Ecosystem Services of Landscape Plants: A Guide for Green Industry Professionals

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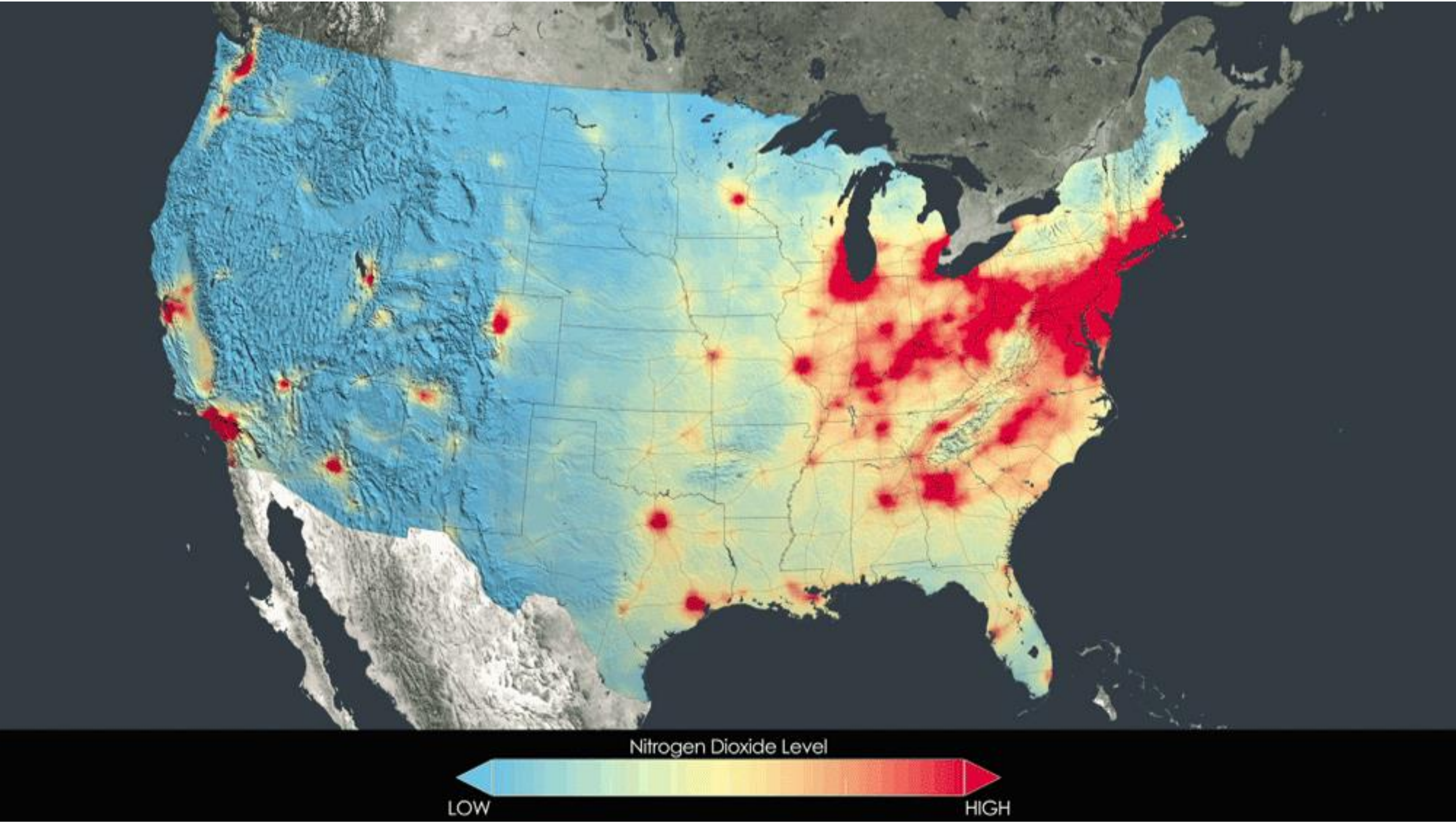
What are Ecosystem Services

- ecosystem services = benefits provided to human from ecosystems.
- Landscapes / built environment primarily concerned with "regulating" (7) and "cultural" (1) services provided by plants in landscape.

Regulating services (7)

1. Air Quality
2. Human Health
3. Biodiversity Potential / Wildlife Habitat
4. Carbon Sequestration
5. Energy Conservation and Microclimate Regulation
6. Noise Reduction
7. Stormwater management

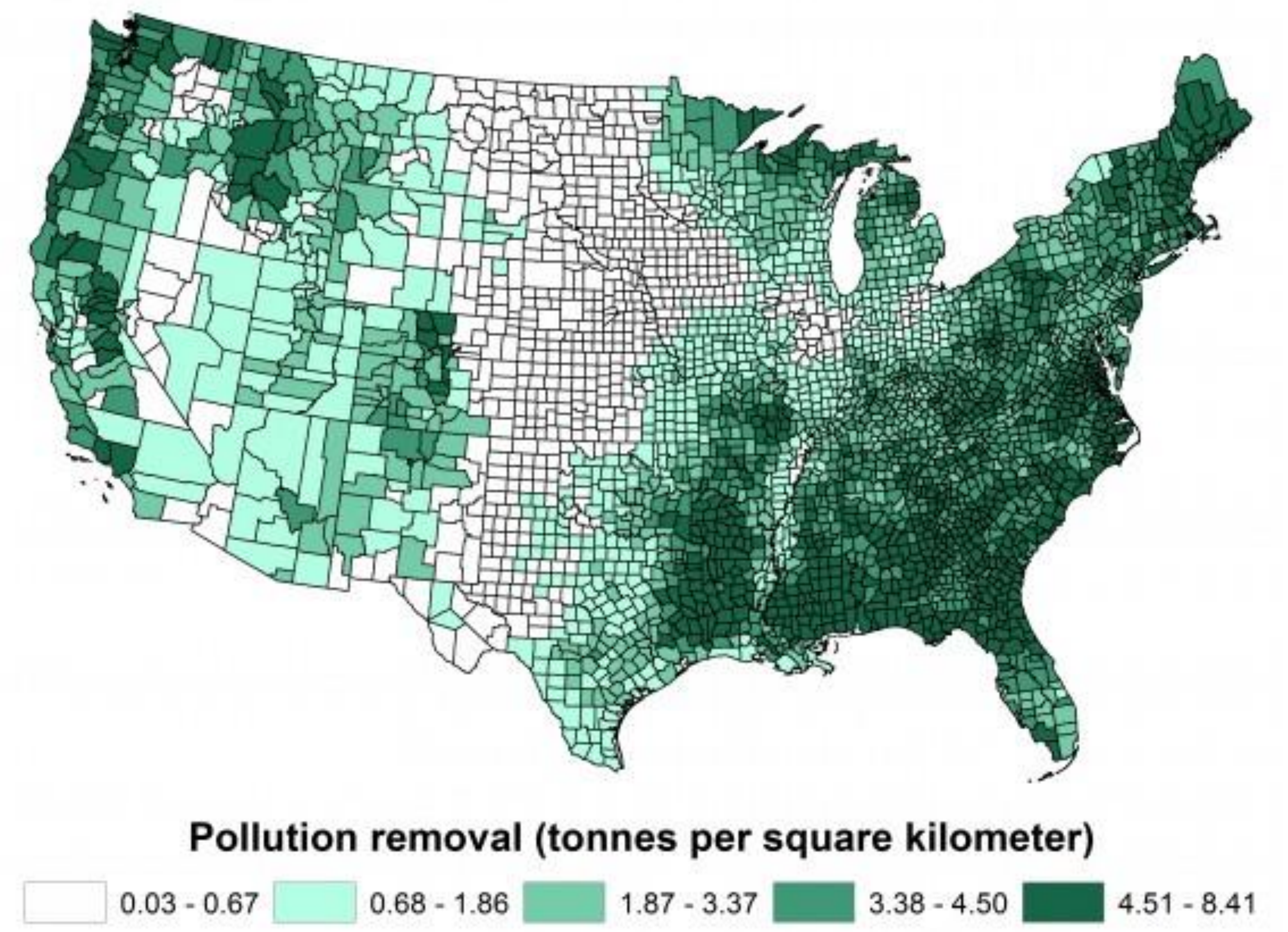
Air Quality (1/7)


Nitrogen Dioxide Level
LOW
HIGH

NOx pollution, yearly averages from 2005-2011

Image Credit: NASA

Estimated removal of air pollutants for each US county in 2010


Pollution removal (tonnes per square kilometer)
0.03 - 0.67
0.68 - 1.86
1.87 - 3.37
3.38 - 4.50
4.51 - 8.41

“**Trees in urban areas are substantially more important than rural trees** due to their proximity to people. The **greatest monetary values** are derived in areas with the greatest population density”

Source: US Forest Service

Carbon Monoxide (CO)

product of fuel combustion

Sulfur and Nitrogen Oxides (CO_x, NO_x)

products of fuel combustion

sulfur = industrial facilities

nitrogen = transportation, off-road equipment

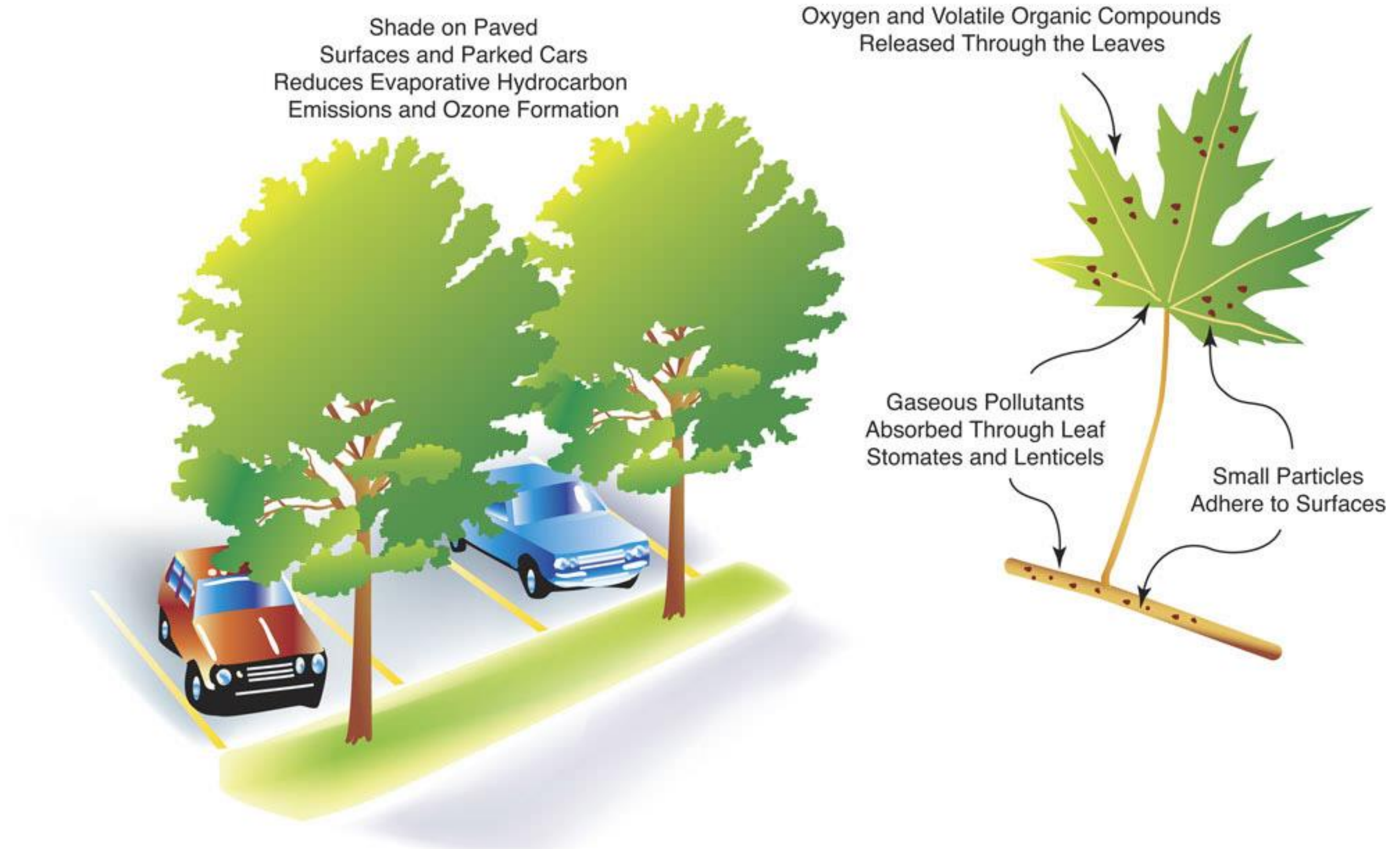
*100% increased concentrations within 175’ of roadways

Ozone (O_3)

from reaction of sunlight and products of fuel combustion (CO, CO_x, NO_x)

PM10 (Particulate Matter, diameter < 10 µm)

soot, smoke, & CO_x / NO_x reacting with atmosphere


Shade on Paved Surfaces and Parked Cars Reduces Evaporative Hydrocarbon Emissions and Ozone Formation
Oxygen and Volatile Organic Compounds Released Through the Leaves
Gaseous Pollutants Absorbed Through Leaf Stomates and Lenticels
Small Particles Adhere to Surfaces

Source: International Society of Arboriculture

Human Health (2/7)

Stress reduction
Reduced blood pressure
Reduced cortisol levels
Reduced headaches
Reduced mortality rates from circulator disease
Faster healing
Addiction recovery
Perceived health/well-being
Increased self-esteem
Improved mood
Reduced anger/frustration
Psychological well-being
Reduced anxiety
Improved behavior
Attentional restoration
Reduced mental fatigue
Improved academic performance
Education/learning opportunities
Improved ability to perform tasks
Improved cognitive function in children
Facilitated social interaction
Enables social empowerment
Reduced crime rates
Reduced violence
Enabled interracial interaction
Social cohesion
Social support

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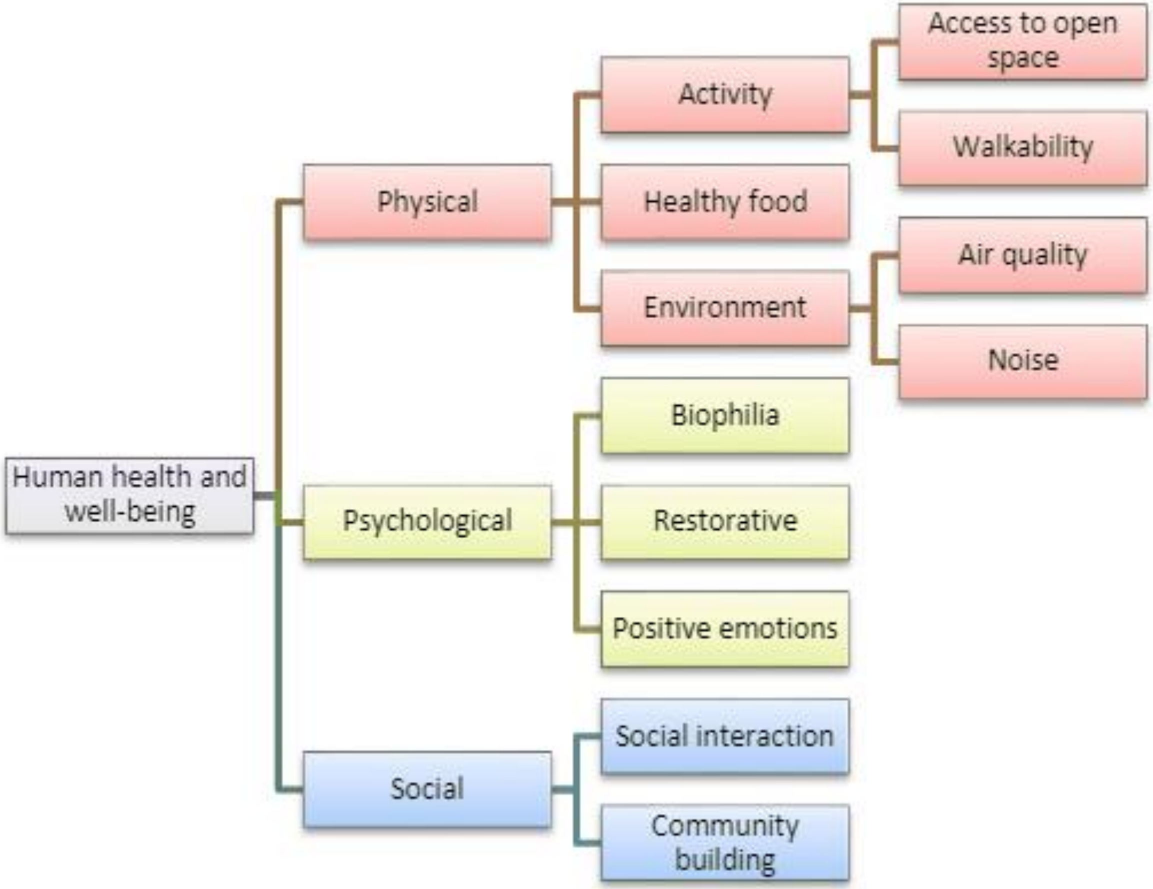
Social support

Physical

Mental

Social

Summary of human health and well-being benefits of Green Infrastructure


Human health and well-being

Physical

Activity

Access to open space

Walkability

Healthy food

Environment

Air quality

Noise

Psychological

Biophilia

Restorative

Positive emotions

Social

Social interaction

Community building

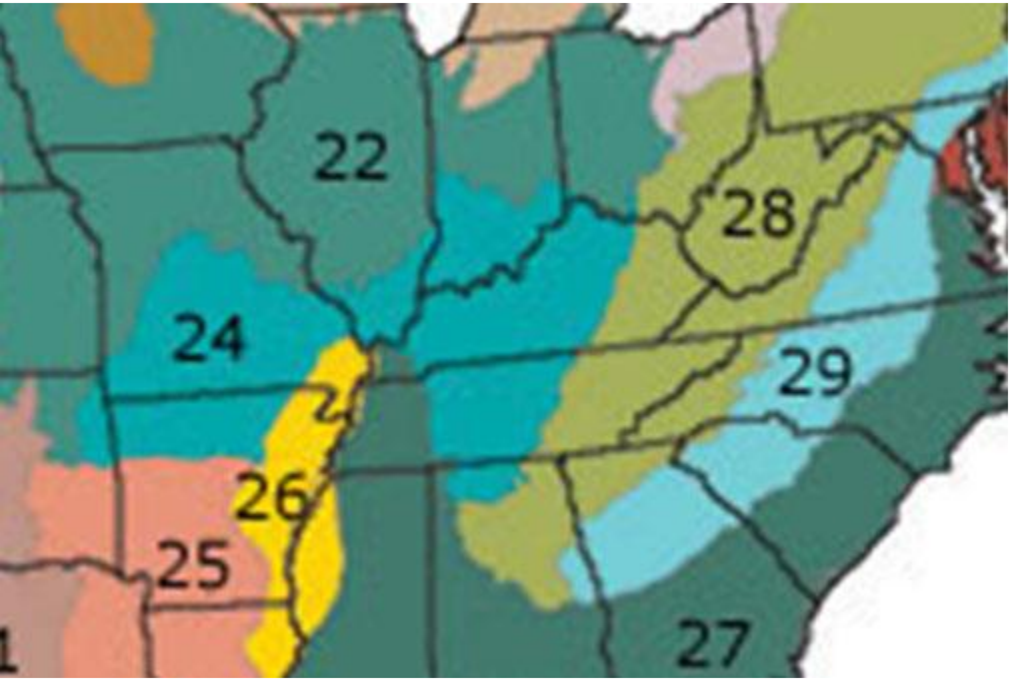
Source: M. Ely and S. Pitman 2014

Wildlife Habitat (3/7)

- Native plants support native insects.
- Native insects support larger native wildlife, including songbirds.

Kentucky warbler

Photo: Brian E. Small/Vireo



Source: American Bird Conservancy
abcbirds.org

- More than 150 species of songbirds regularly occur in Kentucky, 50 of these are winter residents or "transient" species.
- Kentucky sits within 4 bird conservation regions (BCR)

Appalachian Mountains (Eastern KY)

Central Hardwoods

Southeastern Coastal Plain (Western KY)

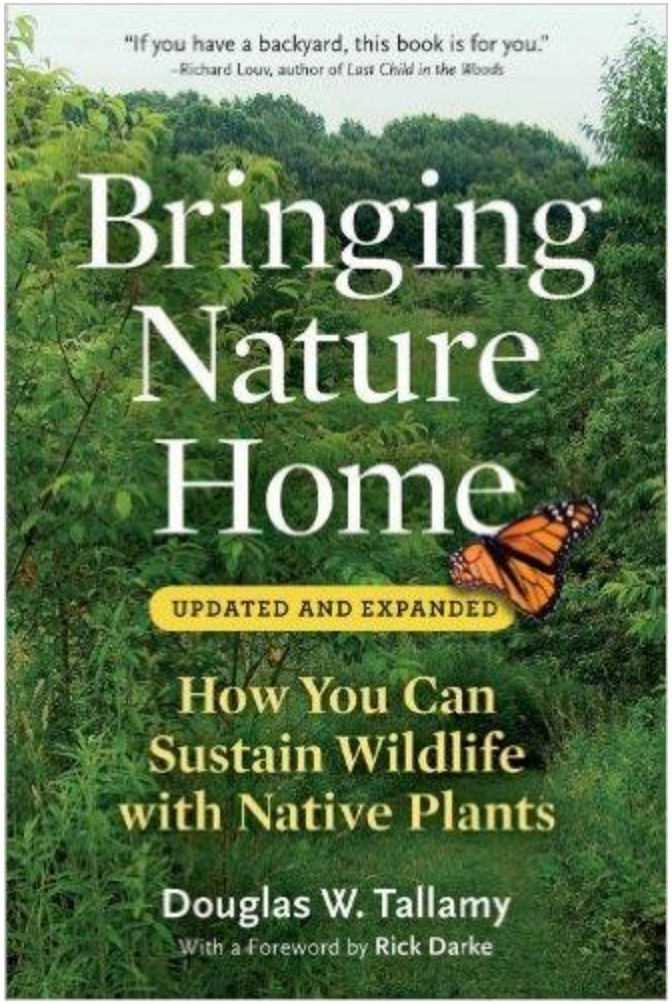
Mississippi Alluvial Valley (Far Western KY)

Strategy #1

“Diversity attracts diversity”

- Use plants of different heights to create habitats and food sources at several heights
  - ☐tall/meadow grasses
  - ☐shrubs
  - ☐midstory
  - ☐canopy

Different bird species nest and eat at different heights.


"If you have a backyard, this book is for you."
–Richard Louv, author of Last Child in the Woods
Bringing Nature Home
UPDATED AND EXPANDED
How You Can Sustain Wildlife with Native Plants
Douglas W. Tallamy
With a Foreword by Rick Darke

Strategy #2

Plant for all seasons:
provide food all year round for wildlife

- **Spring – insect-attracting blooms**
  - ☐ Common, Speckled or Brookside Alder
  - ☐ Highbush Blueberry

- **Summer – Sugar filled fruits**
  - ☐ Highbush Blueberry
  - ☐ Serviceberry
  - ☐ Common Elderberry

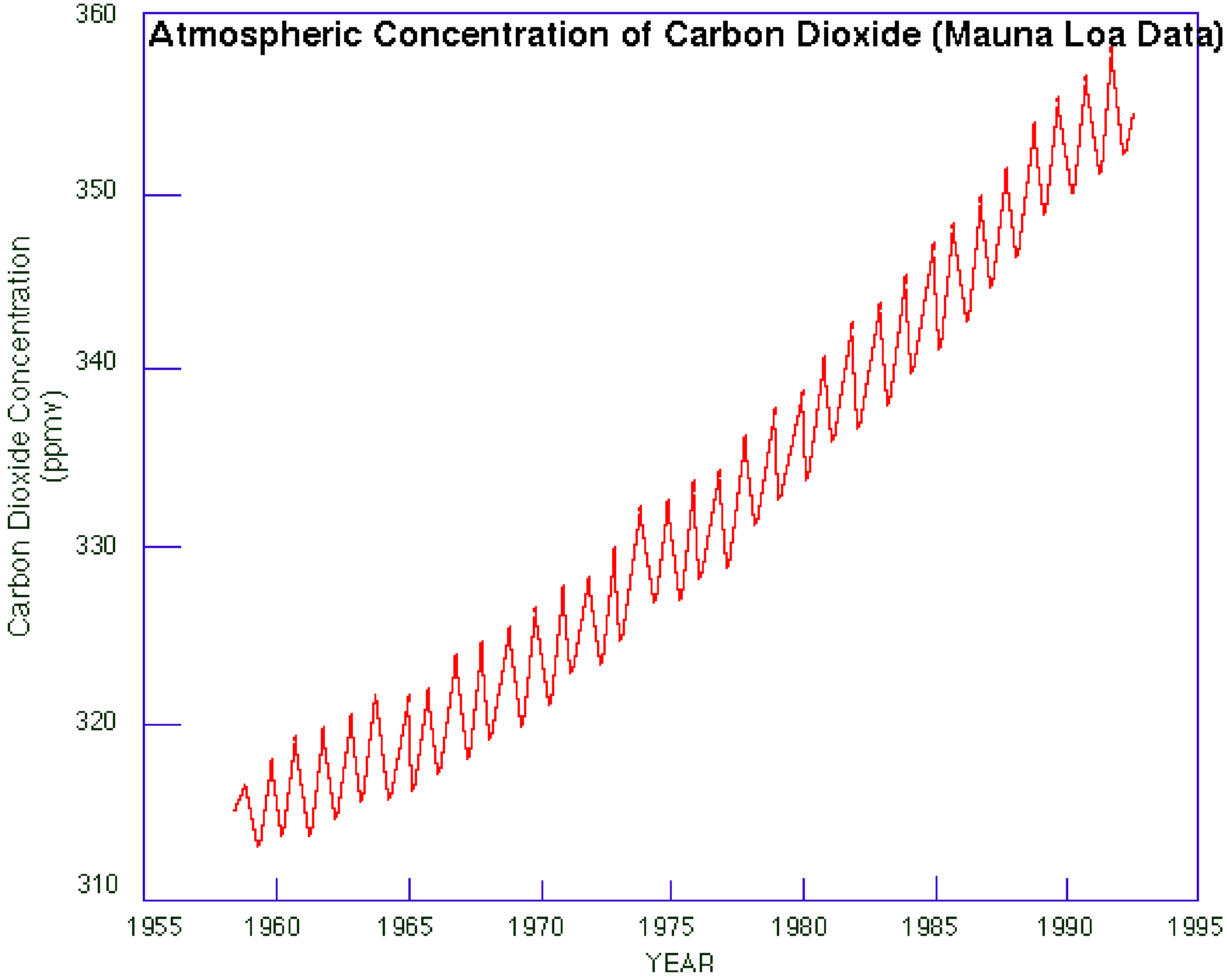
Fall – Fat-heavy fruits to fuel long-distance autumnal flights

- ☐ Flowering Dogwood
- ☐ Pagoda Dogwood
- ☐ Silky Dogwood (shrub)
- ☐ Gray-stem Dogwood (shrub)
- ☐ Spicebush

Winter – Tough fruits that withstand harsh weather

- ☐ American Holly
- ☐ Winterberry Holly
- ☐ Inkberry Holly
- ☐ Eastern Red Cedar
- ☐ Winged, Staghorn or Smooth Sumac
- ☐ Arrowwood Viburnum

Carbon Sequestration (4/7)



Graph Source: University of Wyoming, Atmospheric Sciences

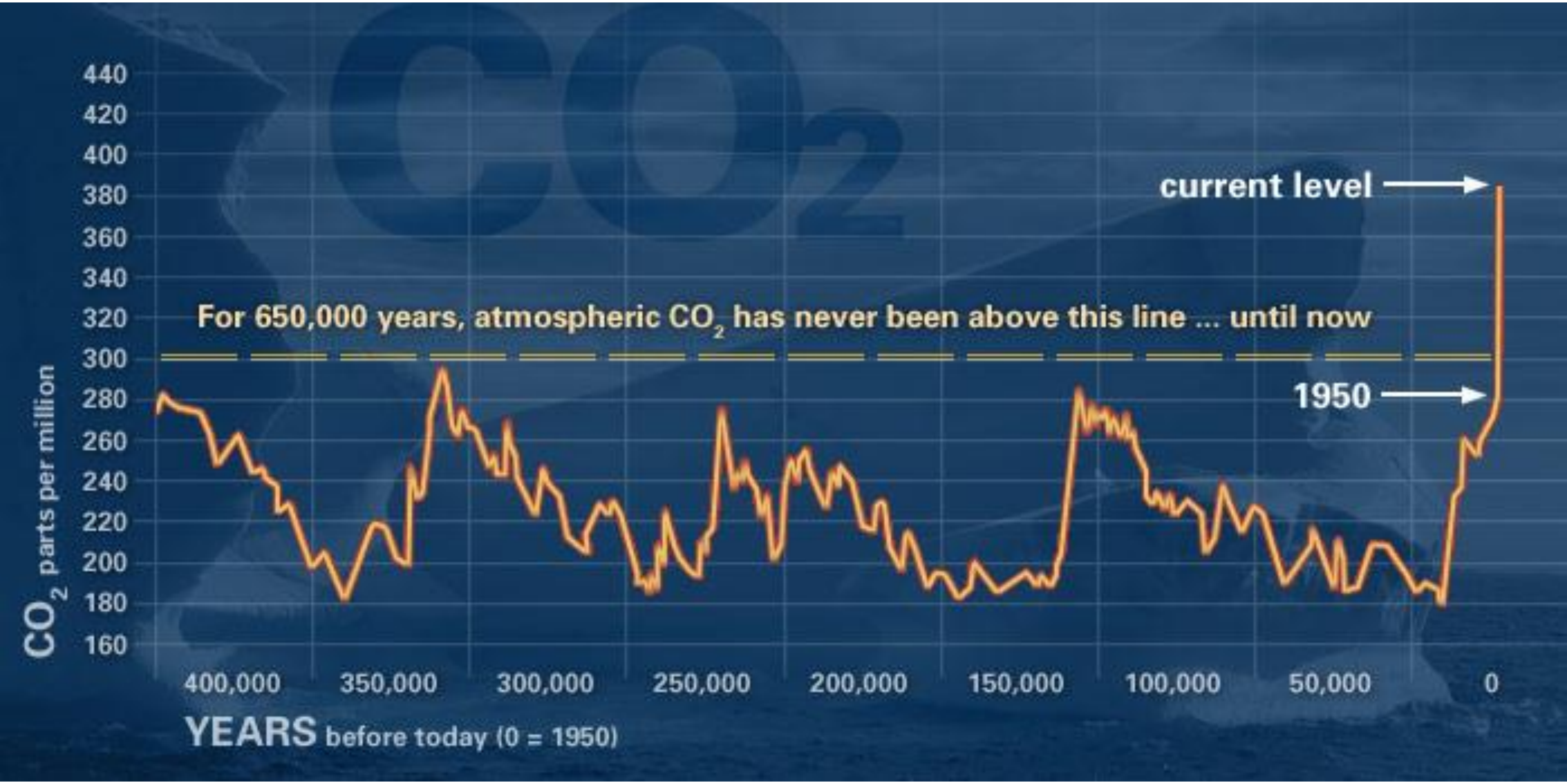
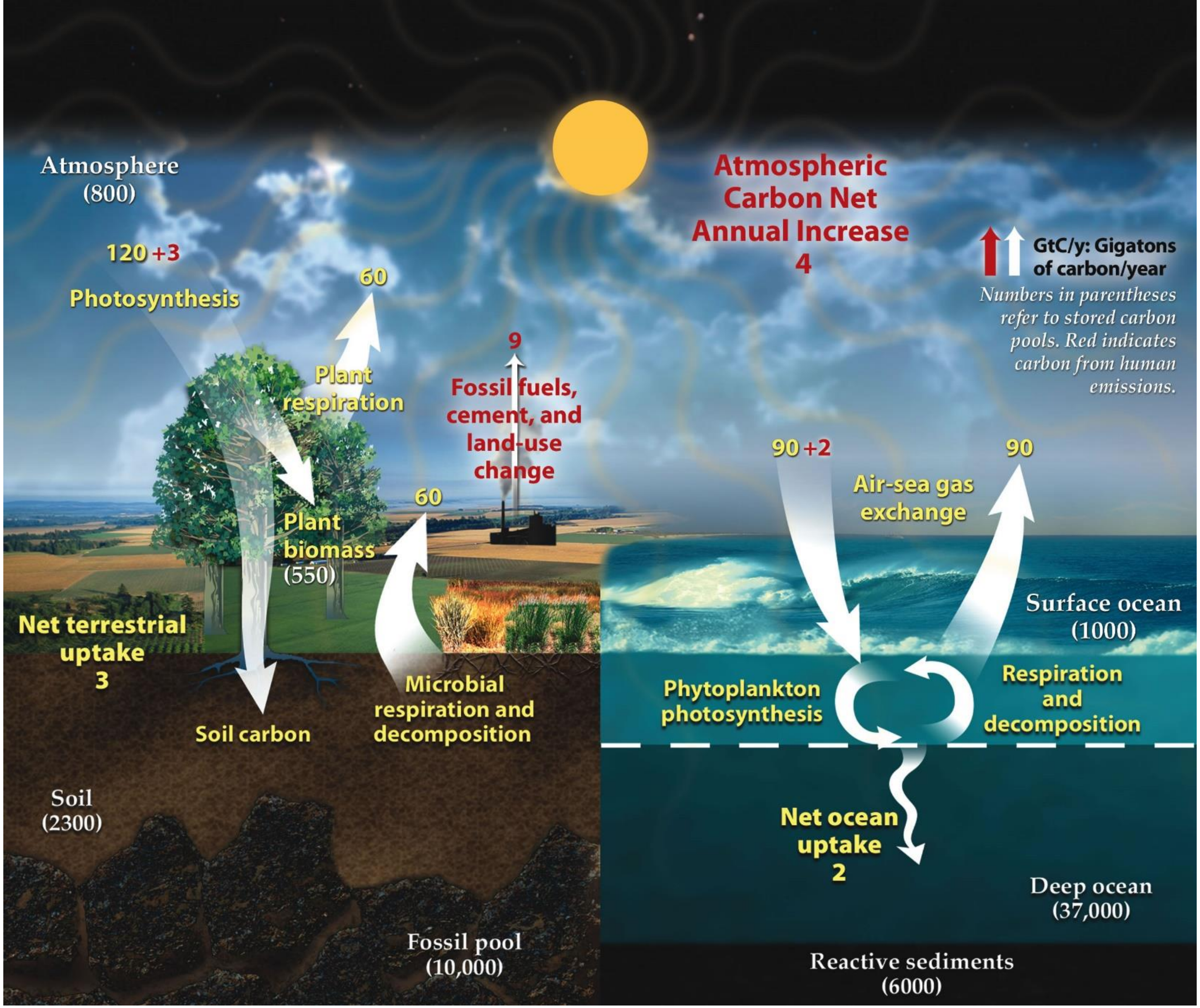
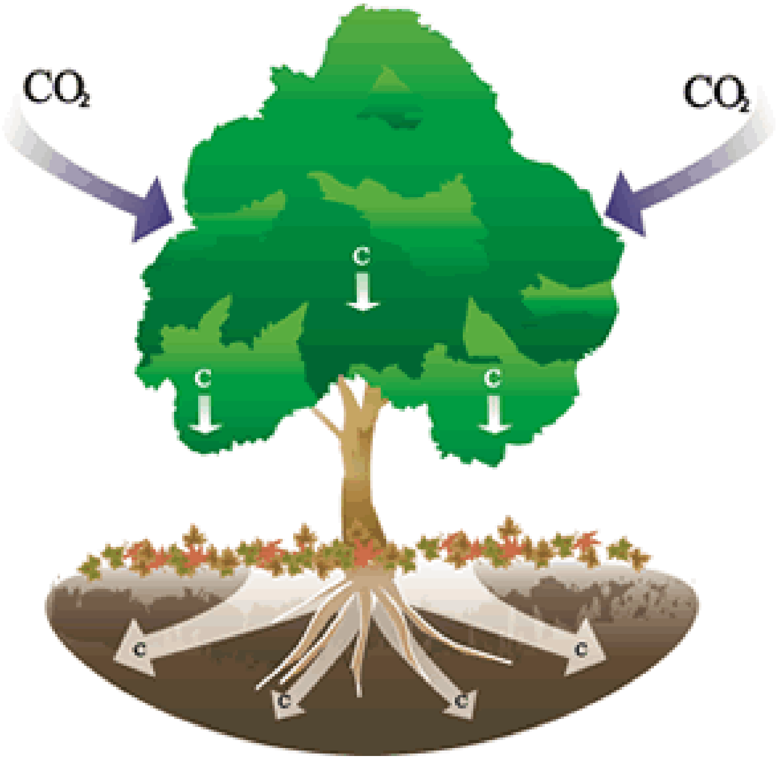


Image: University of California, Riverside


Atmosphere
(800)
120 +3
Photosynthesis
60
Plant respiration
9
Fossil fuels, cement, and land-use change
Atmospheric Carbon Net Annual Increase
4
GtC/y: Gigatons of carbon/year
60
Plant biomass
(550)
Net terrestrial uptake
3
Soil carbon
Microbial respiration and decomposition
Soil
(2300)
Fossil pool
(10,000)
90 +2
Air-sea gas exchange
90
Surface ocean
(1000)
Phytoplankton photosynthesis
Respiration and decomposition
Net ocean uptake
2
Deep ocean
(37,000)
Reactive sediments
(6000)

Numbers in parentheses refer to stored carbon pools. Red indicates carbon from human emissions.

Diagram: U.S. Department of Energy



Landscape Plant	kg CO2
Red maple tree – *Acer rubrum*	655
Evergreen tree – *Picea pungens*	430
Flowering deciduous tree – *Cercis canadensis*	63
Deciduous shrub – *Viburnum spp.*	11
Evergreen shrub – *Taxus spp.*	9

Reduced global warming impact of above ground growth plant's life expectancy, after accounting for emissions during production and take down at end of life.

50% of an individual tree or shrub's dry biomass is carbon, sequestered from the atmosphere via photosynthesis.

______

Below ground, long term sequestration in soil not quantified at this time, but may be substantial for some plants.

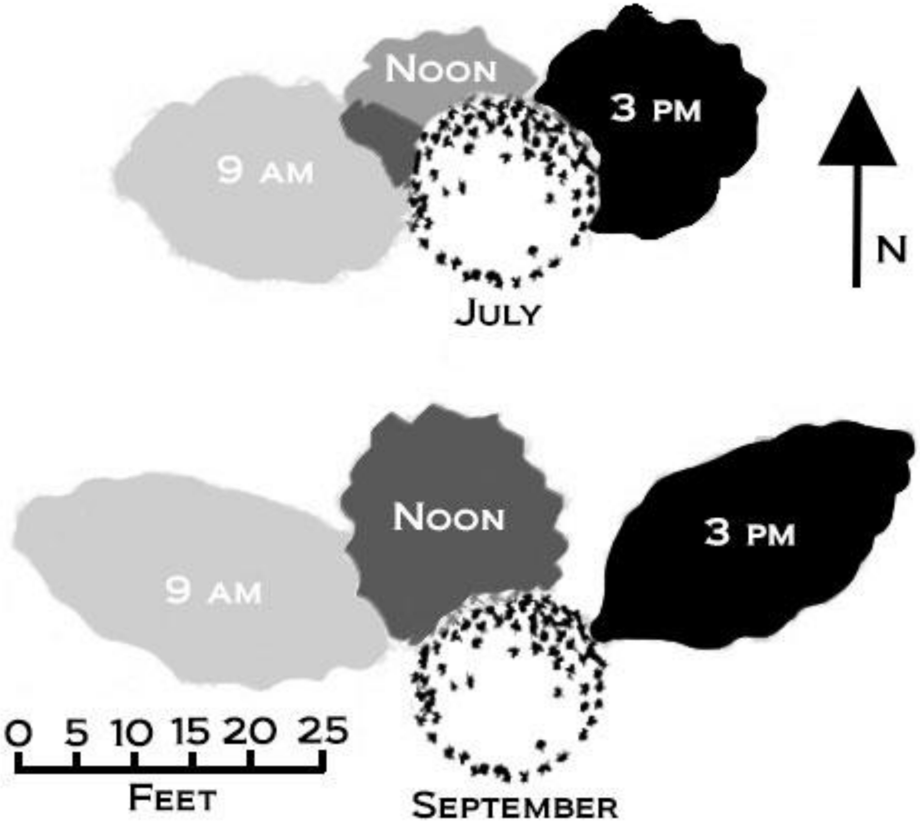
Image: US Forest Service

Tree Species and "System" Comparisons

	Blue Spruce	Red Maple	Redbud
Liner - inputs	0.013	0.115	0.153
Liner - equipment use	0.021	0.311	0.169
Liner transport	0.008	0.105	0.123
Liner nursery overhead	0.001	0.005	0.157
Field Production - inputs	3.467	2.878	3.649
Field Production - equipment use	13.069	10.146	12.016
Field nursery overhead	0.581	1.083	1.304
Sequestered C in production	-9.000	-12.100	-10.539
Transport to landscaper	2.434	4.565	3.831
Transport to site & transplant	3.142	3.766	1.633
Use phase sequestered C	-593.034	-901.355	-165.111
Take down & disposal	147.785	239.546	88.444
Net Positive Life Cycle Impact	**-431.556**	**-655.261**	**-64.769**

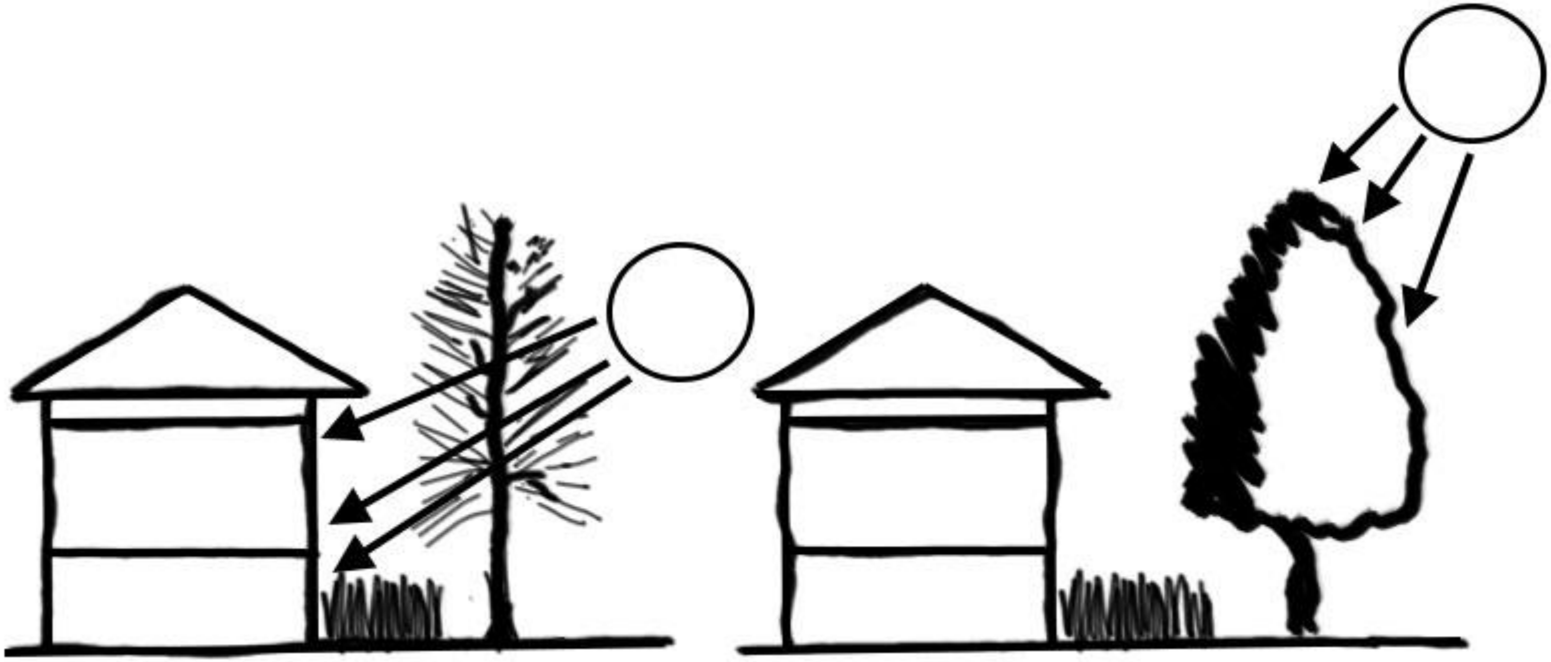
All units: Global Warming Potential (GWP) in kg CO2 equivalents

Microclimates and Energy Conservation (5/7)


NOON
9 AM
3 PM
JULY
N
NOON
9 AM
3 PM
0 5 10 15 20 25
FEET
SEPTEMBER

Shade patterns shift **daily and seasonally**

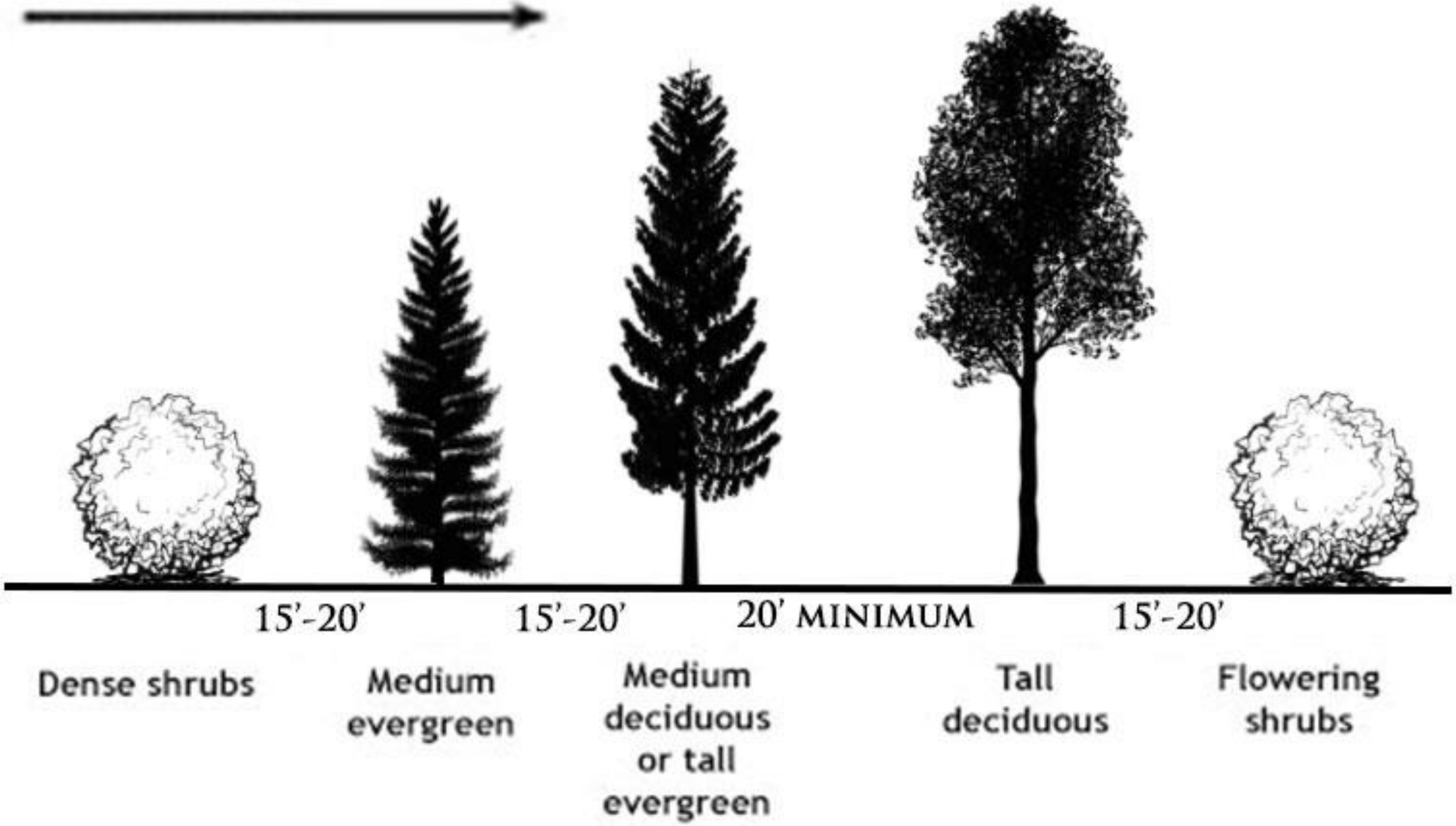
Seasonal Shade (Deciduous)



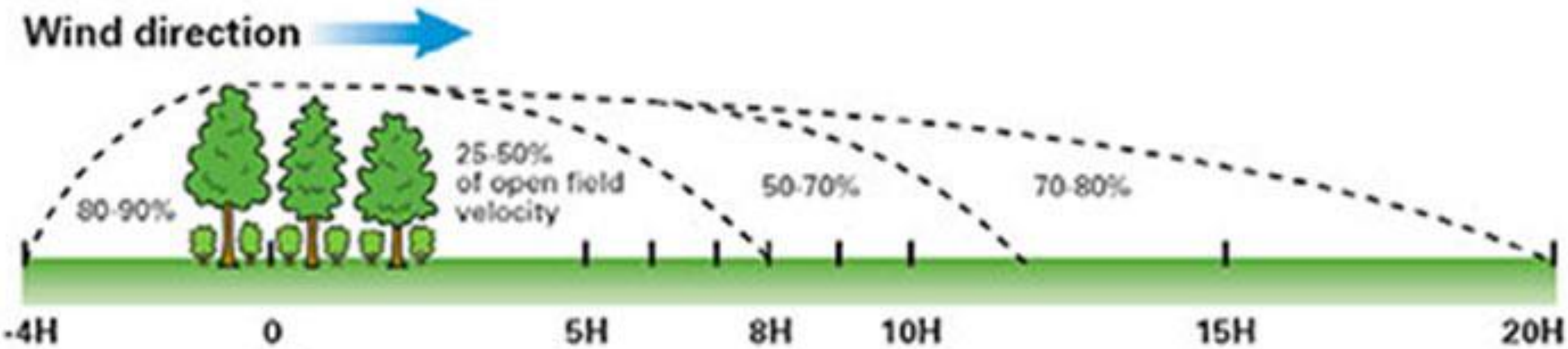
Winter

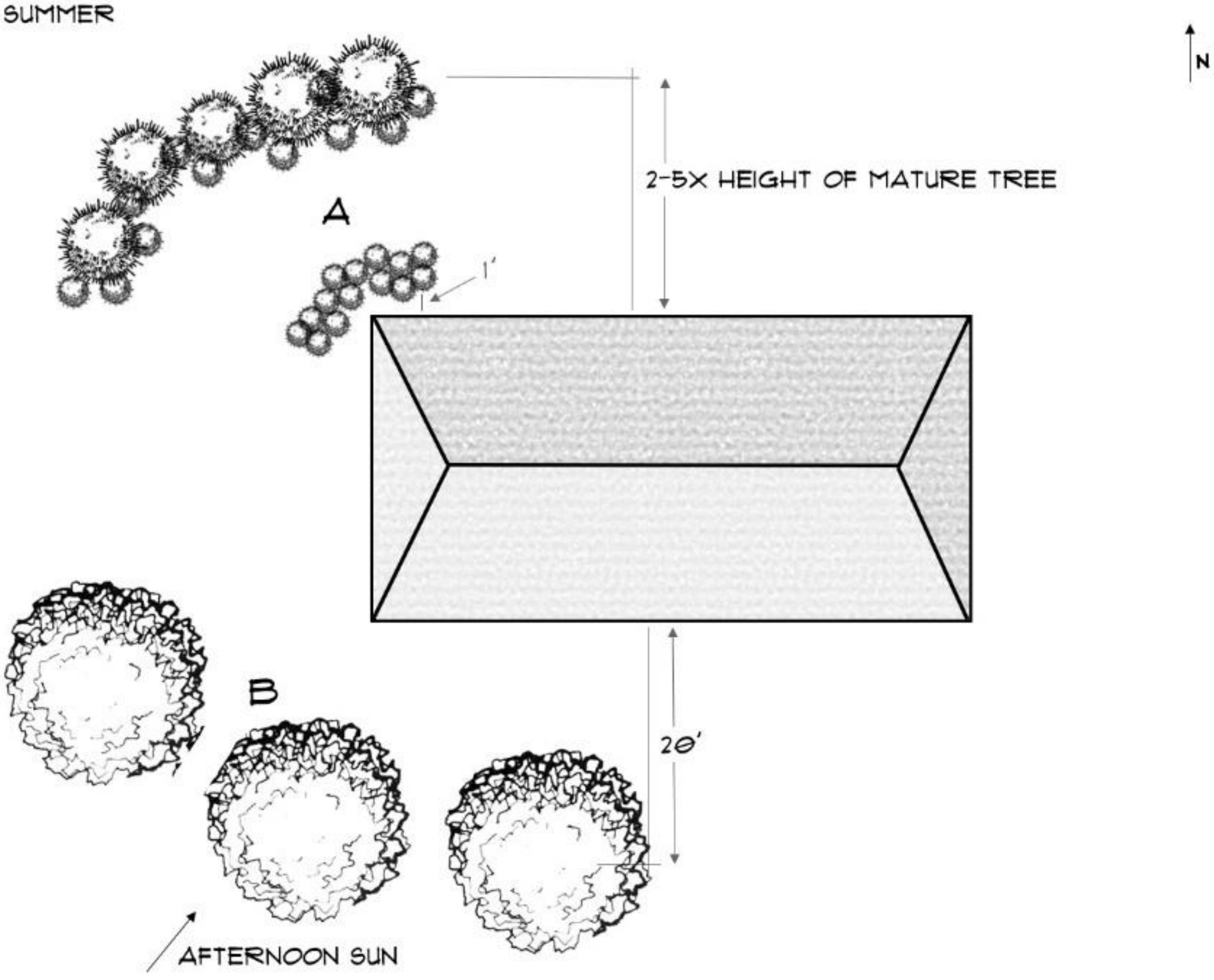
Summer

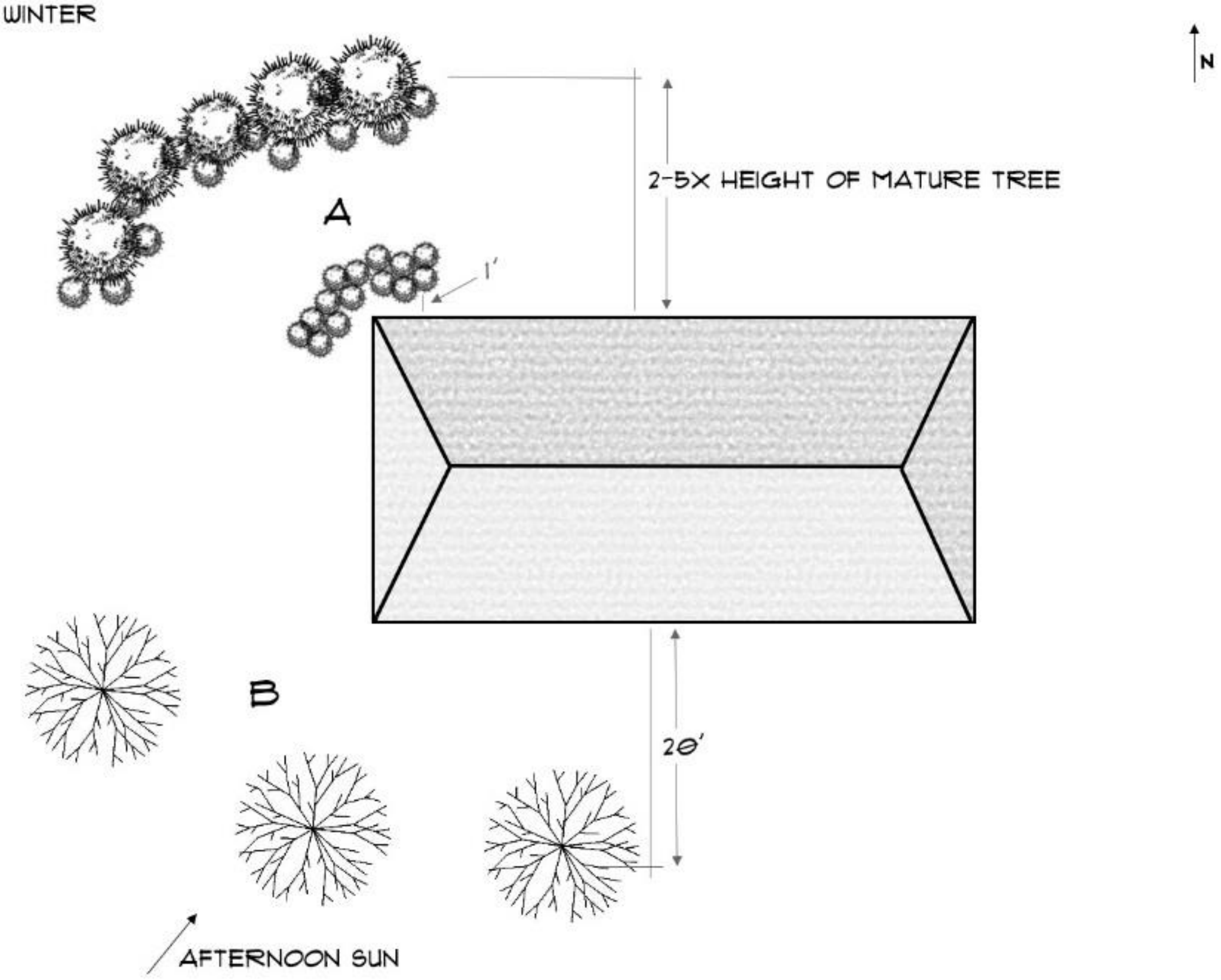
WIND BREAK DESIGN

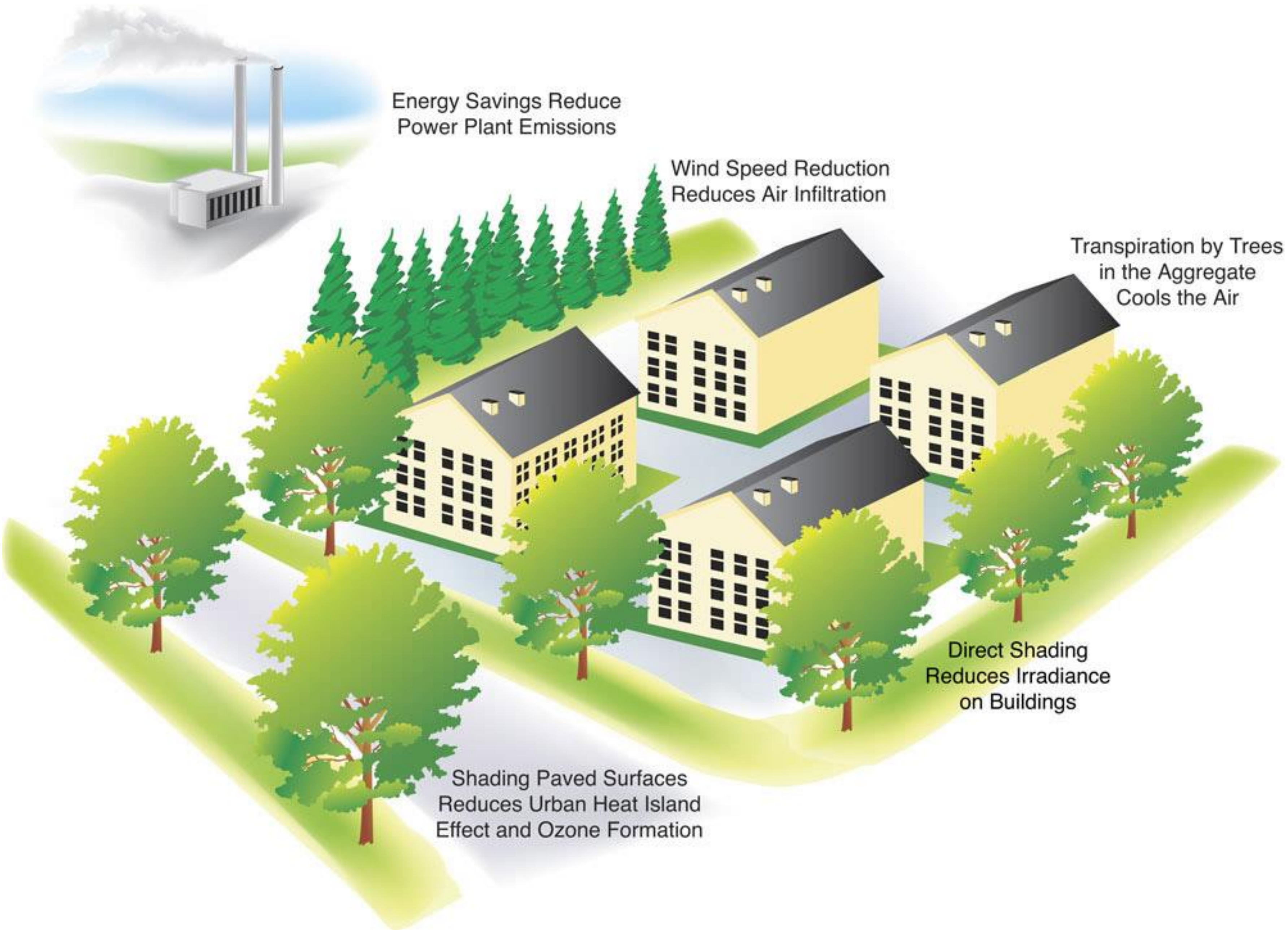

15'-20'
15'-20'
20' MINIMUM
15'-20'
Dense shrubs
Medium evergreen
Medium deciduous or tall evergreen
Tall deciduous
Flowering shrubs

Height vs. Distance


Wind direction
80-90%
25-50%
of open field
velocity
50-70%
70-80%
-4H
0
5H
8H
10H
15H
20H


SUMMER
N
2-5X HEIGHT OF MATURE TREE
A
1'
B
20'
AFTERNOON SUN


WINTER
N
2-5X HEIGHT OF MATURE TREE
A
1'
B
20'
AFTERNOON SUN



Energy Savings Reduce
Power Plant Emissions
Wind Speed Reduction
Reduces Air Infiltration
Transpiration by Trees
in the Aggregate
Cools the Air
Direct Shading
Reduces Irradiance
on Buildings
Shading Paved Surfaces
Reduces Urban Heat Island
Effect and Ozone Formation

Suburbs with trees:
Air 4-6 degrees cooler

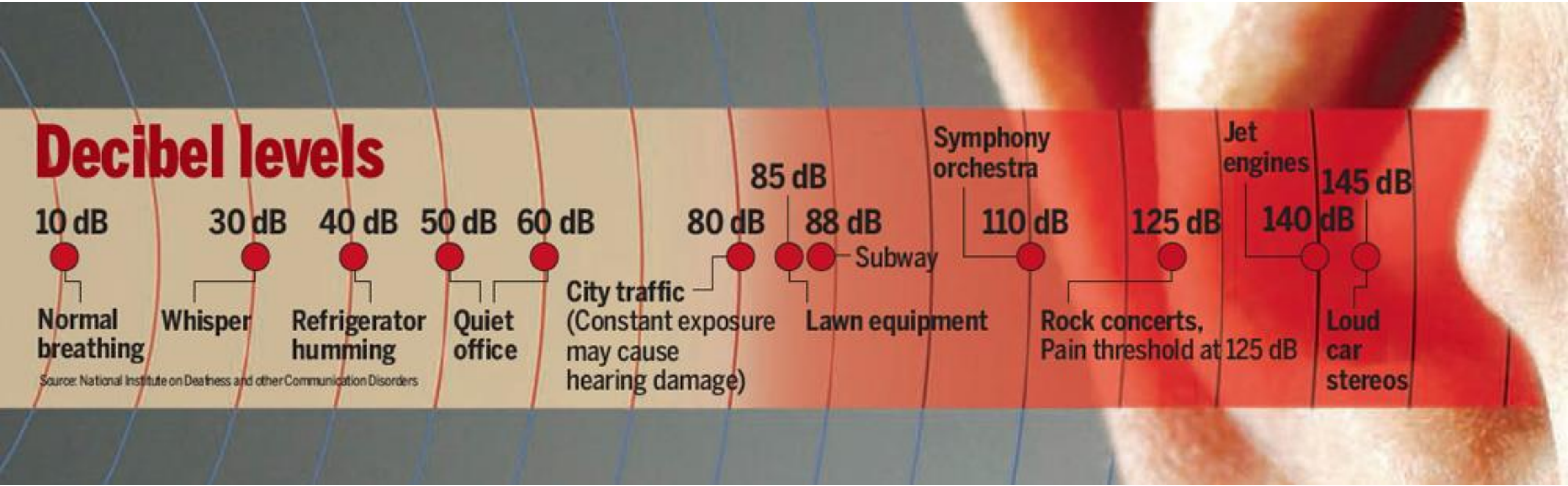
Schoolyards with trees:
Air 20 degrees cooler

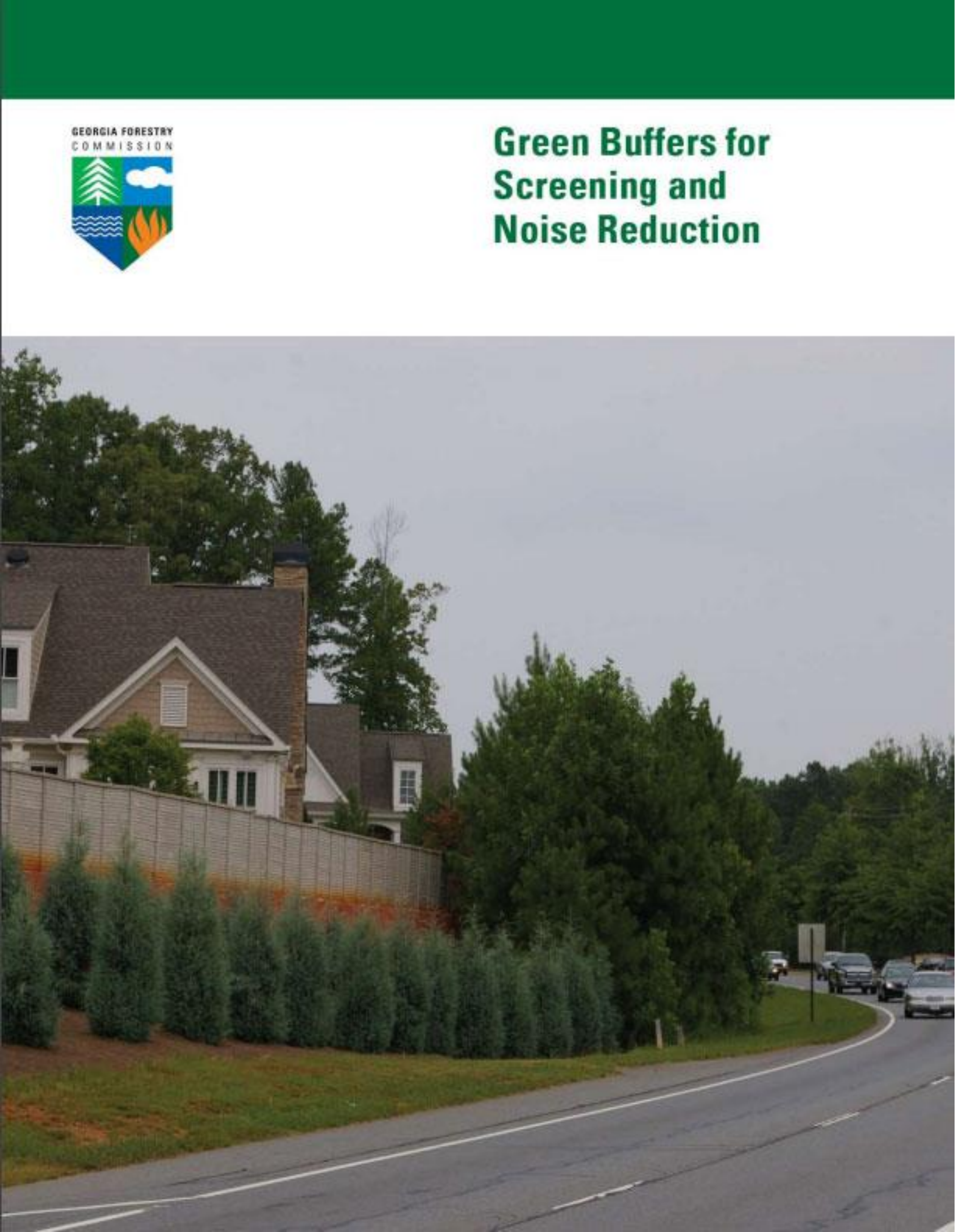
1 Properly watered tree can evaporate-transpire
40 gallons of water each day:
offsetting heat equivalent from
100x 100 watt lamps burning for 8 hours.

Moogk-Soulis, Carol. Schoolyard Heat Islands: A Case Study in Waterloo, Ontario (2011)
Rosenfeld. Painting the Town White – And Green (1997)

Noise Reduction (6/7)

- Cities are loud
- Constant exposure to city traffic sounds can cause hearing damage!
- Decibel is a logarithmic unit: “small” unit increases or decreases are more noticeable at higher levels





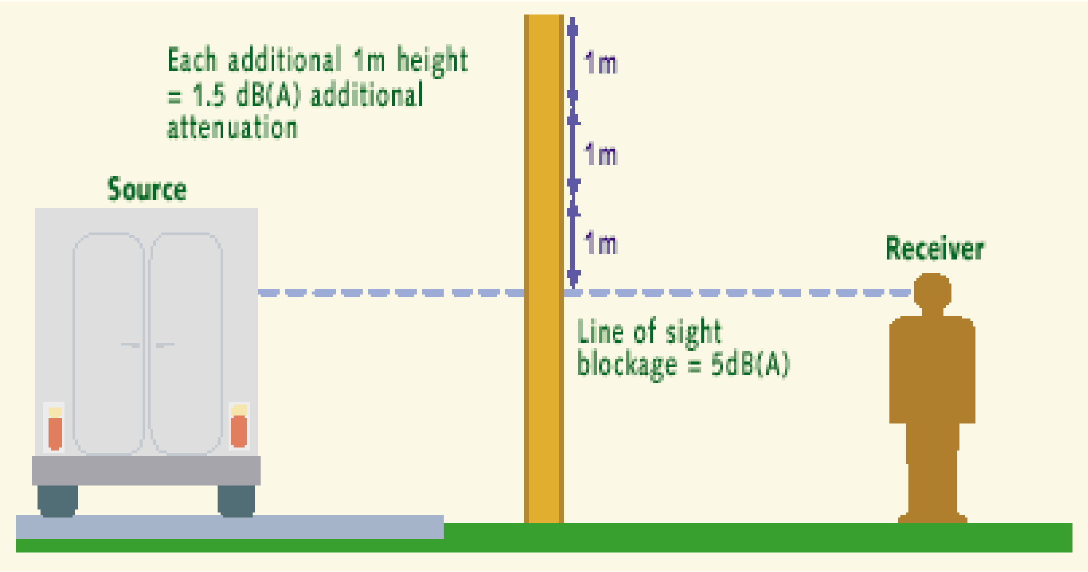
GEORGIA FORESTRY COMMISSION

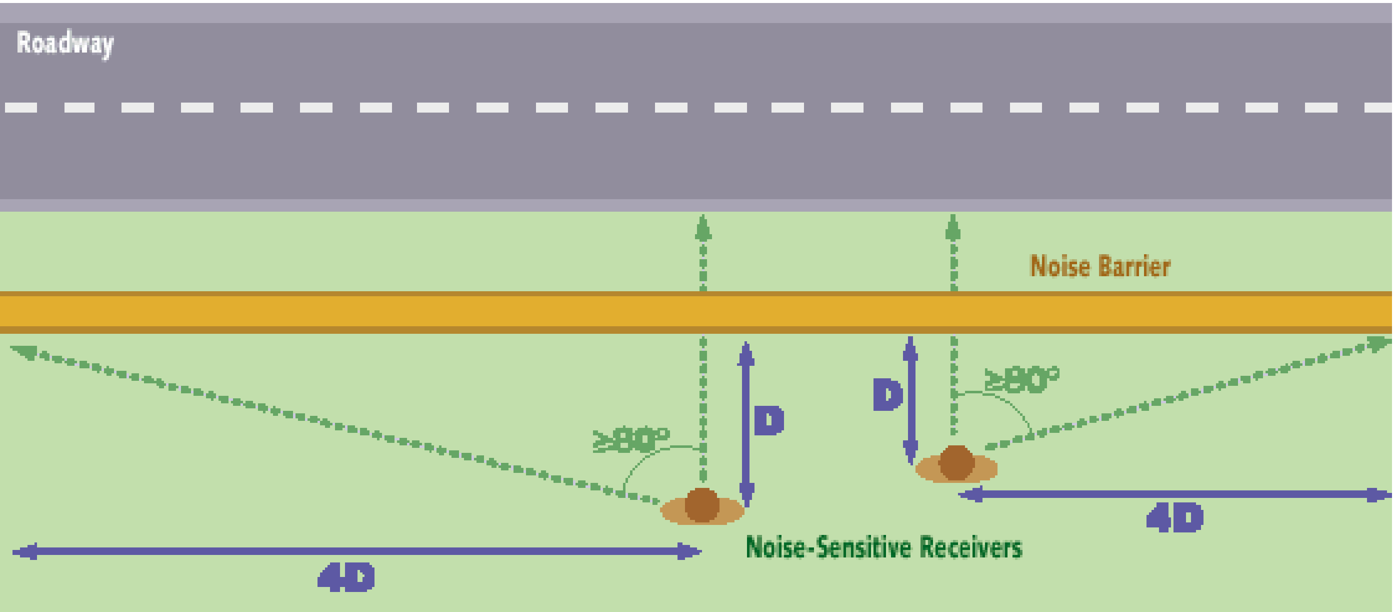
Green Buffers for Screening and Noise Reduction

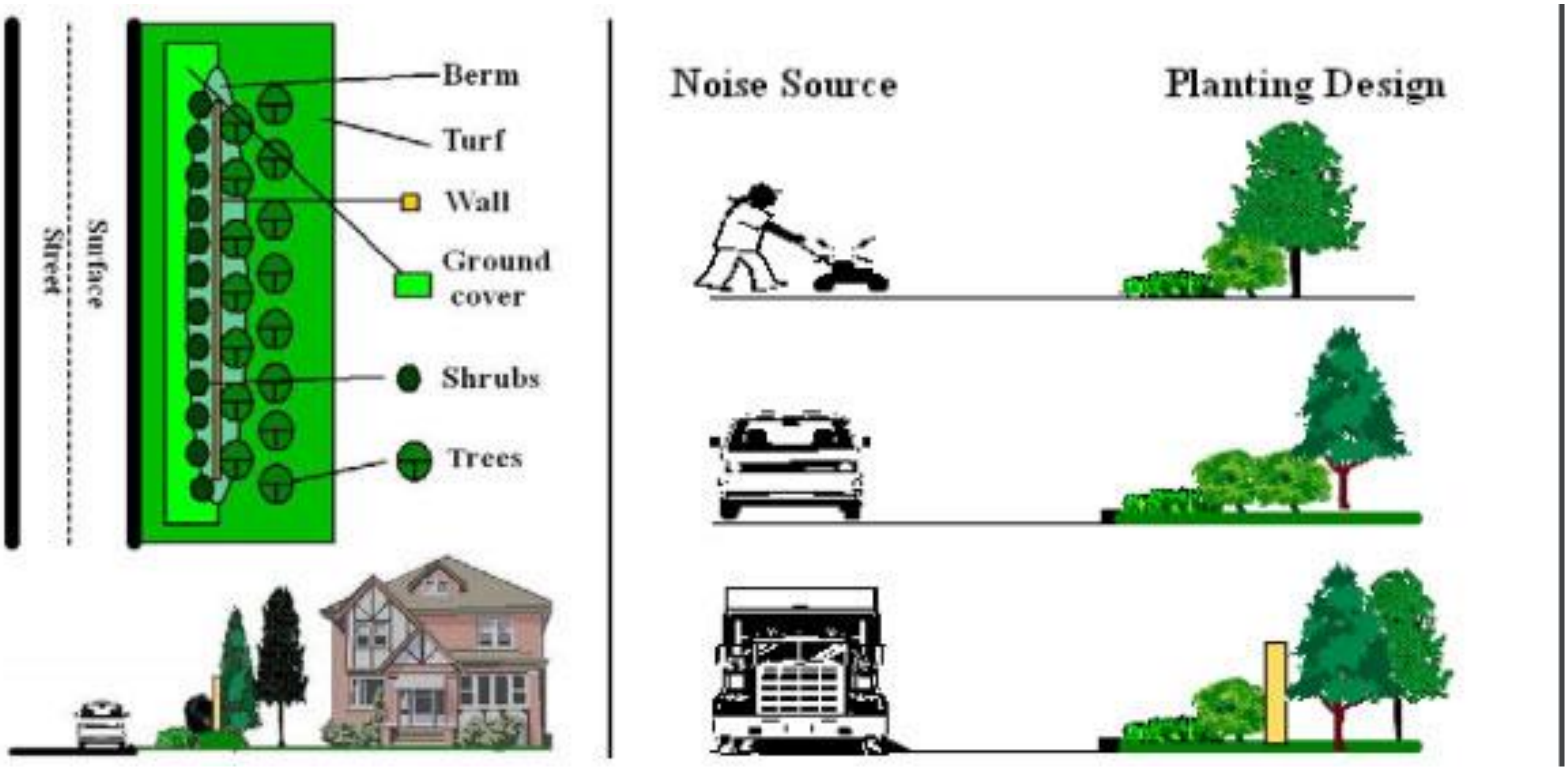
"Plant materials help attenuate sound and 'calm' the noise. Some types of plants are better at performing this function than others. **Efficient trees and shrubs have thick, waxy leaves, dense evergreen foliage, and branches that extend to the ground**."

- Georgia Forestry Commission

- **Height** of barrier determines noise reduction
- **Length** of barrier is important (>4X distance from listener to barrier is ideal)

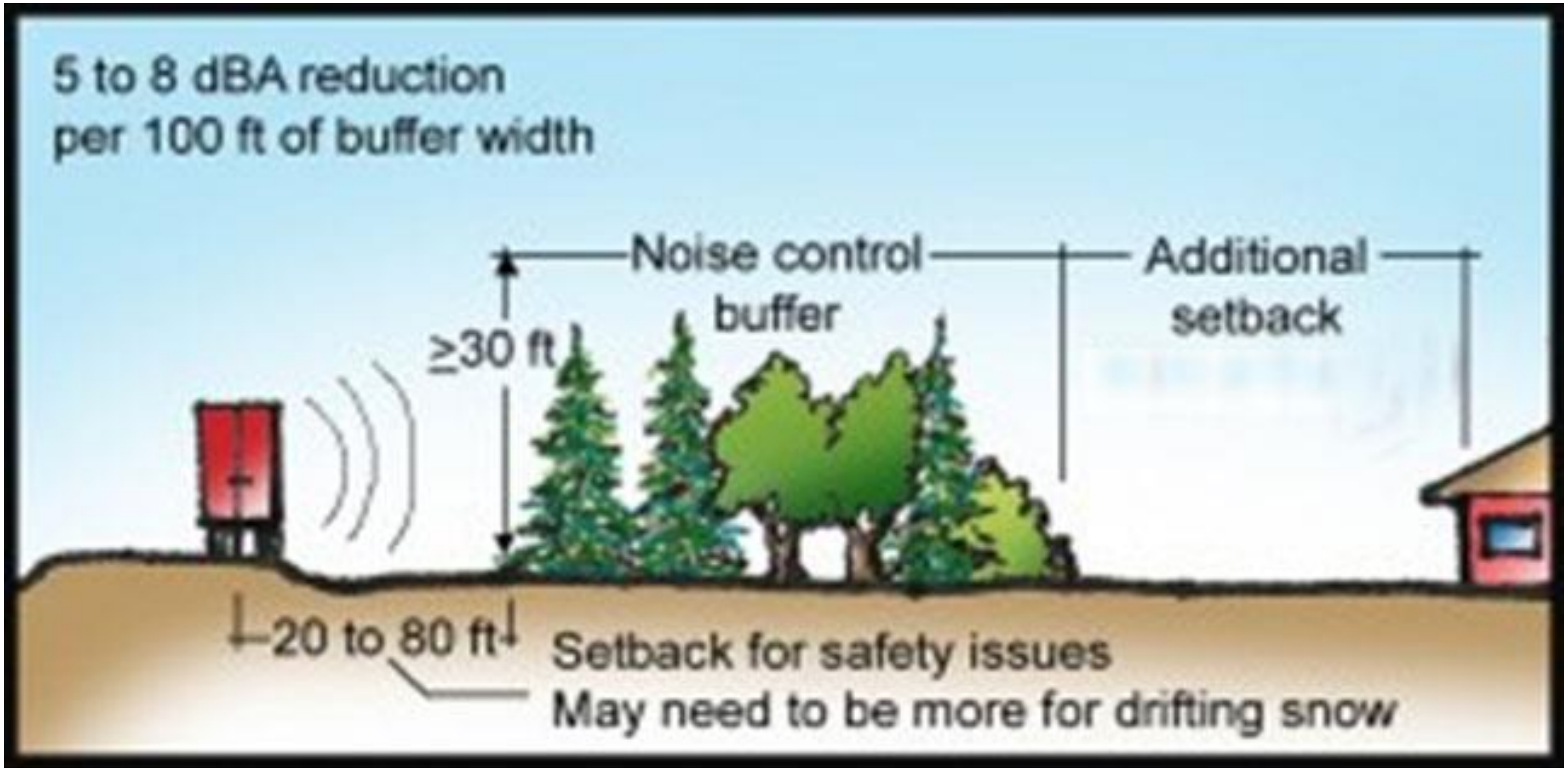

Each additional 1m height = 1.5 dB(A) additional attenuation
Source
1m
1m
1m
Receiver
Line of sight blockage = 5dB(A)


Roadway
Noise Barrier
≥80°
D
D
≥80°
4D
Noise-Sensitive Receivers
4D

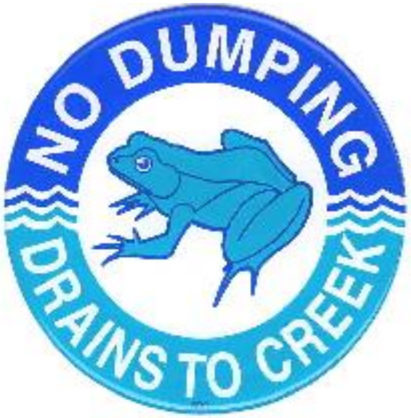

Berm
Turf
Wall
Ground cover
Shrubs
Trees
Surface
Street
Noise Source
Planting Design

More layers reduce louder noises.

Source: Georgia Forestry Commission


5 to 8 dBA reduction
per 100 ft of buffer width
Noise control buffer
Additional setback
≥30 ft
20 to 80 ft
Setback for safety issues
May need to be more for drifting snow

Stormwater Management (7/7)


NO DUMPING
DRAINS TO CREEK

Impervious Surfaces cause Stormwater Runoff

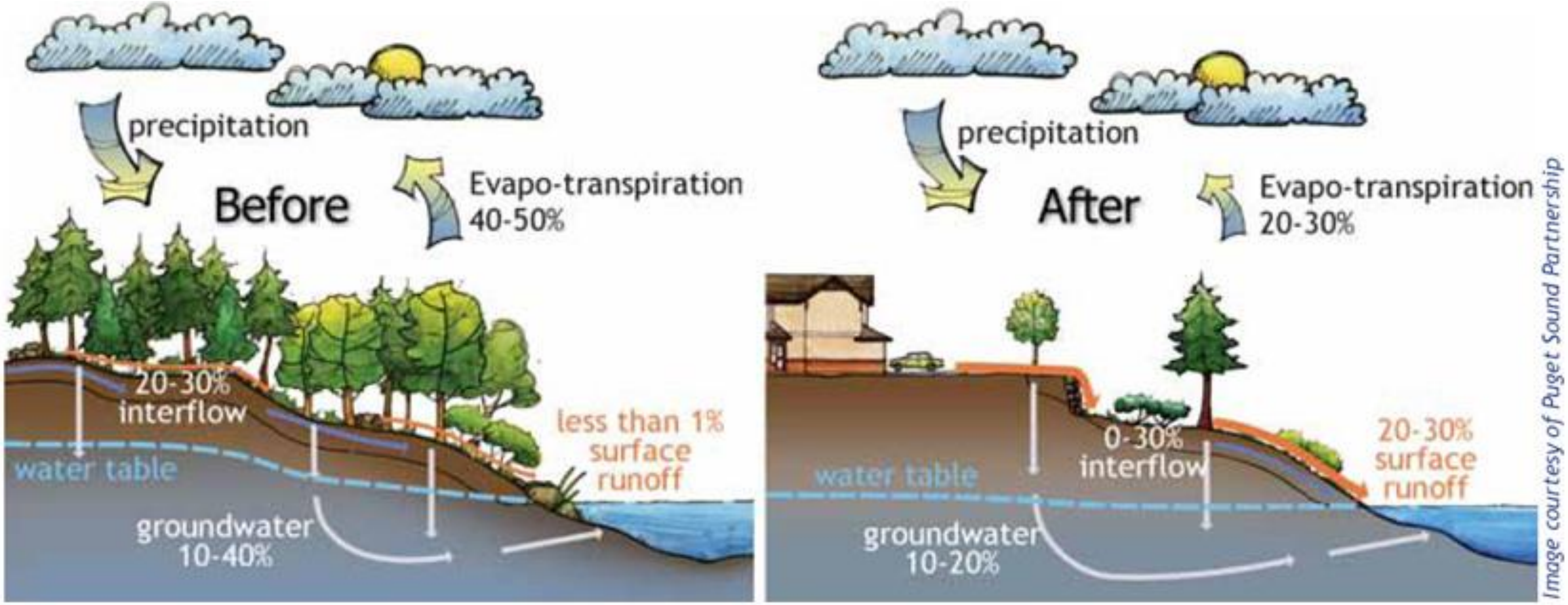

precipitation
Before
Evapo-transpiration
40-50%
20-30%
interflow
less than 1%
surface
runoff
water table
groundwater
10-40%
precipitation
After
Evapo-transpiration
20-30%
0-30%
interflow
20-30%
surface
runoff
water table
groundwater
10-20%

Image courtesy of Puget Sound Partnership

Before *development almost all rainfall is taken up by plants, evaporates or infiltrates through the ground.*
After *conventional development, surface runoff increases significantly while evaporation and infiltration into the ground decrease.*

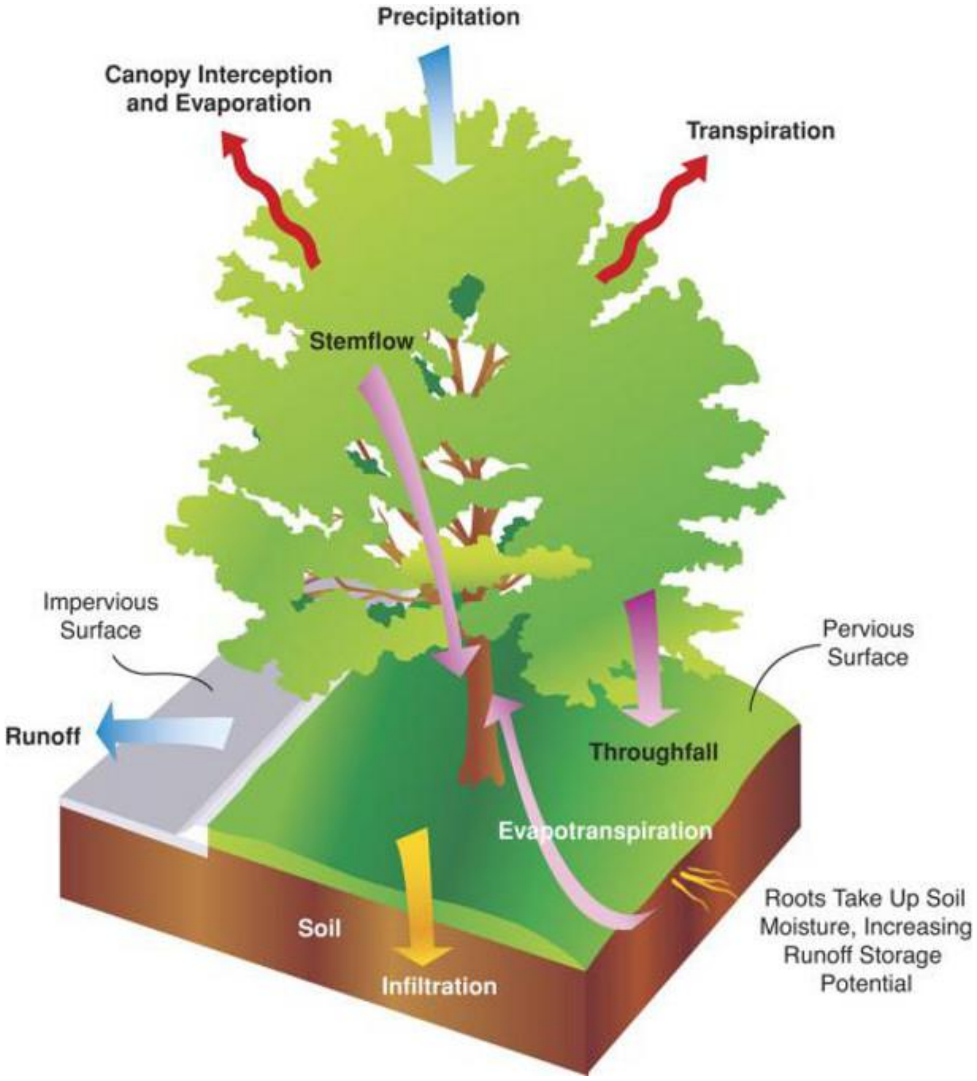
Problems with runoff:

- Toxic! Metals, animal waste, pathogens.
- Gravelly/Sandy soils allow rapid infiltration of stormwater, can contaminate ground water.
- Leading cause of water pollution in urban creeks/waterways.
- Impaired habitat for fish / wildlife.

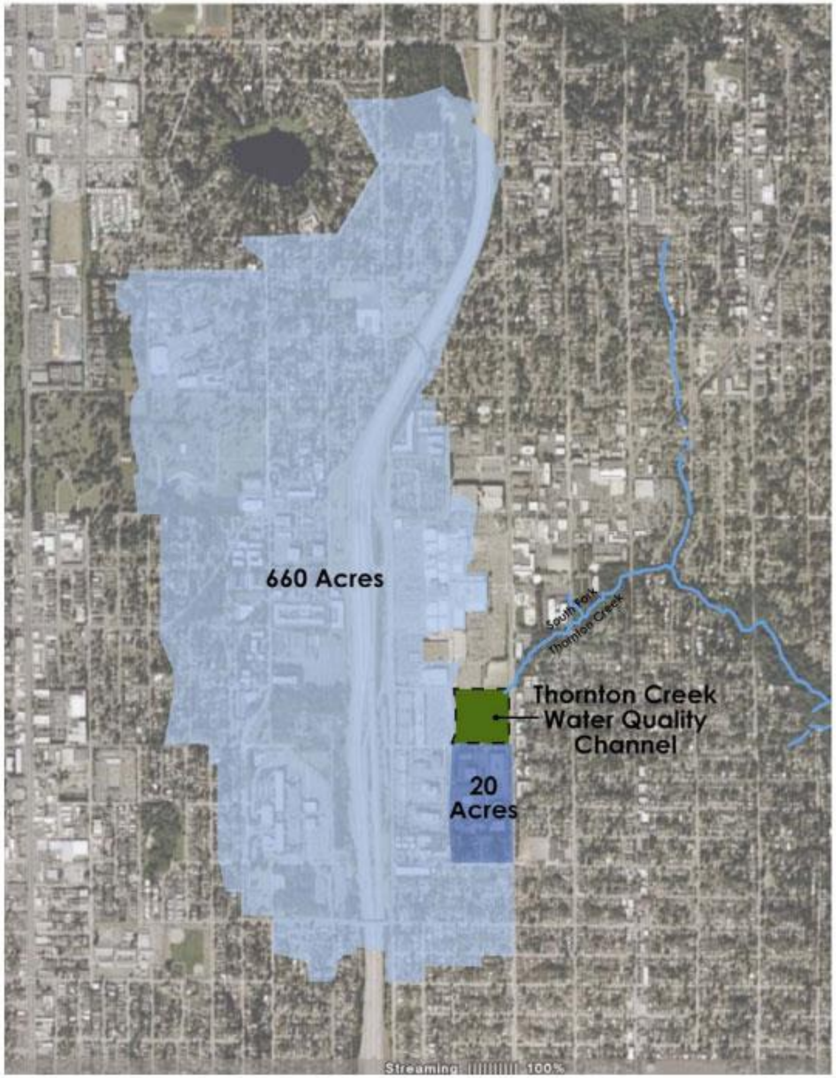
Grey infrastructure is at risk during peak events.

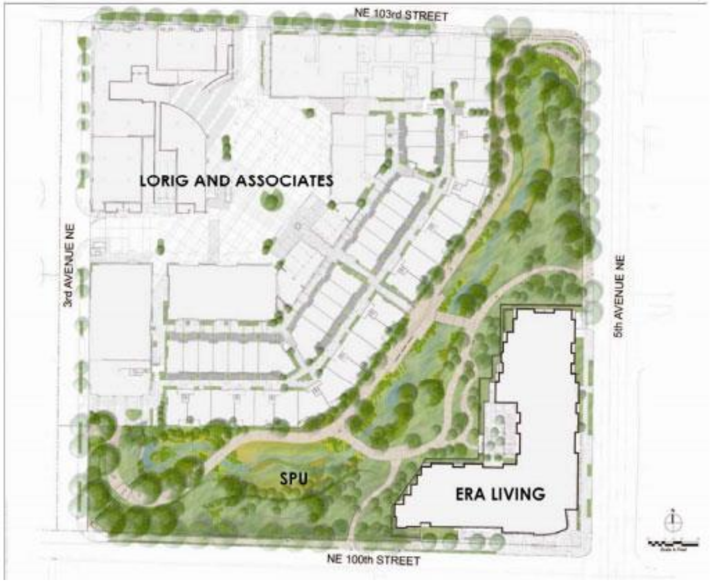
Green infrastructure flattens these peaks by slowing runoff during and after rainfall events.

Green infrastructure improves the capacity of existing grey infrastructure, saving public funds.

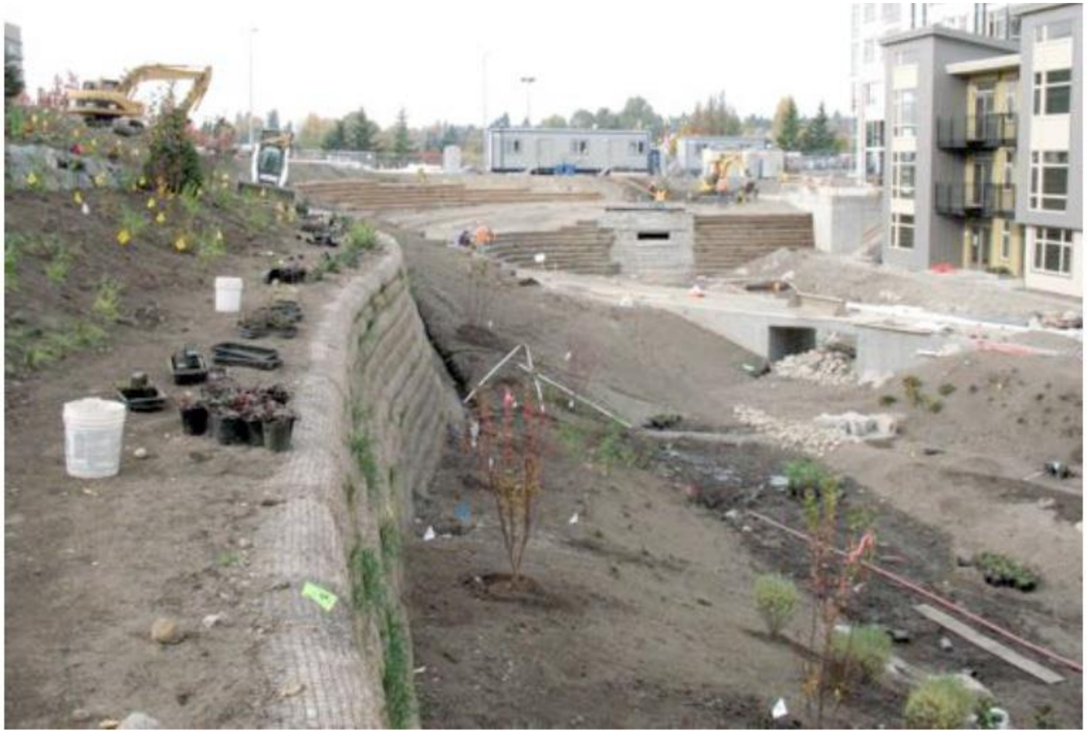

Precipitation
Canopy Interception and Evaporation
Transpiration
Stemflow
Impervious Surface
Pervious Surface
Runoff
Throughfall
Evapotranspiration
Soil
Infiltration
Roots Take Up Soil Moisture, Increasing Runoff Storage Potential

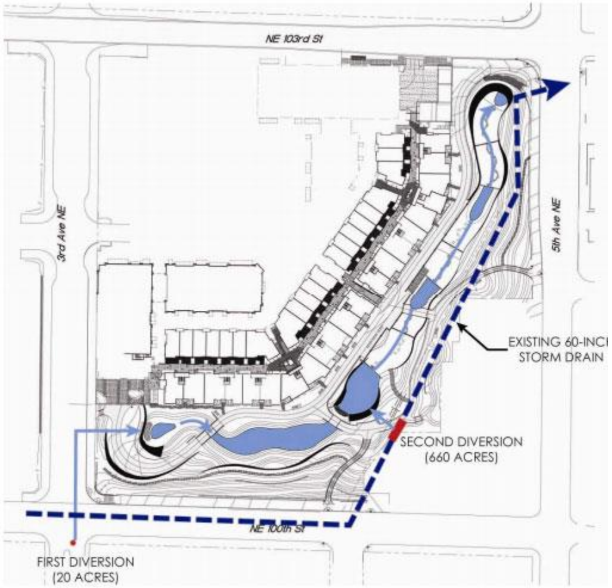
Case Study: Thornton Creek Watershed Plan Shoreline, WA - October 2009

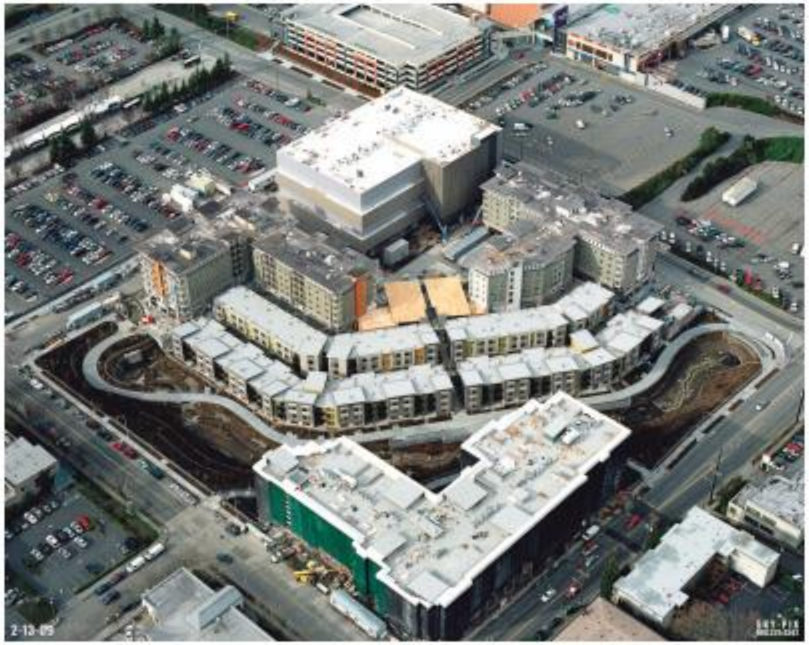

660 Acres
South Fork Thornton Creek
Thornton Creek Water Quality Channel
20 Acres
Streaming 100%


NE 103rd STREET
LORIG AND ASSOCIATES
3rd AVENUE NE
5th AVENUE NE
SPU
ERA LIVING
NE 100th STREET

Site preparation and hydrology




NE 103rd St
3rd Ave NE
5th Ave NE
EXISTING 60-INCI
STORM DRAIN
SECOND DIVERSION
(660 ACRES)
NE 100th St
FIRST DIVERSION
(20 ACRES)



Plant selection for Biofiltration swales or "bioswales"

- Maintain upright biomass several inches about 10" flow depth
  - **emergent rushes (*Juncaceae*), sedges (*Cyperaceae*), and bulrushes (*Scirpus* spp.)15" = 36" in height** with wide selection/diversity
- Spaced for maximum density between soil surface and 10" water height
- Ongoing monitoring to evaluate successful species

Cultural Services (1/1)

- Aesthetic, Recreation and Cultural values difficult to quantify, though Property Values representative

- “150% return on investment is **conservative**” – John Gidding, HGTV’s “Curb Appeal”

- Standard suggestion: invest 5-10% of value of home in landscaping.

- Beware: extensive landscaping can give the impression of *extensive maintenance requirements*.

"low-maintenance" landscape characteristics:

- ✓ limited lawn size
- ✓ hardscaping
- ✓ use groundcovers, bark chips/mulches for weed control
- ✓ native plant materials
- ✓ flowering trees and shrubs for color, small flower beds
- ✓ compact varieties; insect and disease-resistant varieties
- ✓ simple design

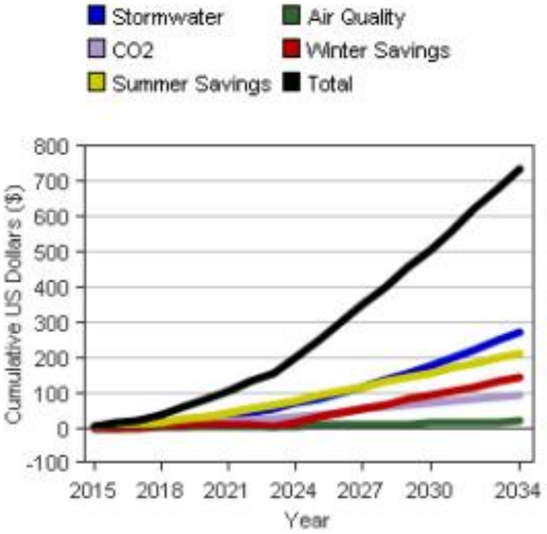
"low-maintenance" practices are often sustainable landscape practices

Summary

Over 20 years, a single red maple planted in 2015 located ~25' from the southwest corner of a climate controlled structure will

- Save **$143** in winter heating costs
- Save **$210** in summer cooling costs
- Intercept 44,028 gallons of water
  - Saving the community **$273** in stormwater reduction costs
- Save **$18** in air quality improvement upgrades
- Reduce contributions to atmospheric carbon by 9,766 lbs through sequestration and decreased energy production needs.

- Total Value Added: **>$700**



Cumulative tree benefit forecast for a properly sited red maple planted in 2015.

Source: i-Tree Design itreetools.org

Species reference table

Species	Common Name	Lexington Street Tree	Native KY	Max Height (feet)	Relative Growth Rate	Resistance to Insect pests	Resistance to disease problems	Resistance to storm Damage	Will grow on poorly drained soil	Will grow in hot dry areas	Easy to transplant	Withstands city conditions	Storm water Reduction	Air quality improvement	Wind Reduction	Carbon sequestration
Large Trees																
Elm	**Elm**															
Ulmus americana*	American elm*	A	Yes	120	●●●	○	○	●	●●	●	●●●	●●	●●●	●●●	●●●	●●●
Ulmus pumila[2]	Siberian elm[2]		No	70	●●●	○	●	○	●●	●●●	●●●	●●	●●	●●●	●●●	
Maple	**Maple**															
Acer platanoides[1]	Norway[1]		No	70	●●	●●	●●	●●	●	●	●●	●●	●●●	●●●	●●●	●●●
Acer rubrum	Red		Yes	90	●●●	●●	●●	●	●●●	●	●●	●	●●●	●●●	●●●	●●●
Acer saccharinum	Silver	NO	Yes	90	●●●	●●	●●	○	●●●	●	●●	●	●●	●●	●●	●●●
Acer saccharum	Sugar	A	Yes	90	●●	●	●	●●	●	●	●●	○	●●●	●●	●●	●●●
Oak	**Oak**															
Quercus alba	White	A	Yes	80	●	●●	●●●	●●●	●	●●●	○	●●	●	●●	●●	●●●
Quercus bicolor	Swamp white	A	Yes	60	●●	●●	●●	●●●	●●●	●●	●●	●●●	●	●●	●●	●●●
Quercus imbricaria	Shingle	A	Yes		●●	●●	●●	●●●	●●	●●	●	●●	●	●●●	●●	●●●
Quercus macrocarpa	Bur		Yes	80	●	●●	●●●	●●●	●	●●	●	●●●	●●	●●	●●	●●●
Quercus meuhlenbergii	Chinkapin		Yes	50	●●	●●	●●	●●	●●	●●	●	●●	●●	●	●●	●●●
Quercus nigra	Water	A	Yes	70	●●●	●	●	●●	●	●●	●●●	●	●●	●●	●●	●●●
Quercus palustris	Pin	NO	Yes	70	●●	●●	●●	●●●	●●	●	●●	●●	●	●	●●	●●●
Quercus phellos	Willow	A	Yes	75	●●●	●●	●●	●●	●●	●	●●●	●●●	●●	●●●	●●	●●●
Quercus robur	English		No	60	●●	●●	●●●	●●●	●	●●	●●	●●	●	●	●●	●●●
Quercus rubra	Red, Scarlet	A	Yes	70	●●●	●●	●	●●	●●●	●●●	●●	●●●	●	●●●	●●	●●●
Quercus shumardii	Shumard	A	Yes	80	●●●	●●	●●	●●	●●	●●	●●	●●	●●●	●●●	●●●	●●●
Fagus grandifolia	American beech	A	Yes	60	●	●●●	●●●	●●	●	●	●●	●●	●●●	●●●	●●	●●●
Ginkgo biloba	Ginkgo (male)			60	●	●●●	●●●	●●●	●	●●	●●	●●●	●●●	●●	●●	●●●
Gymnocladus dioicus	Kentucky Coffeetree	A	Yes	75	●	●●	●●	●●	●	●●	●●	●●	●●	●	●●●	●●●
Larix decidua	European larch	A	No	60	●●	●●●	●●●	●●	●	●●●	●●	●●	●●●	●●●	●●●	●●
Liquidambar styraciflua	Sweet gum	A	Yes	80	●●	●●	●	●●	●●●	●	●	●●	●●●	○	●●	●●
Liriodendron tulipifera	Tulip poplar	A	Yes	100	●●	●●	●●	●	●	○	●	●●	●●●	●●●	●●●	●●●
Platanus occidentalis	American Sycamore		Yes	100	●●●	●●	●	●●	●●●	●●	●●	●●	●●●	○	●●●	●●●
Taxodium distichum	Bald cypress	A	Yes	100	●●	●●●	●●●	●●	●●●	●●	○	●●	●●●	●●	●●	●●
Tilia americana	American basswood	A	Yes	80	●●	●●	●●	●●	●	●●	●●	●●●	●●●	●●●	●●●	●●●
Medium-sized trees																
Betula nigra	River birch		Yes	60	●●	●●	●●●	●●	●●●	●	●●	●●	●●	●●	●●	●●
Cladrastis kentukea	Yellowwood		Yes	40	●	●●●	●●●	●●	●	●●	●	●●	●●	●●	●●	●●●
Nyssa sylvatica	Black gum		Yes	30	●	●●●	●●●	●●	●●	●	○	●	●●	●●	●●	●●
Sophora japonica	Japanese pagoda tree		No	40	●●	●●●	●●	●●	●	●●	●●	●●●	●●	●●	●●	●●●
Small trees																
Acer buergerianum	Trident maple		No	30	●●	●●	●●	●●	●	●●●	●●●	●●	●●	●●	●●	●●
Koelreuteria paniculata	Golden-rain tree		No	20	●	●●●	●●	●	●	●●	●●●	●●	●●	●●	●●	●
○	poor				*	resistant cultivars only										
●	fair				[1]	invasive plant list for IL, CT, VT, & MA										
●●	good				[2]	invasive plant list for IL, VT, & NM										
●●●	excellent															

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