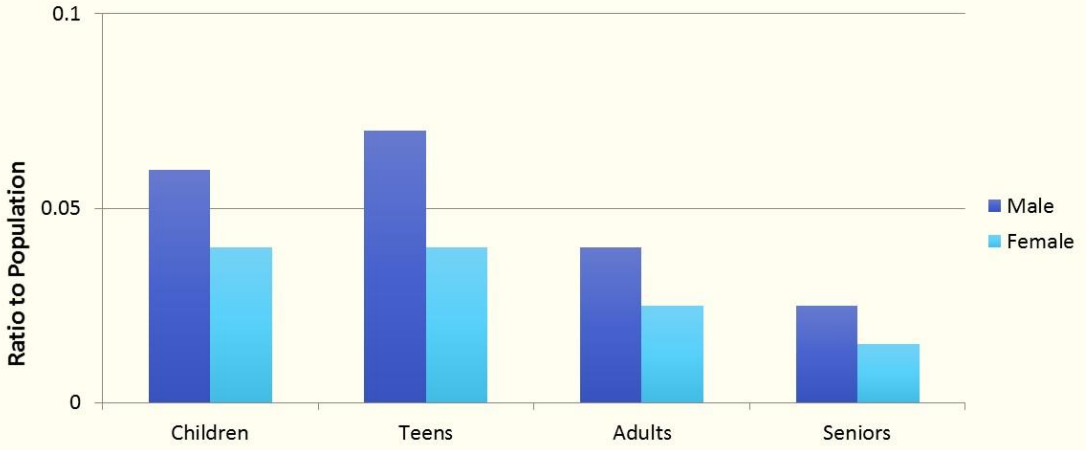


Park Users by Age Group and Gender

Cohen DA, et al, 2006

14

Relative to their numbers in 1-mi radius, children/teens use parks more



Ratio of Park Users to Local Population in a 1-mile Radius

Cohen DA, et al, 2006

15

Some general weaknesses

- We know very little about how / whether susceptibility to the benefits (harms) of contact with nature varies by population sub-group (more on this tomorrow)
- This is because few experimental studies are designed to explore these differences
- The conventional measures of exposure – particularly those based on proximity to green spaces or distance, rarely include measures of actual visits!
  - Yet, to work at a population level (i.e. millions of people), we need those conventional measures.
- We know that some groups live further from, or appear to have worse access to, natural spaces, but we tend not to know how this affects their use of those spaces.

16

Discussion Questions

- Do we need to measure *exposure* differently for specific populations, e.g., by gender, SEP/race, age?
  - Does relevant type of exposure vary by group?
  - Is duration or frequency different?
  - Is exposure pathway different?
- How do we incorporate a life course perspective into our exposure assessment?

17


Why do these effects occur?

Day 1−Specific populations, exposure considerations

Experimental evidence: field

Park B, Tsunetsugu Y, Kasetani T, Kagawa T, Miyazaki Y. The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. Environmental Health and Preventive Medicine 2010; 15(1):18-26.

Experimental evidence: field

(c) Walking in the City Area

(d) Watching the Landscape in the City Area

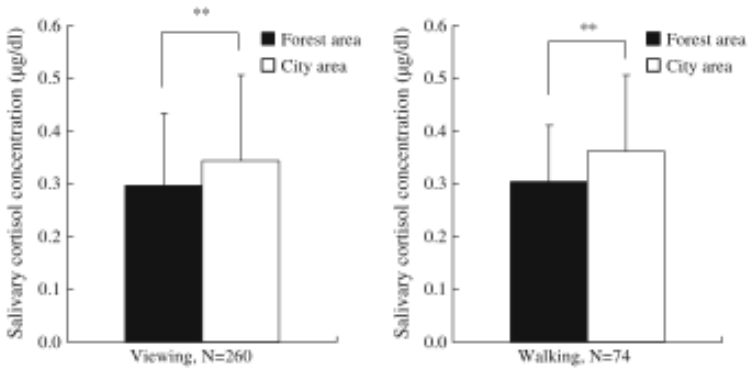
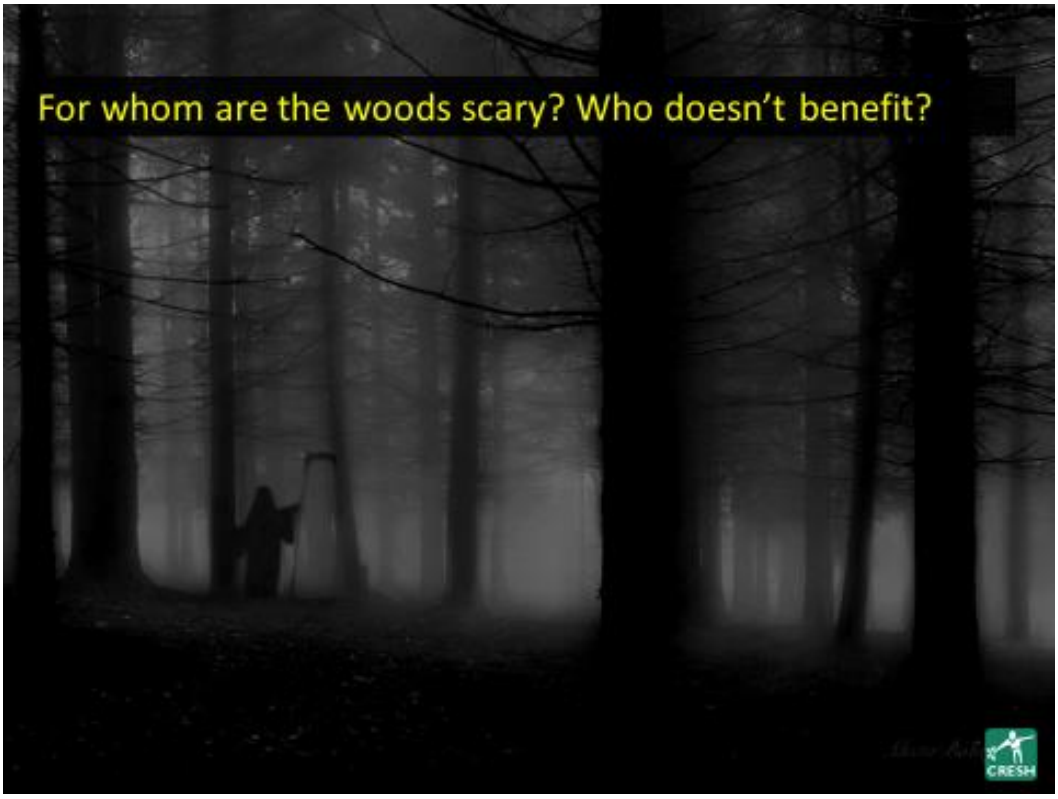


Fig. 2 Change in salivary cortisol concentration after forest viewing and walking. Mean ± standard deviation (SD); ** $p < 0.01$; p-value by t test

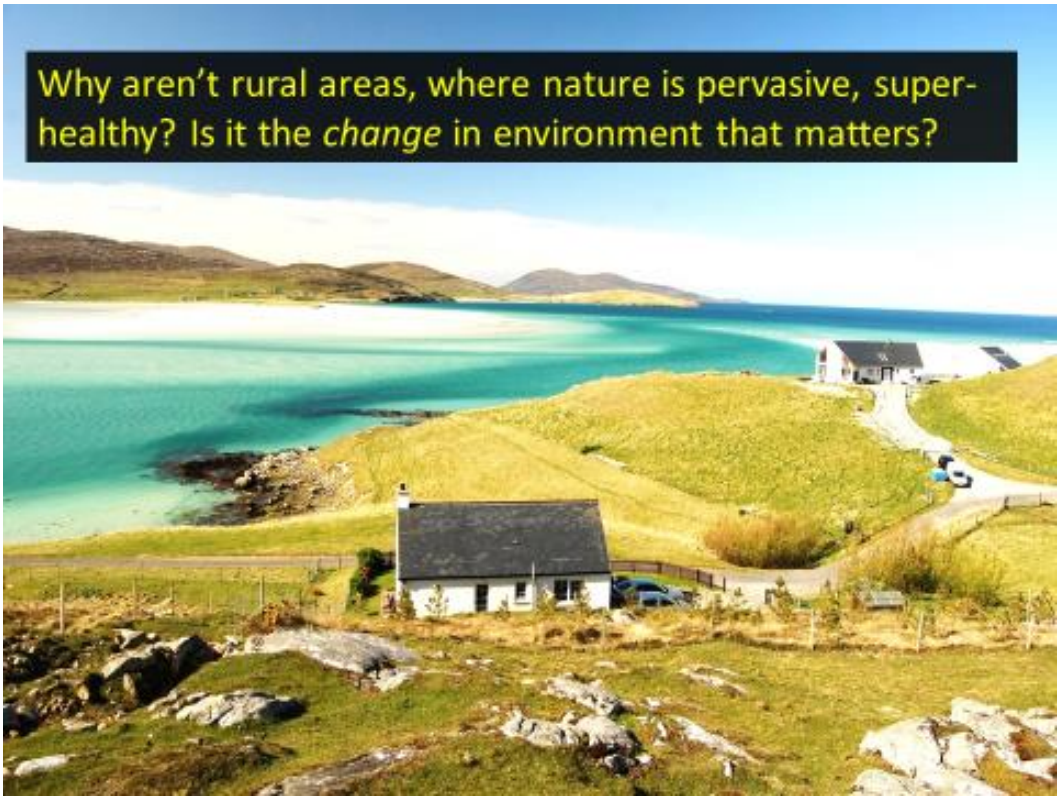
Environ Health Prev Med (2010) 15:18–26

Day 1−Specific populations, exposure considerations

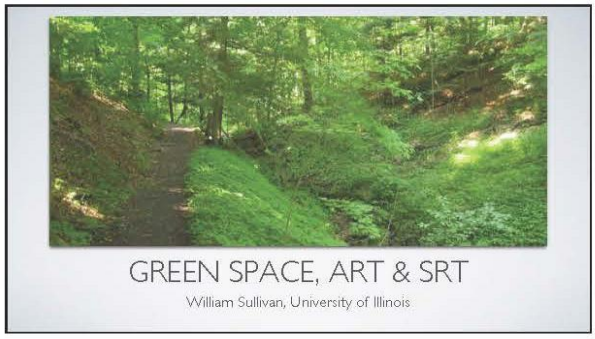
Day 1−Specific populations, exposure considerations

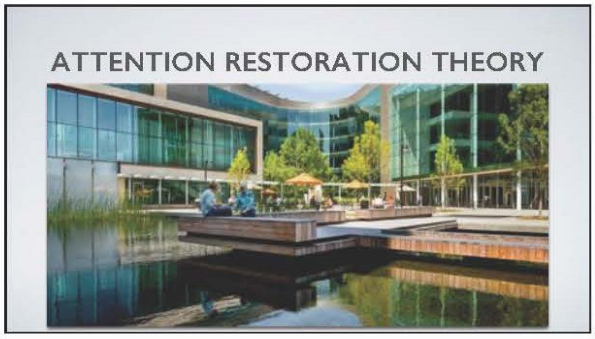


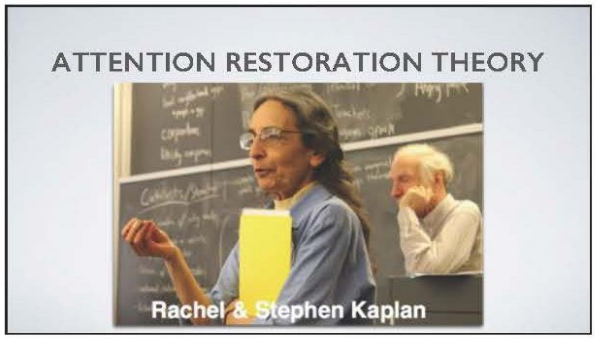
Day 1−Specific populations, exposure considerations



Day 1−Exposure metrics, links to health *(Attention restoration example)*







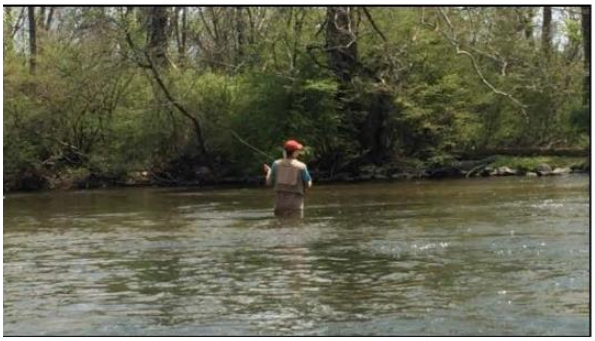
Day 1−Exposure metrics, links to health *(Attention restoration example)*

ATTENTION RESTORATION THEORY

Attention	Effort
Involuntary	
Directed (Paying Attention)	

ATTENTION RESTORATION THEORY

Attention	Effort
Involuntary	No
Directed (Paying Attention)	



ATTENTION RESTORATION THEORY

Attention	Effort
Involuntary	No
Directed (Paying Attention)	Yes

Day 1−Exposure metrics, links to health *(Attention restoration example)*

ATTENTION RESTORATION THEORY

Attention	Effort	Fatigue
Involuntary	No	
Directed (Paying Attention)	Yes	

ATTENTION RESTORATION THEORY

Attention	Effort	Fatigue
Involuntary	No	No
Directed (Paying Attention)	Yes	

ATTENTION RESTORATION THEORY

Attention	Effort	Fatigue
Involuntary	No	No
Directed (Paying Attention)	Yes	Yes

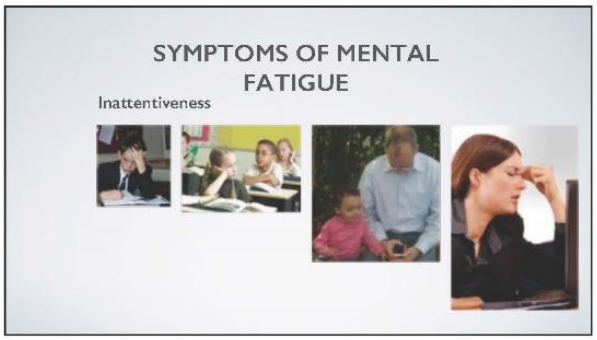
ATTENTION FATIGUES

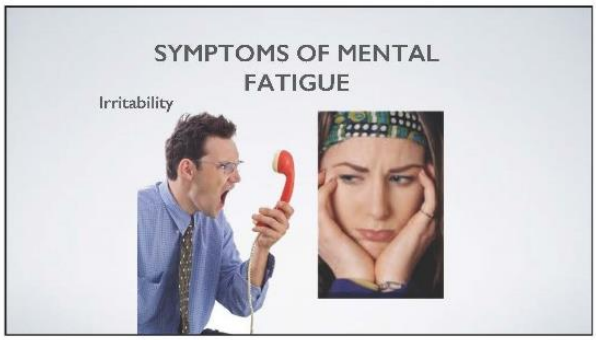
PAYING ATTENTION

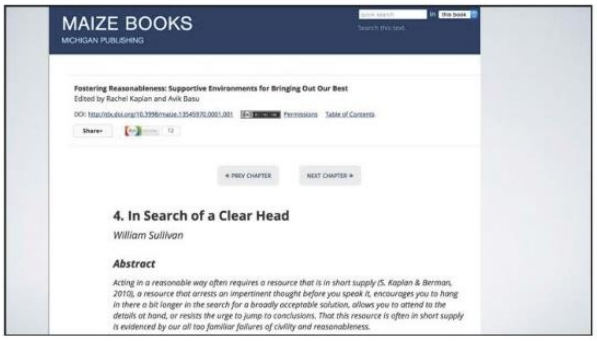
Matters for everything we care about

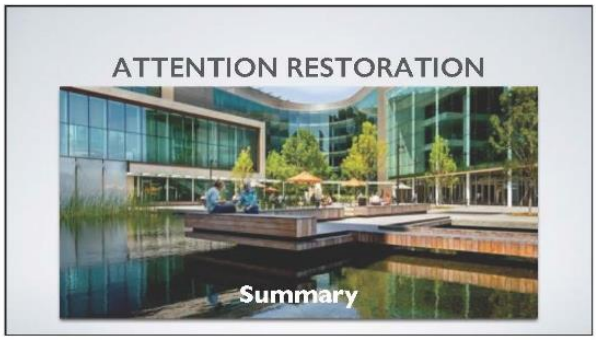
- Learning
- Problem solving
- Planning, initiating & carrying out tasks
- Self monitoring & self regulation
- Effective social functioning

Day 1−Exposure metrics, links to health *(Attention restoration example)*

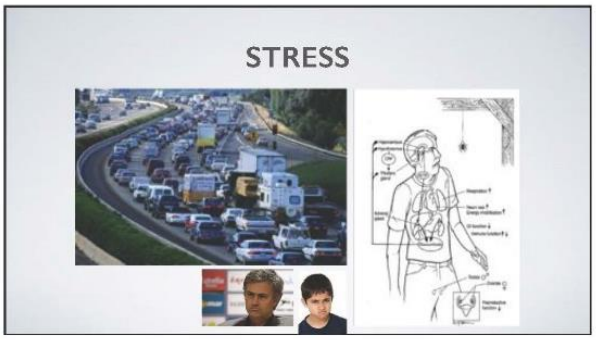


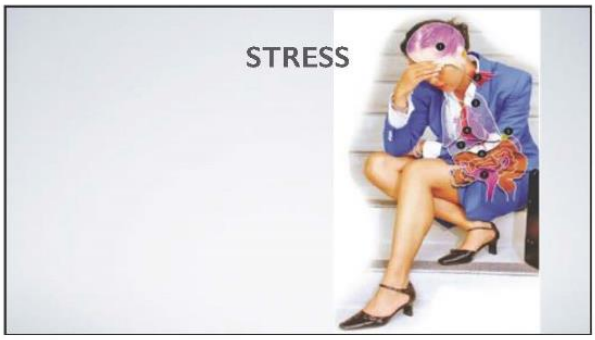


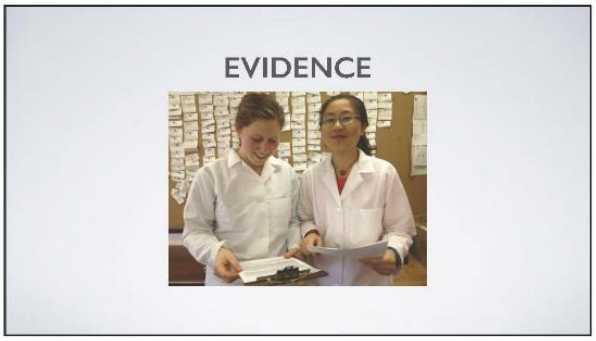




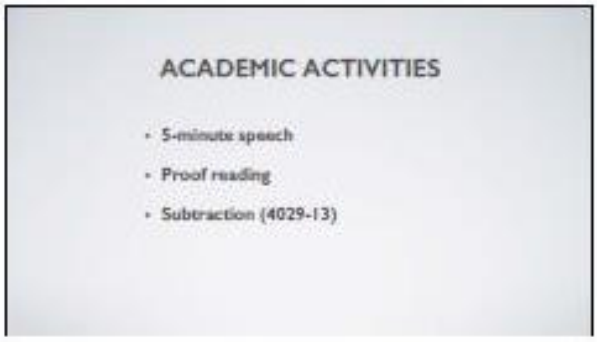
Day 1−Exposure metrics, links to health *(Attention restoration example)*

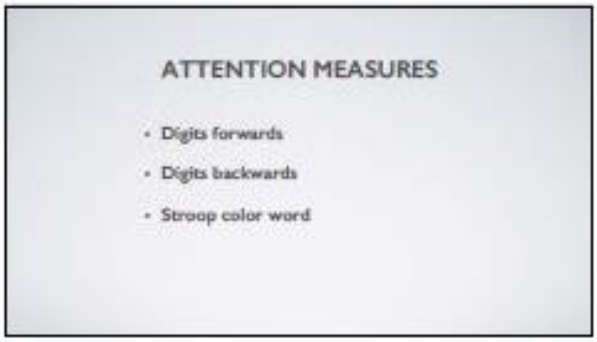




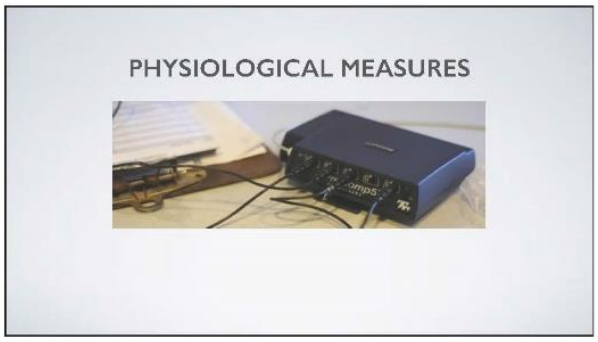


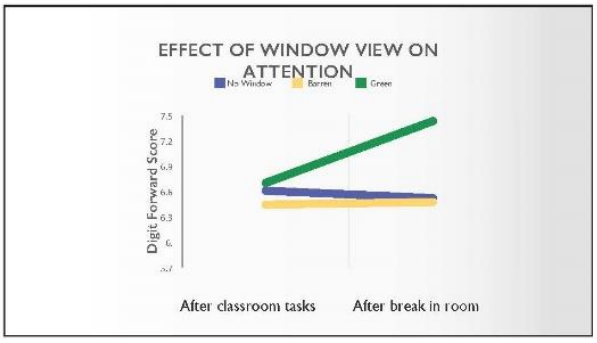
Day 1−Exposure metrics, links to health *(Attention restoration example)*

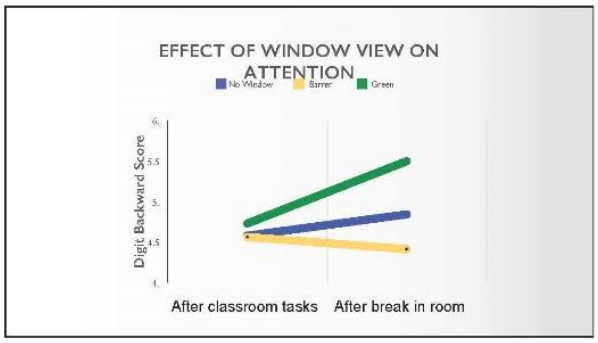


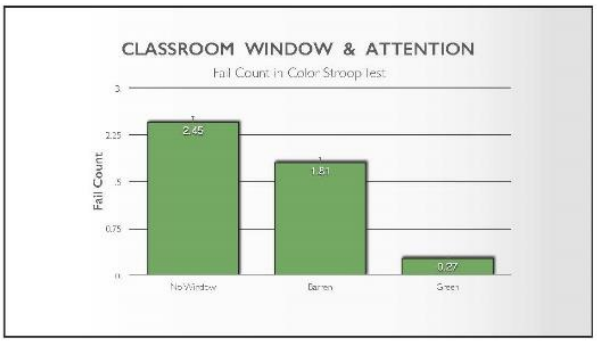


Day 1−Exposure metrics, links to health *(Attention restoration example)*

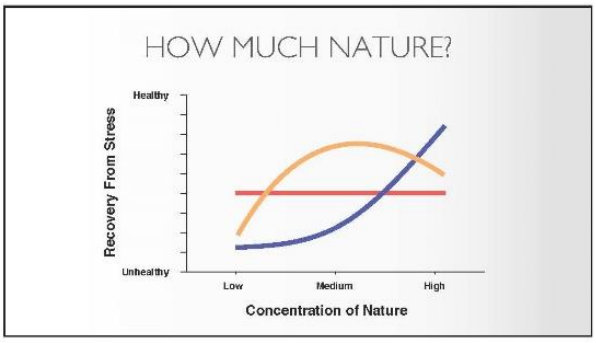


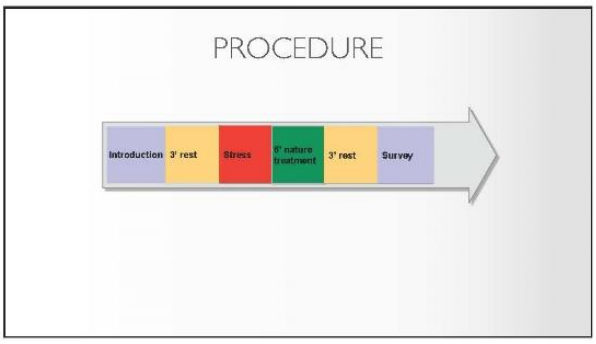




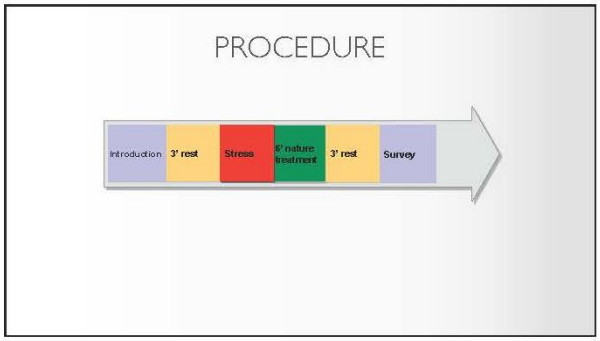


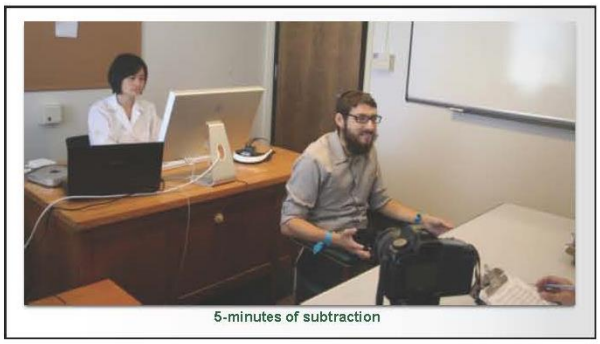
Day 1−Exposure metrics, links to health *(Attention restoration example)*

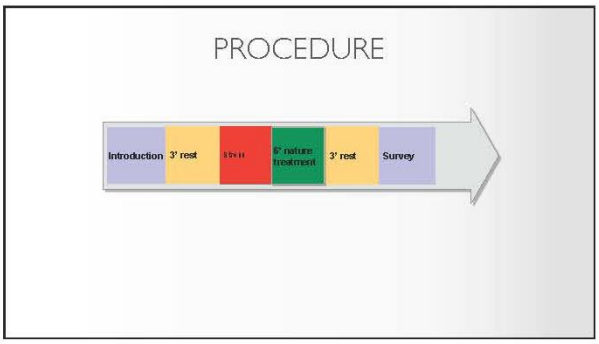




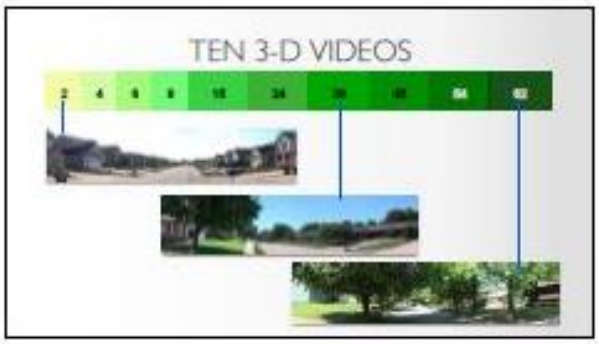
Day 1−Exposure metrics, links to health *(Attention restoration example)*



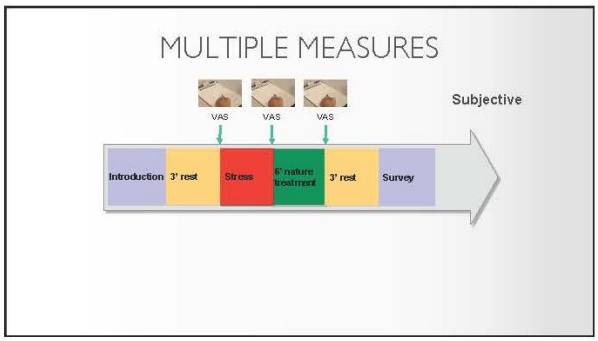


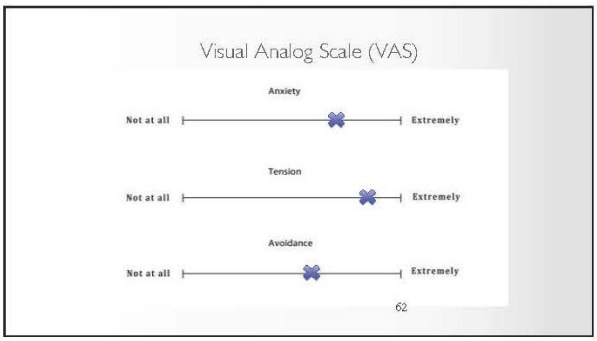


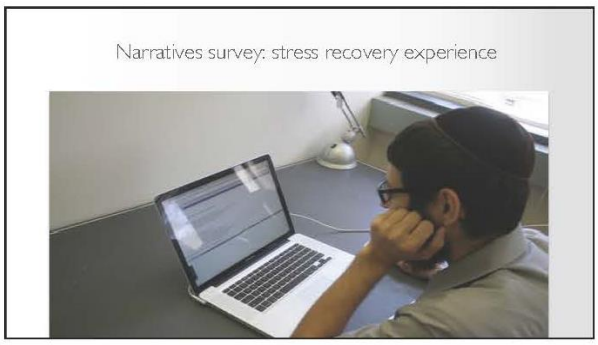
Day 1−Exposure metrics, links to health *(Attention restoration example)*

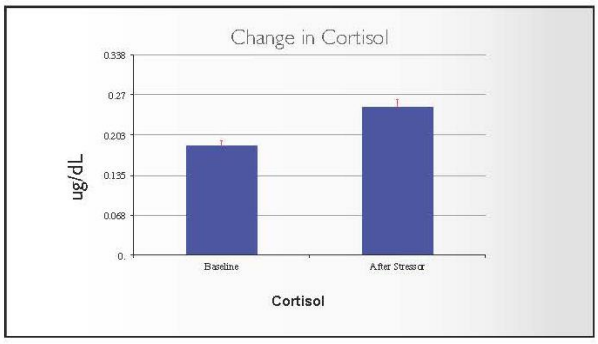


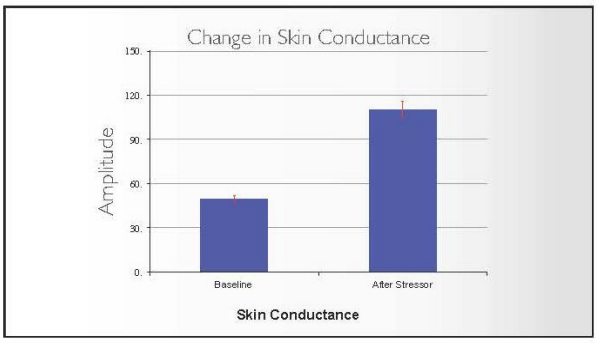
Day 1−Exposure metrics, links to health *(Attention restoration example)*



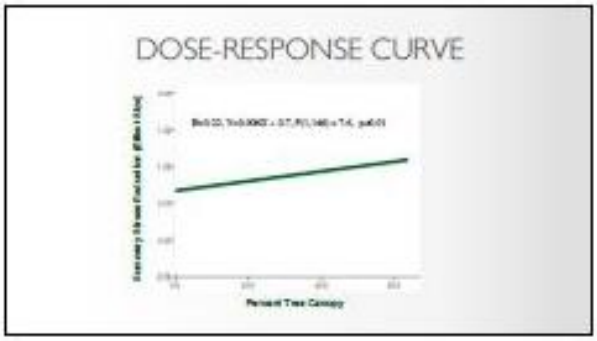


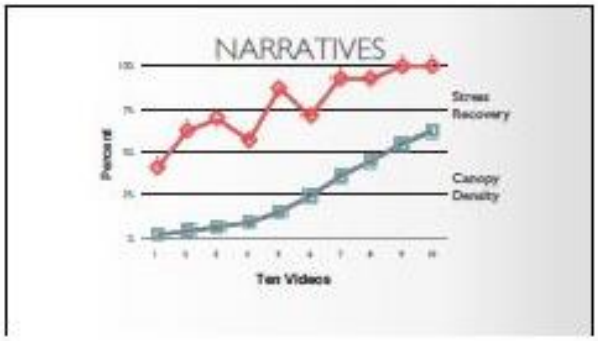






Day 1−Exposure metrics, links to health *(Attention restoration example)*





Day 1−Exposure metrics, links to health *(Attention restoration example)*