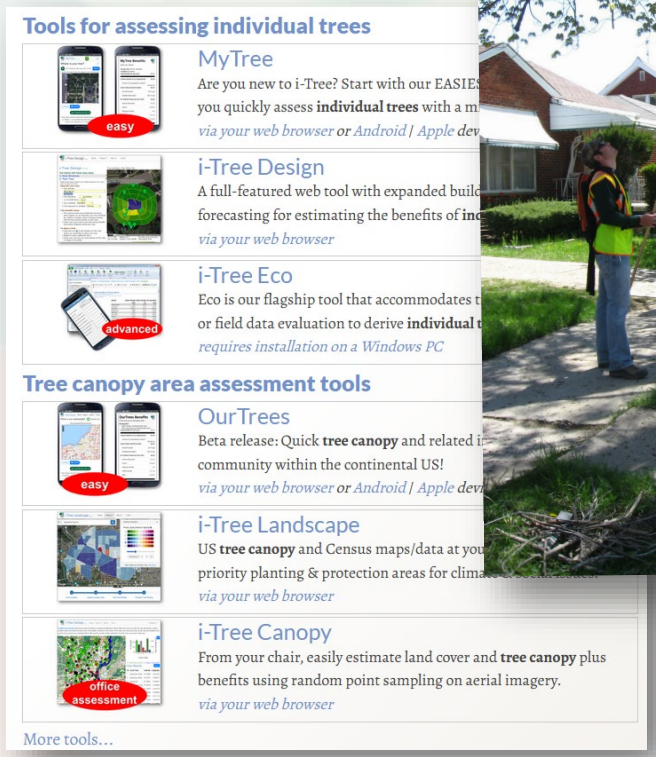
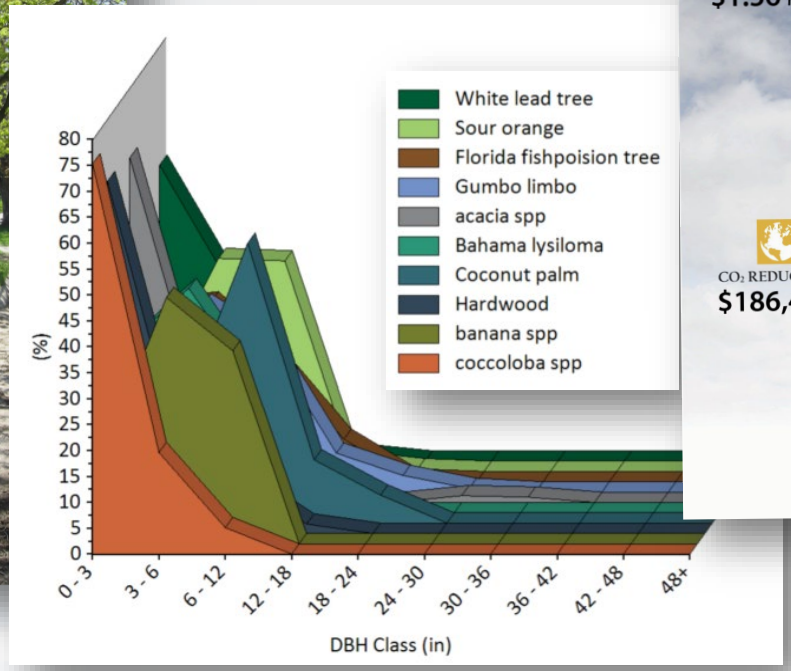
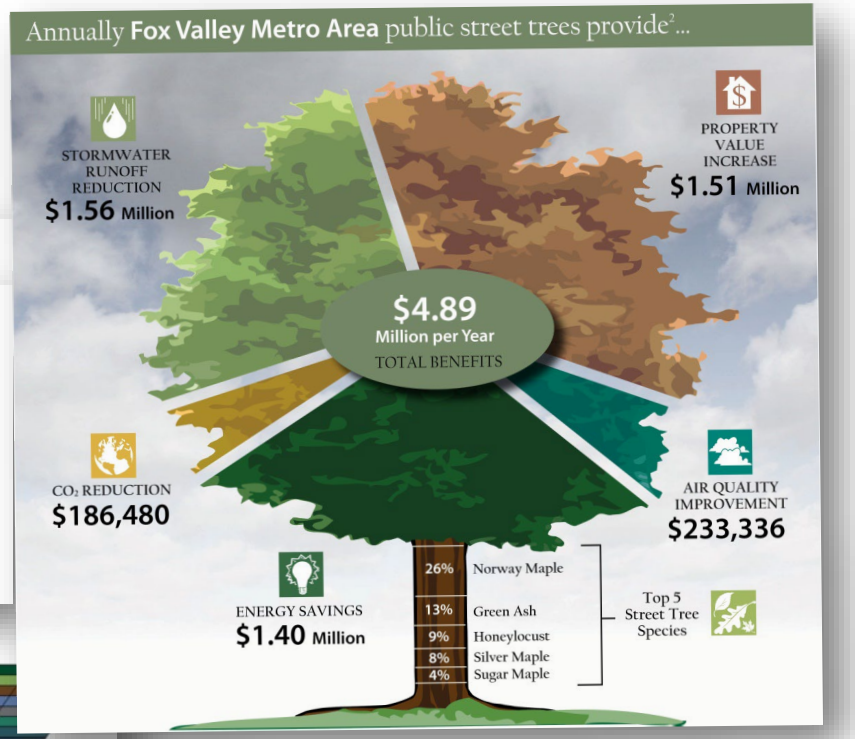
Assessing ecosystem services with i-Tree Eco: methods, approaches, and models







Jason Henning
The Davey Institute and
USDA Forest Service, Philadelphia Field Station

Plan for today…

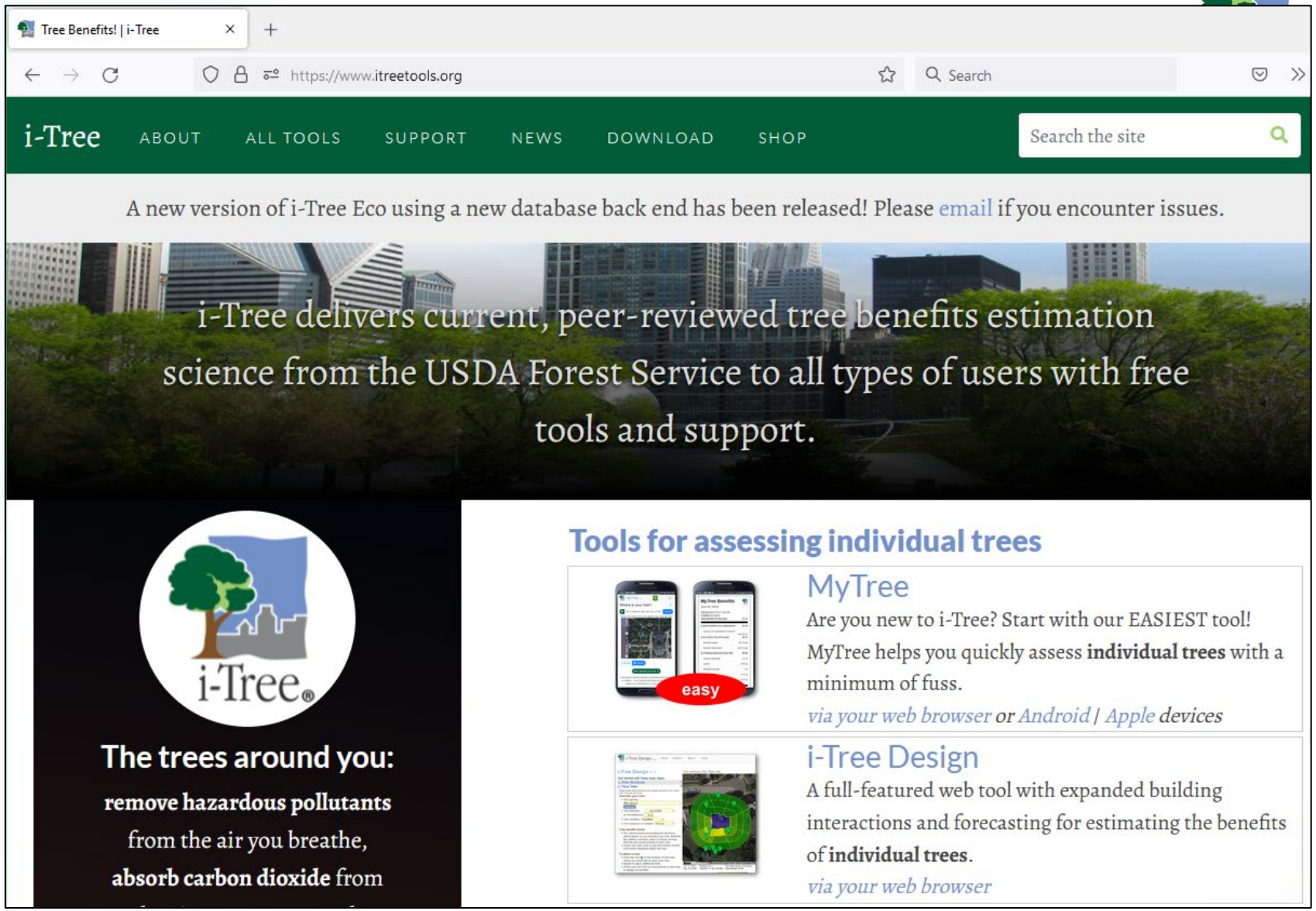
- Introduction to i-Tree
- The core ecosystem services
  - Carbon
  - Air pollution
  - Stormwater
  - Energy

What is i-Tree?

"Putting USFS Urban Forest science into the hands of users"

- Public domain science
- Free tools
- Technical support
- Continuously improved

www.itreetools.org



i-Tree is a Cooperative Initiative

DAVEY

Arbor Day Foundation

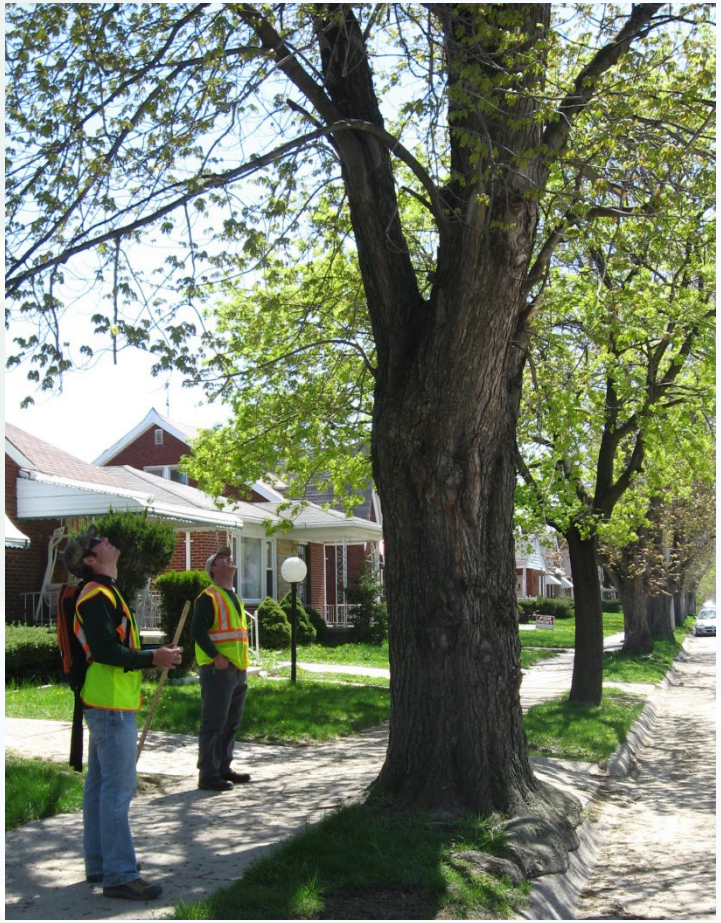
sma SOCIETY OF MUNICIPAL ARBORISTS

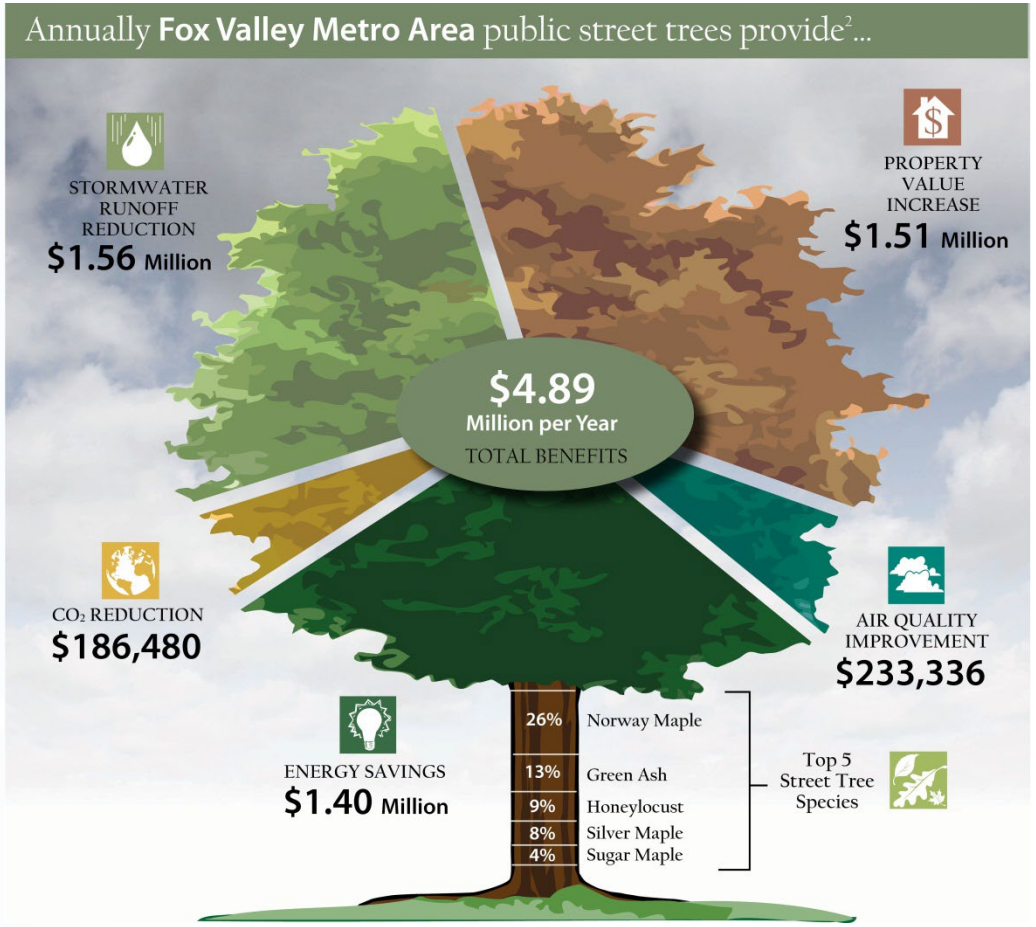
ISA

Casey Trees

ESF

i-Tree: Demonstrating Tree Value

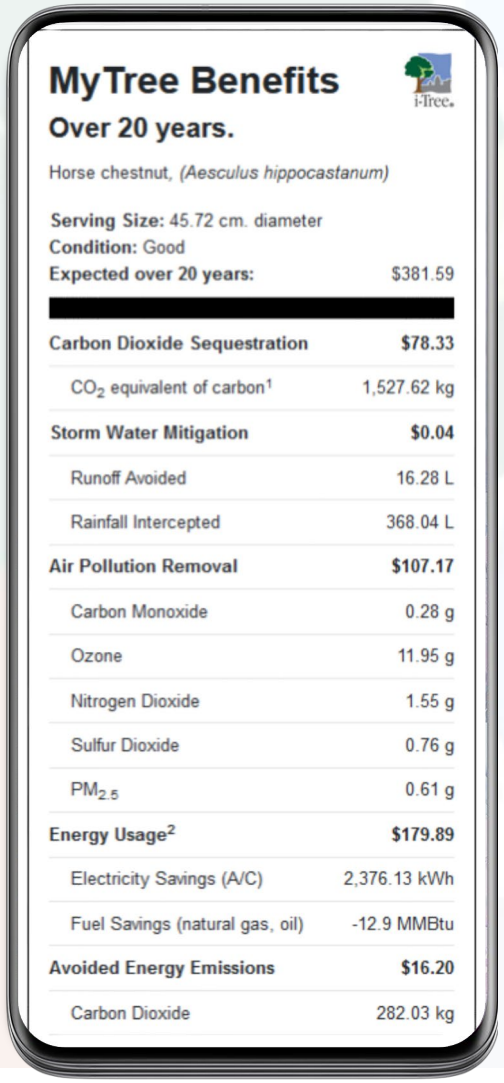




Structure → Function → Value

The 2022 i-Tree International Tools

MyTree



MyTree Benefits

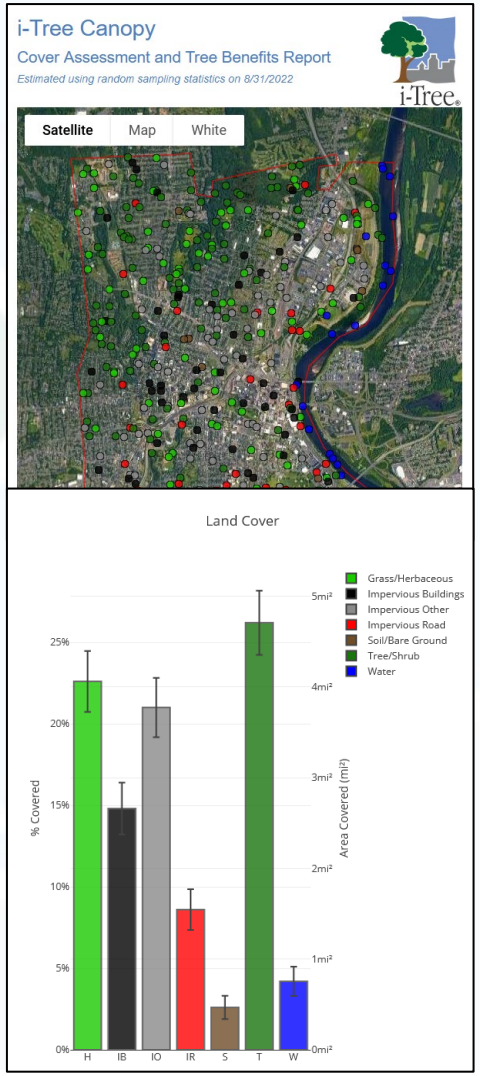
Over 20 years.

Horse chestnut, *(Aesculus hippocastanum)*

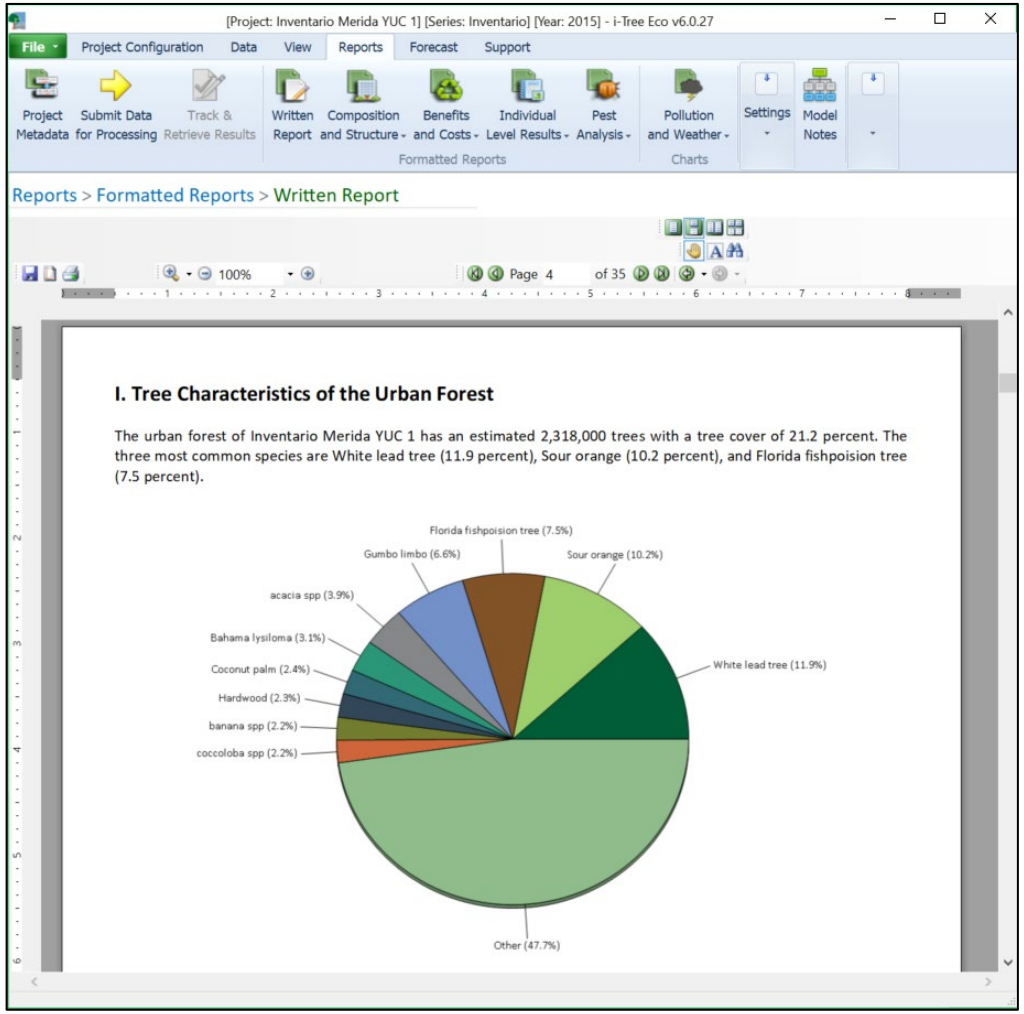
Serving Size: 45.72 cm. diameter
Condition: Good
Expected over 20 years: $381.59

Carbon Dioxide Sequestration	**$78.33**
CO_2 equivalent of carbon[1]	1,527.62 kg
Storm Water Mitigation	**$0.04**
Runoff Avoided	16.28 L
Rainfall Intercepted	368.04 L
Air Pollution Removal	**$107.17**
Carbon Monoxide	0.28 g
Ozone	11.95 g
Nitrogen Dioxide	1.55 g
Sulfur Dioxide	0.76 g
$PM_{2.5}$	0.61 g
Energy Usage[2]	**$179.89**
Electricity Savings (A/C)	2,376.13 kWh
Fuel Savings (natural gas, oil)	-12.9 MMBtu
Avoided Energy Emissions	**$16.20**
Carbon Dioxide	282.03 kg

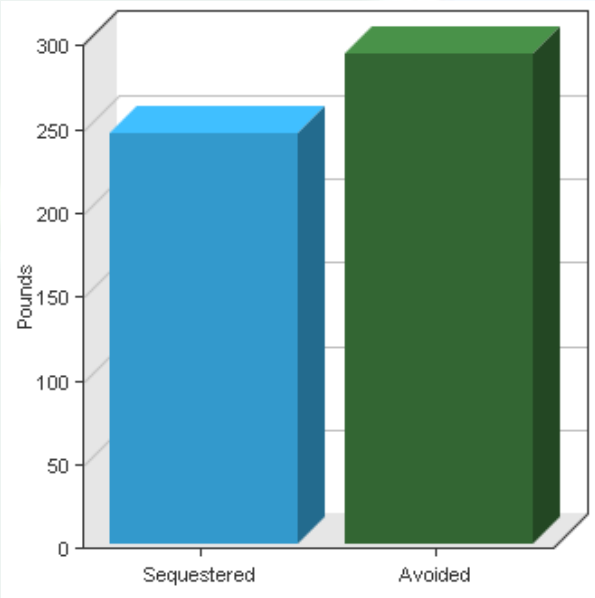
i-Tree Canopy



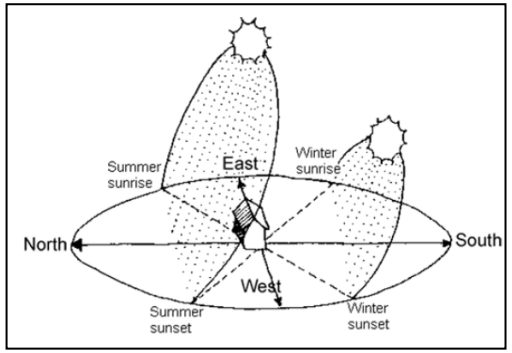
i-Tree Eco



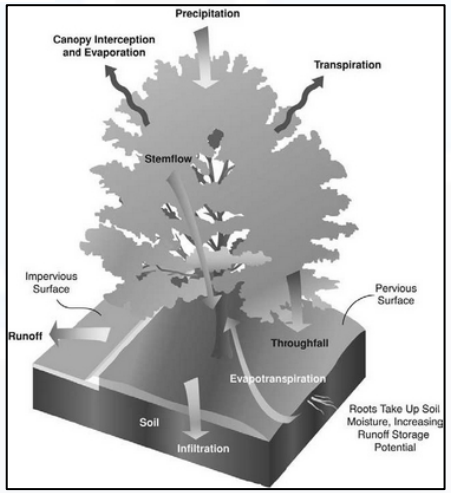
Tree Benefits 101: What does i-Tree Estimate and Why?



Carbon dioxide
Storage and sequestration of a greenhouse gas

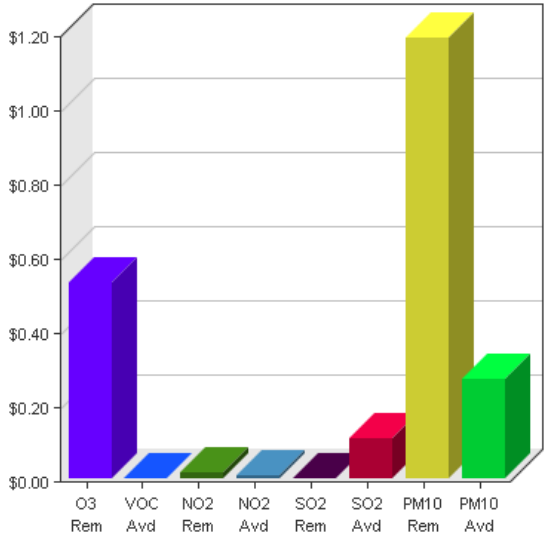


Energy
Tree impacts on heating and cooling



Stormwater
Avoided runoff, evaporation, transpiration

Air Quality
Interaction with EPA criterion pollutants resulting in improved health



Carbon Step 1: Measure tree structure

Tree species = Shumard oak
dbh = 18.3 cm

Crown Light Exposure = 4

Crown dieback = 15%
Total tree height = 4.0 m

Carbon Step 1: Measure tree structure

Required:
Tree species = Shumard oak
d.b.h = 18.3 cm

Default:
Crown Light Exposure = 3

Default: Crown dieback = 17%
Modeled: Total tree height = 3.0 m

Carbon Step 2: Current carbon stored in a tree

Biomass Equations

Table 27.—Dry weight biomass equations, by species, used in i-Tree. x = d.b.h. in cm unless otherwise noted; Y= total tree dry weight biomass in kg unless otherwise noted. DHT: x = d.b.h.2 (cm2) x total tree height (m); AGB = aboveground dry weight biomass. These equations were derived from various sources (see Nowak 1994b, Nowak et al. 2002b, and GlobAllomeTree 2017).

Species	Equation form	A	B	C	D	E	F	G	x	Y
Picea abies	$Y=A+Bx+C^2X+D^3x+E^4x+F^5x$	10	-1.3638	0.4216	0.0041	-3E-05	1E-07			
Picea glauca	$Y=e^{(A+B*Ln(X)+(C/2))}$	-1.73798	2.22809	0.05189						
Picea rubens	$Y=A+Bx+C^2X+D^3x+E^4x+F^5x+G^6x$	0.25	-0.3531	0.2983	0.0041	-4E-05	3E-07	-7E-10		
Picea spp.	$Y=e^{(A+B*Ln(X)+(C/2))}$	-1.87821	2.25867	0.04823						
Pinus banksiana	$Y=A+Bx+C^2X+D^3x+E^4x+F^5x+G^6x$	0.21	-0.1925	0.1914	0.0051	-5E-05	3E-07	-9E-10		
Pinus caribaea	$Y=Ax^B$	0.07035	2.56							AGB (kg)
Pinus contorta	$Y=Ax^B$	0.11886	2.2333							

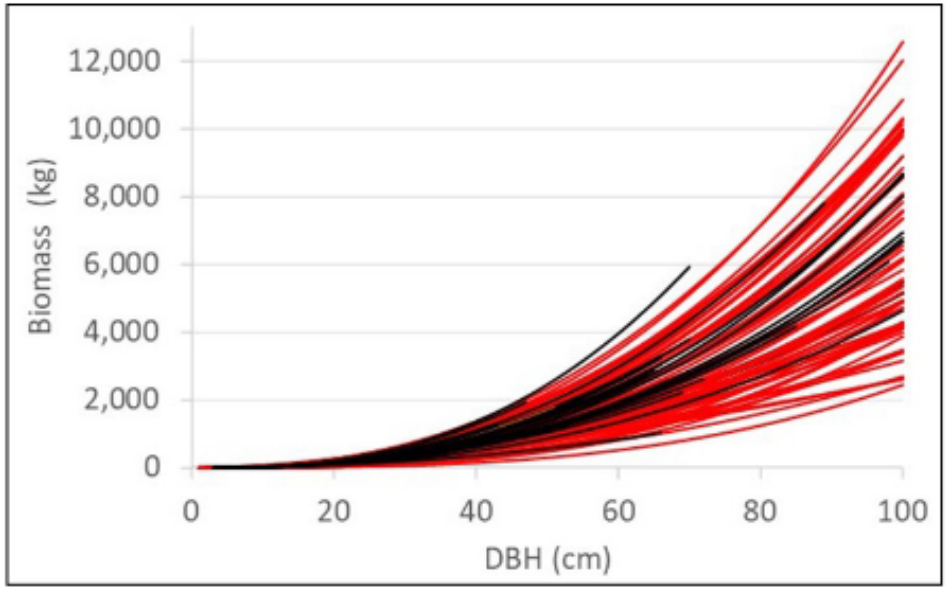


Figure 12.—Estimates of dry weight biomass for numerous species using various equations across a large diameter range. Red lines are i-Tree equation estimates (appendix 10); black lines are estimates from equations from Jenkins et al. (2003). Carbon estimates are one-half of dry weight biomass.

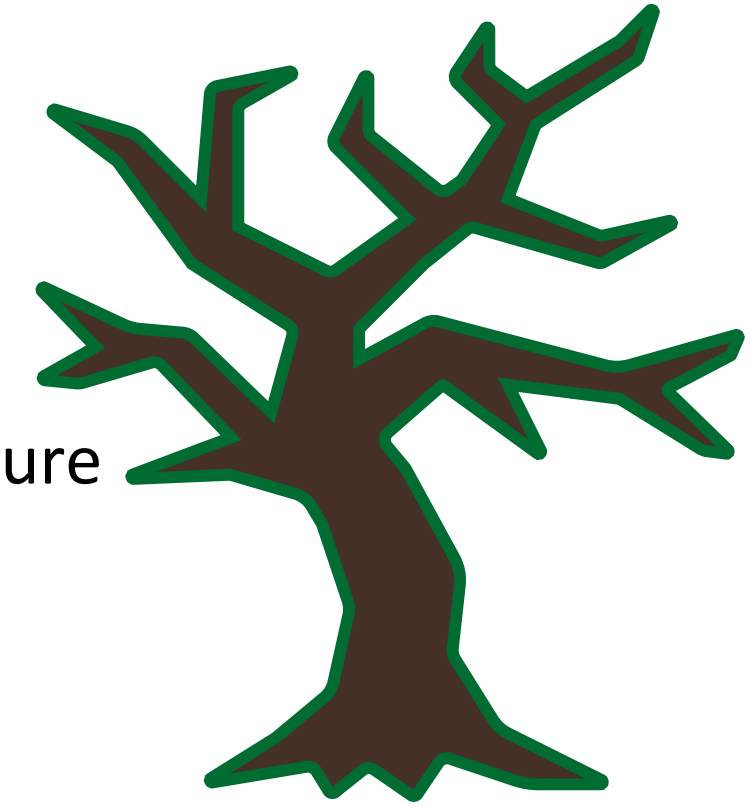
- Estimate tree dry weight biomass from existing species models
- Equations rely on species, dbh, and in some cases height
- Carbon currently stored in the tree is calculated at ½ of biomass

Understanding i-Tree document
https://www.fs.usda.gov/treesearch/pubs/63636

Carbon Step 3: Estimate annual carbon sequestration

Estimate diameter growth

- Average rate for open grown trees = 0.84 cm/yr
- Adjust for growing season length
- Adjust for species (fast, medium, slow)
- Adjust for available sun based on crown light exposure
- Adjust for tree health based on dieback



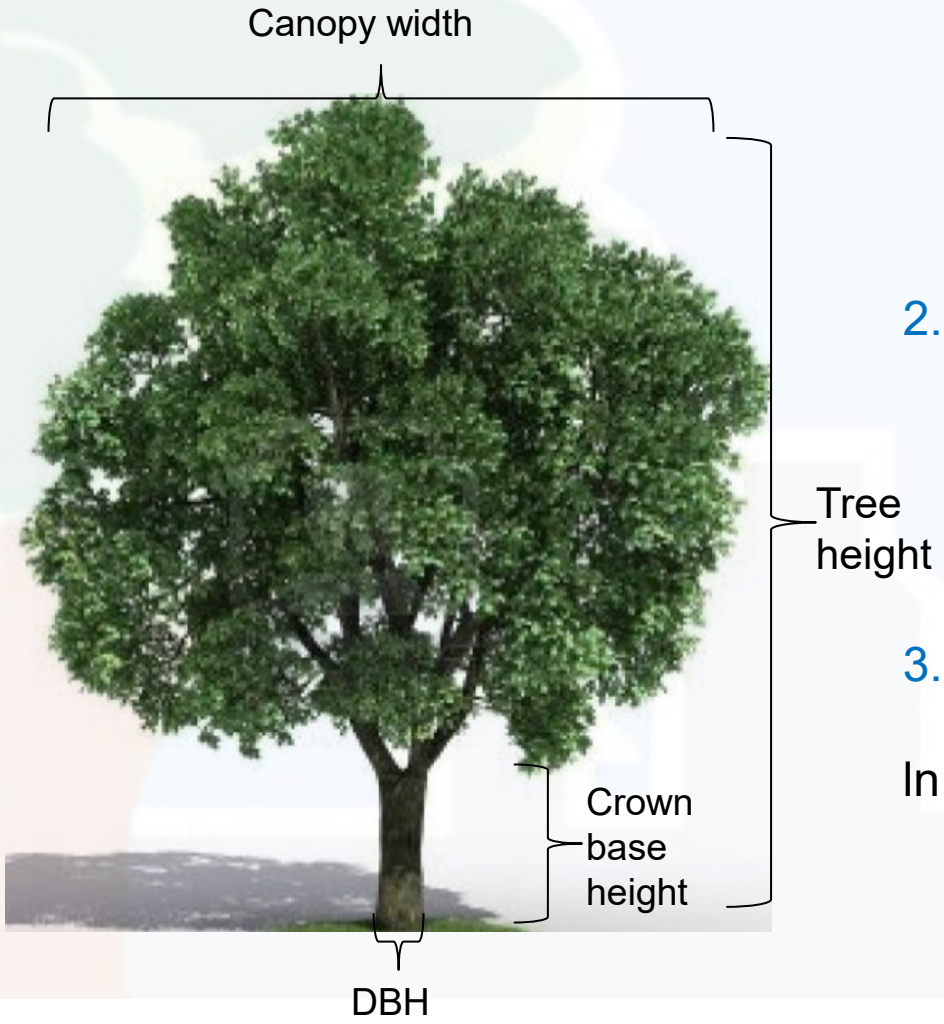
Estimate carbon stored after growth

carbon seq. = carbon stored year 2 – carbon stored in year 1

Monetary value from the US Social Cost of Carbon

Air Pollution Step 1: Estimate tree structure

Leaf surface area

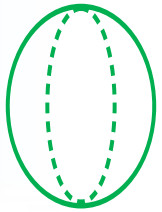


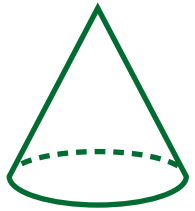
1. With at least dbh and species we can predict crown size measurements

Red maple height = $e^{(2.6393 + (\ln(DBH) * 0.5613))}$

46 cm red maple has an estimate height of 21.3 m

2. With crown size measurements we can estimate crown volume





3. With volume we can estimate leaf surface area

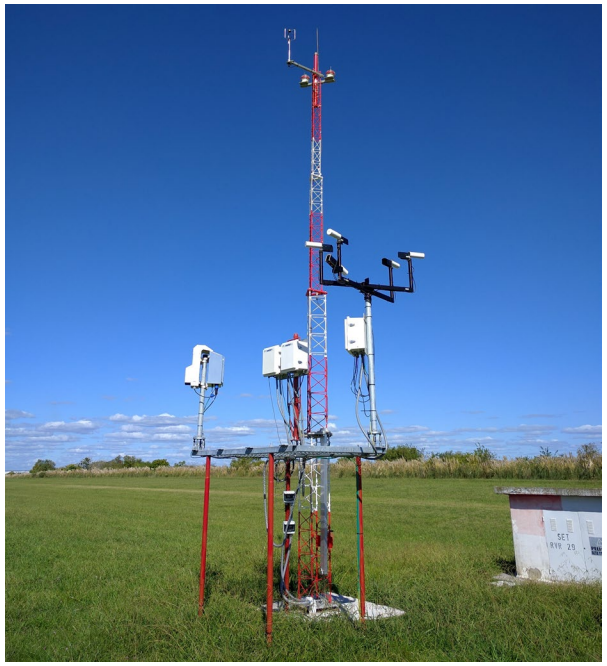
ln (leaf area) = -4.33 + 0.29 * ht +
+0.7312 * crown diam
+ 5.72 * species leaf density
+ -0.015 * crown surface area

Leaf surface area for our 46 cm red maple = **543 sq m**

Air Pollution Step 2: Estimate tree function

Gas exchange - NO_2, O_3, SO_2

Deposition - particulate matter (PM2.5) and CO



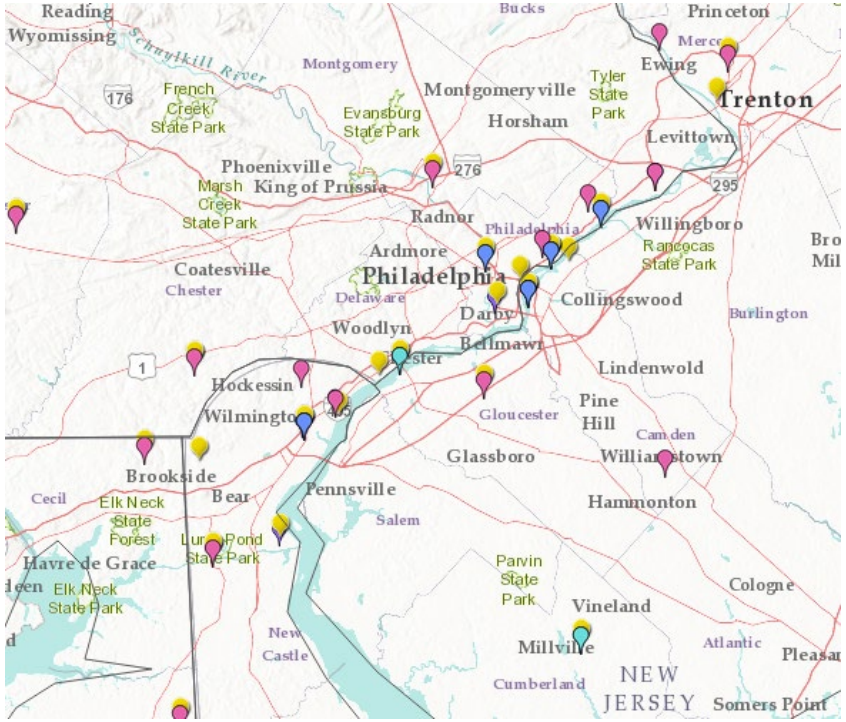
Local hourly weather data:

- windspeed
- sunlight
- rainfall
- humidity

Local hourly pollution data

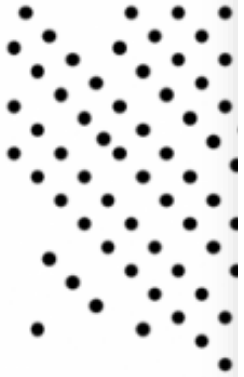
Tree data

- Leaf area
- Leaf on/off dates
- Deciduous vs. evergreen



Air Pollution Step 3: Estimating value pollution removal value

Benefits M



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	PM2.5 Incidence (Reduction/yr)	Value ($/yr)
Acute Bronchitis	0.206	18.12
Acute Myocardial Infarction	0.051	4,543.25
Acute Respiratory Symptoms	112.666	11,043.29
Asthma Exacerbation	88.133	7,164.56
Chronic Bronchitis	0.086	24,042.76
Emergency Room Visits	0.134	55.73
Hospital Admissions		
Hospital Admissions, Cardiovascular	0.030	1,164.32
Hospital Admissions, Respiratory	0.026	821.49
Lower Respiratory Symptoms	2.486	129.08
Mortality	0.285	2,214,131.18
School Loss Days		
Upper Respiratory Symptoms	2.048	91.95
Work Loss Days	19.238	3,298.60
Total	**225.389**	**2,266,504.33**

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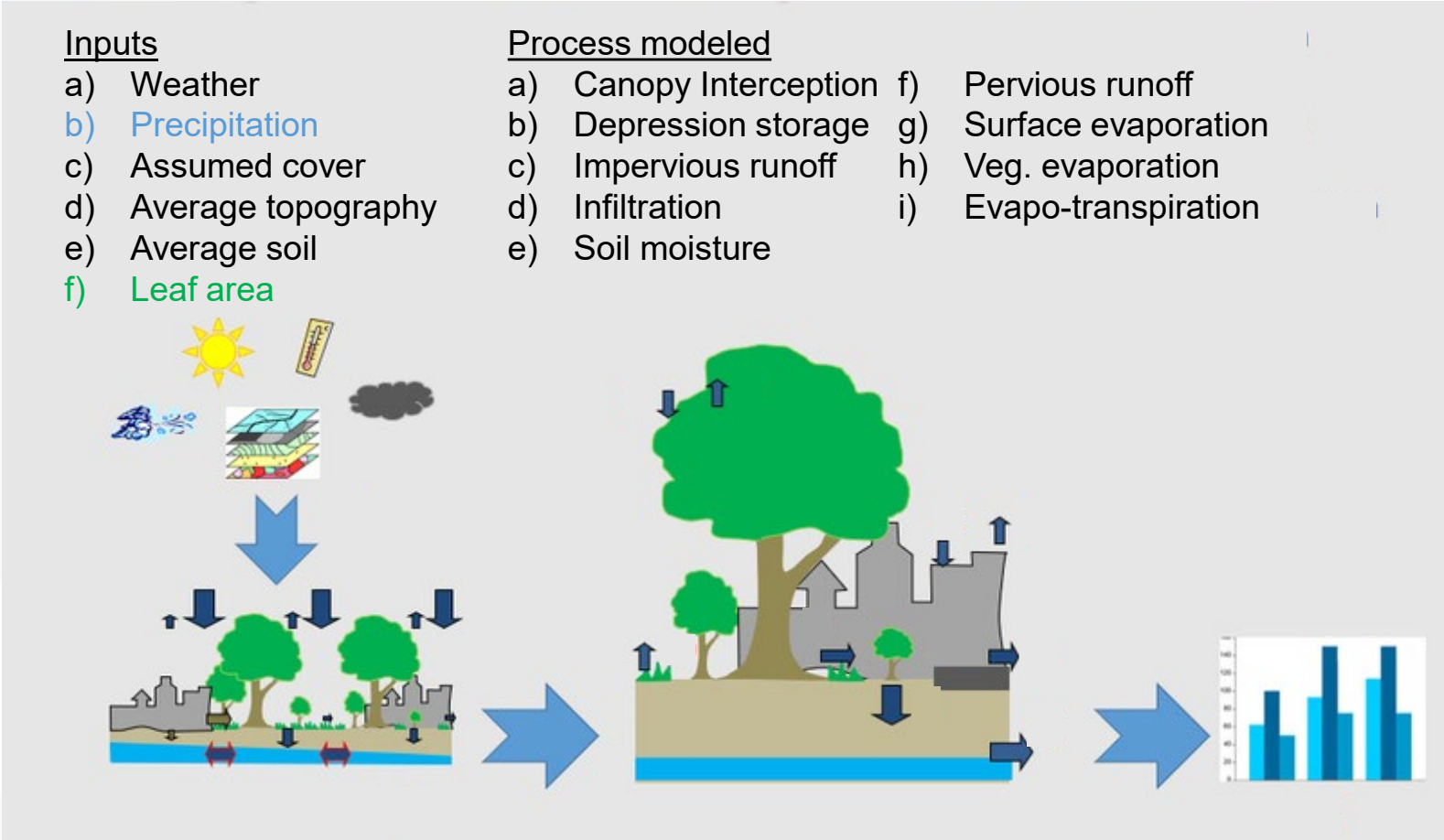
Stormwater

Step 1: Tree/forest structure measurements identical to air pollution to estimate total leaf area

Step 2: Process-based modeling at an hourly time step simulating all hydrology related benefits with and without vegetation

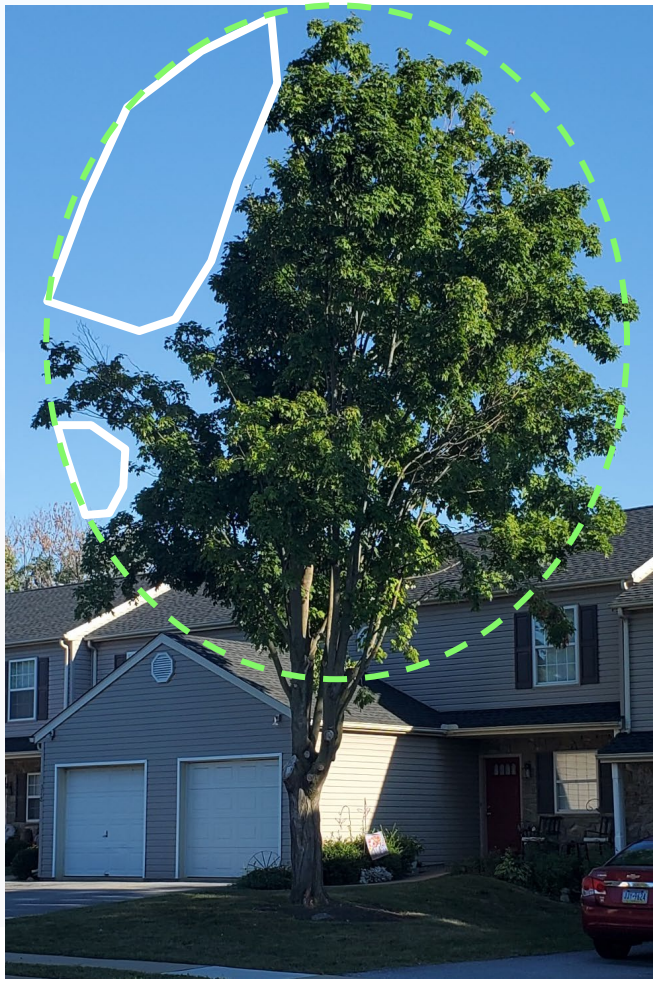
Step 3: Parse benefits to individual trees based on relative leaf area



Energy Step 1: Measure tree structure (within 18 m of house)

Required:
Tree species = Red maple
Total height = 12 m
(can be derived from dbh)

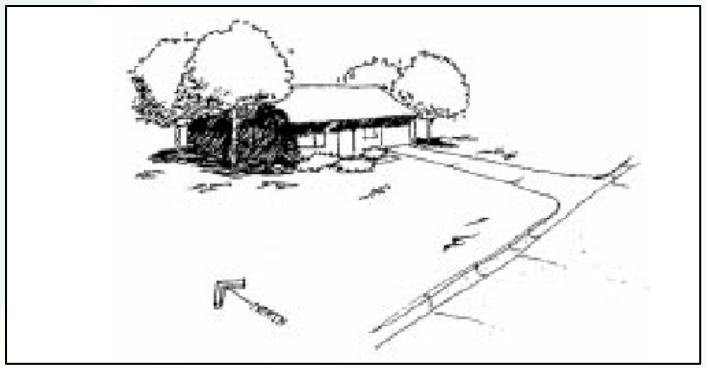
Required or Default:
Crown dieback = 5%
Crown missing = 25%

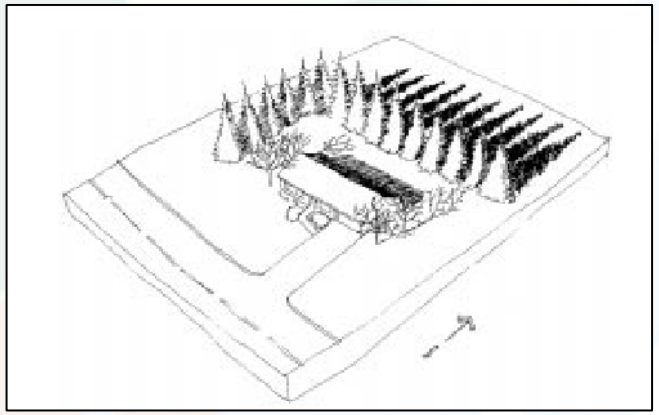


Required: Distance and direction to building
Distance to building = 7.4m
Direction to building = 14 degrees

Energy Step 2: Estimates of function

Shade effects



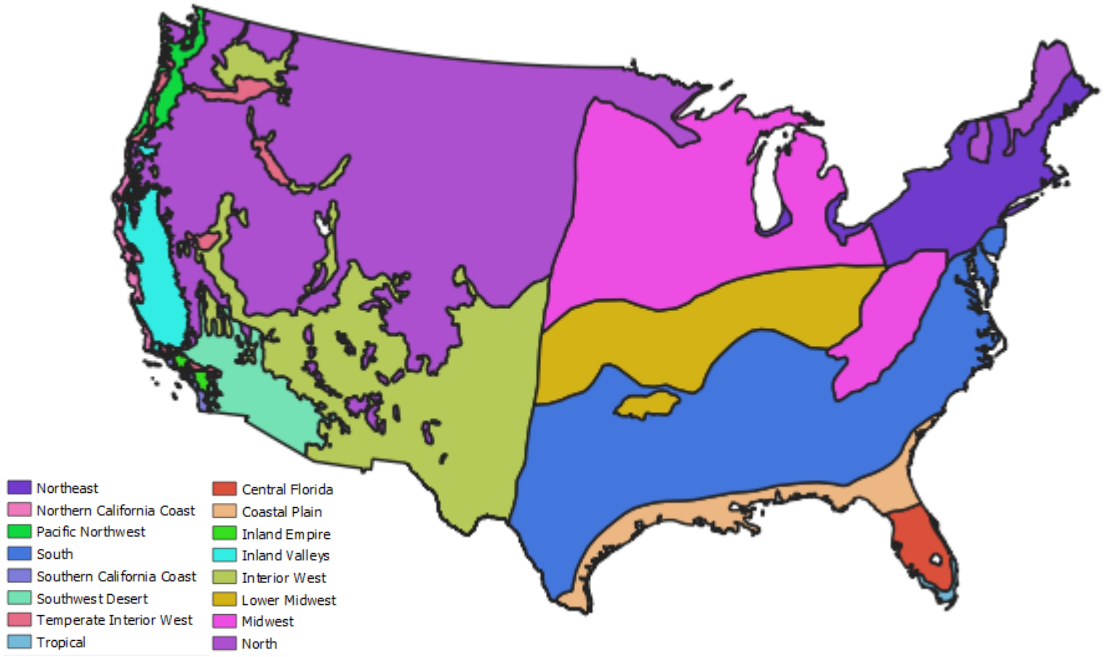


Windbreak effects

Climate effects

Influenced by

- climate region
- building vintage
- tree size
- deciduous vs evergreen
- canopy cover
- distance and direction to building



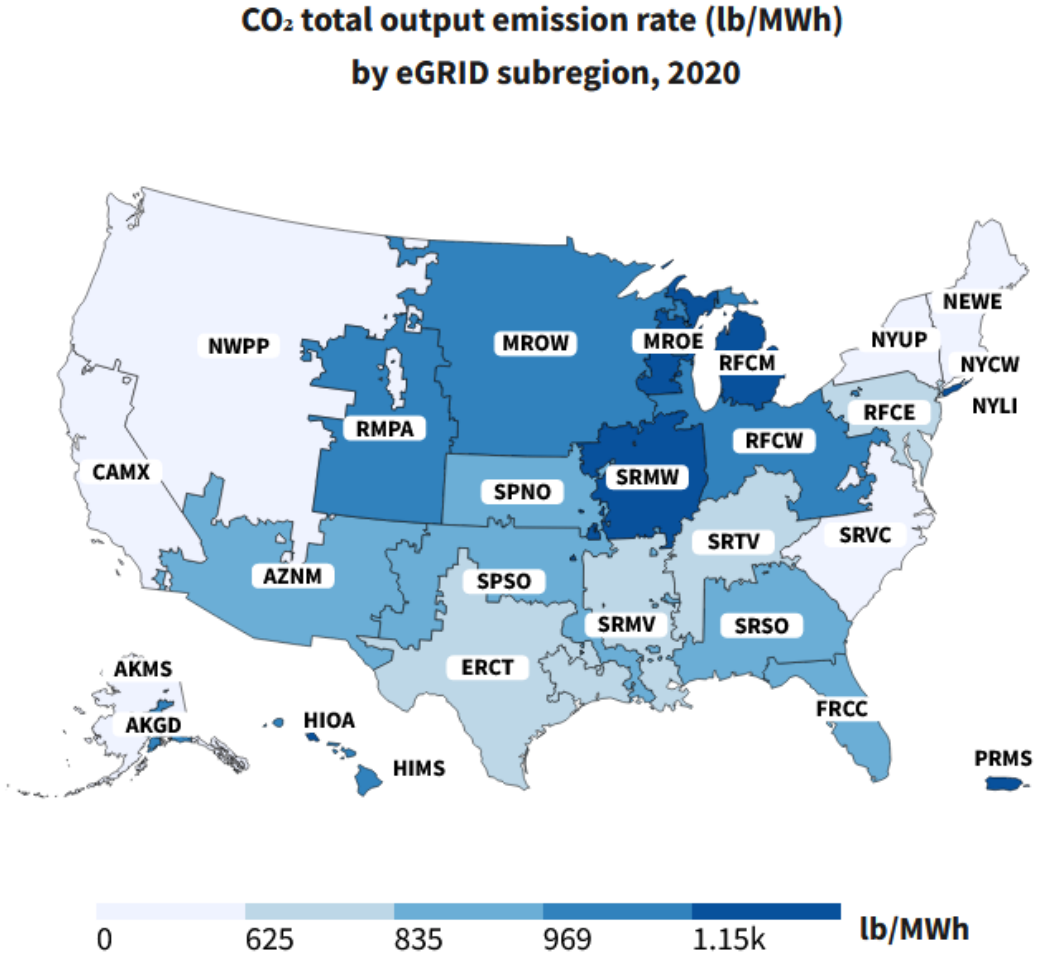
Energy Step 3: Estimate benefits

- Cooling – kwh
- Heating – kwh and therms
- Carbon avoided
- Pollution avoided

State level energy mixes and pollution rates per Therm and kwh from eGRID

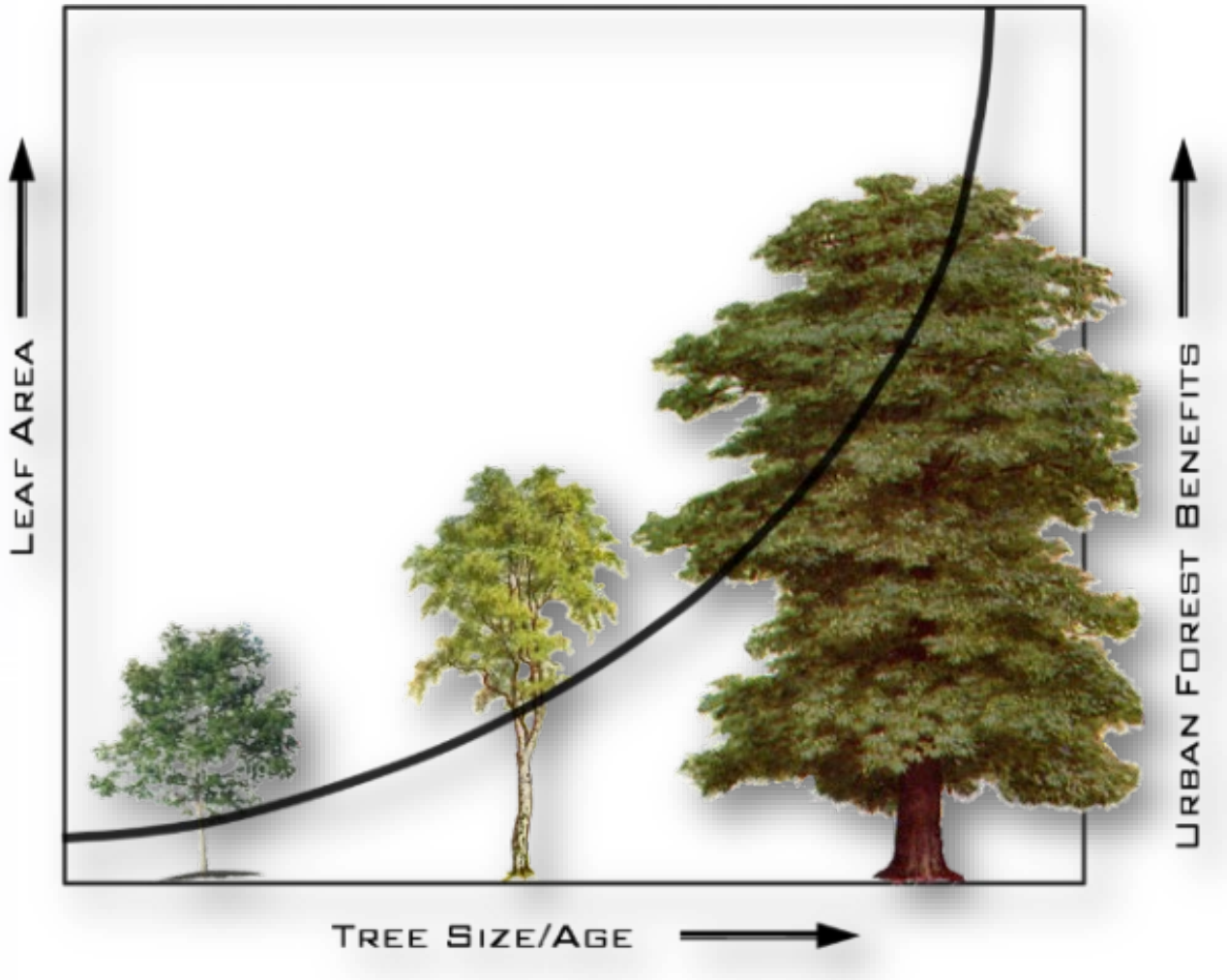
Billing Details Page 2

Previous Balance	$145.80	
Payment Received Jun 27, 2011 - Thank You!	-$145.80	
Balance as of Jul 6, 2011		$0.00
Charges for - Electric Supplier 1234		
Generation & Transmission Charges		
General Service Rate: ESUP for Jun 3 - Jul 5		
Energy Charge 1429 Kwh@ $.0949/Kwh	135.61	
Total Electric Supplier 1234 Charges		$135.61
Charges for - PPL Electric Utilities		
Residential Rate: RS for Jun 3 - Jul 5		
Distribution Charge:		
Customer Charge	8.75	
1,429 kWh at 3.32300000¢ per kWh	47.49	
PA Tax Adj Surcharge at -0.27600000%	-0.16	
Total PPL Electric Utilities Charges		$56.08
Amount Due By Jul 27, 2011		**$191.69**
Account Balance		$191.69



Key points about the science of i-Tree

- Based on research from dozens of different researchers and over 100 publications
- Research is continuously updated
- Estimates are generally conservative
- International estimates often begin based on US conditions, but customization is possible and recommended



For more information…

[Understanding i-Tree]

[i-Tree Methods webpage]

[USFS Treesearch archives]

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