Modeling, Mapping, and Valuing Air Temperature Effects of Urban Vegetation on Human Health

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Background and Motivation

- Tree cover in urban areas provides a myriad of ecosystem services
  - Direct benefits such as aesthetic improvements, noise reduction
  - Indirect benefits through, for example, air temperature changes
    - building energy savings
    - prevention of heat-related health effects and improved comfort
- Why do we need to quantify and value these ecosystem services?
  - Accurate estimates of these benefits can help decision-makers in…..

    …urban planning contexts: Implementation of tree cover projects may be easier to incorporate into budgets and plans by aligning them with specific targets such as reducing urban heat island effects, mitigating air pollution, reducing stormwater run-off, etc.

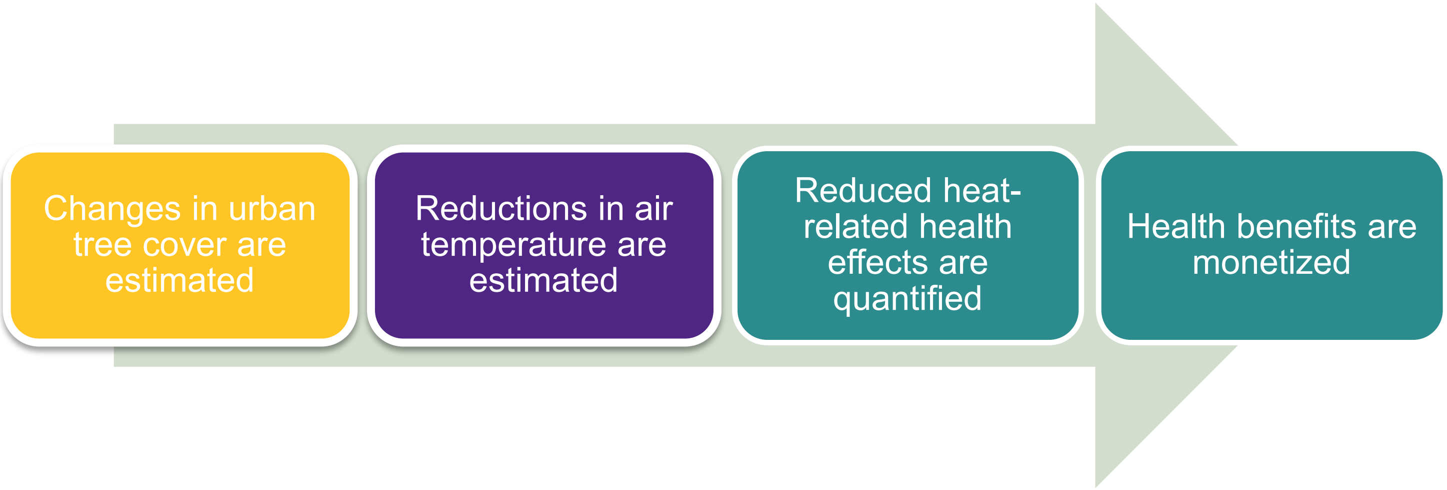
    ….co-benefits contexts: To determine an optimal set of best management practices (BMPs) practices (e.g. reforestation) to achieve clean water in the Chesapeake Bay, it is important to consider ancillary ecosystem service benefits or in addition to improved water quality
- What method/models can we use?
  - i-Tree suite of urban forest modeling tools (US Forest Service): Provides a framework for assessing ecosystem services provided by urban trees

Expanding i-Tree to Include a Temperature Module

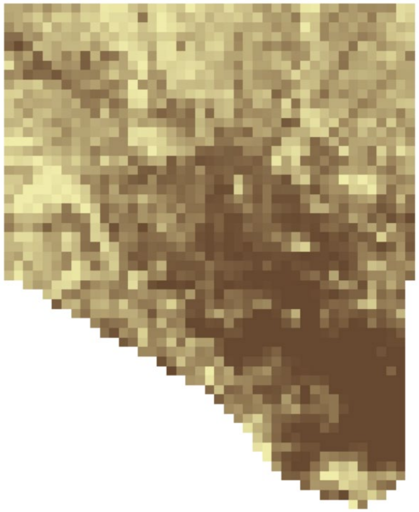
- i-Tree currently quantifies and values many of the benefits provided by urban forests (Nowak et al. 2008, 2013, 2014) :
  - reductions in building energy use and associated power plant emissions
  - stormwater runoff reduction control
  - improvements in public health due to air pollution reduction
- Our study:
  - Expand the suite of benefits in i-Tree to include human health benefits of reduced air temperatures due to presence of urban green cover
  - Case study for Baltimore
- Epidemiological studies show that extreme heat can result in deaths, emergency room visits, hospitalizations, and physician visits
- Health outcomes/endpoints for extreme heat similar to pollution-related ones
  - heat cramps, heat exhaustion and heatstroke
  - exacerbation of chronic conditions, such as cardiovascular disease, respiratory disease cerebrovascular disease and diabetes-related conditions and
  - prolonged exposure can lead to increased hospital admissions and deaths

Four-Step Approach to Quantify and Value Health Benefits

	General i-Tree approach for valuing benefits from trees	Case study-specific approach	Source/Module
1.	Assesses the current forest structure	Changes in tree cover	High resolution land cover maps
2.	Quantify the service provided by structure	Reductions in temperature	Yang et al. 2015
3.	Determine the impact of service	Reductions in heat-related health effects	Epidemiological literature, baseline incidence rates, exposed population
4.	Estimate the value the impact	Value reductions in the risk of death or morbidity	Valuation literature



Step 1. Land Cover Inputs (Current Tree Cover Conditions)



Impervious Cover

Percent

High : 100

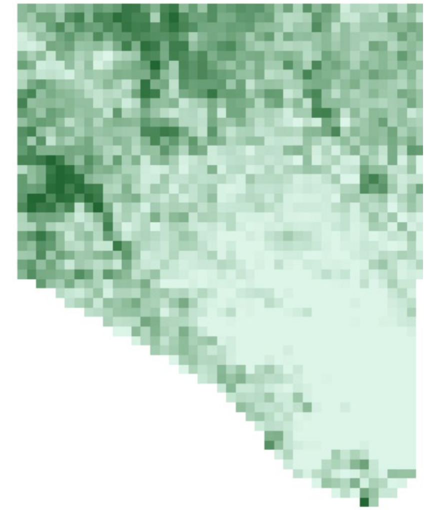
Low : 0

Tree Cover

Percent

High : 100

Low : 0



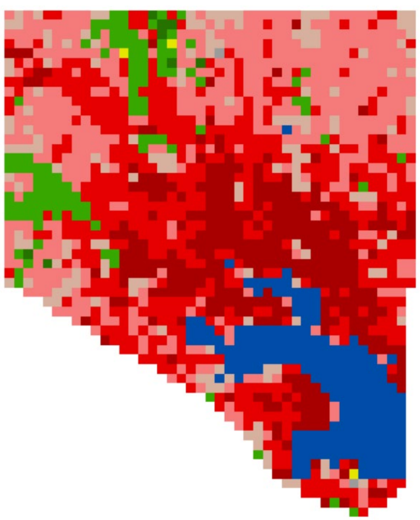
Data Sources

- Impervious, Tree, and Land Cover layers:
  National Land Cover Database (NLCD) 2011

- U.S. Census Block Groups:
  TIGER database 2010

Resolution

370 meter cell size; model is flexible



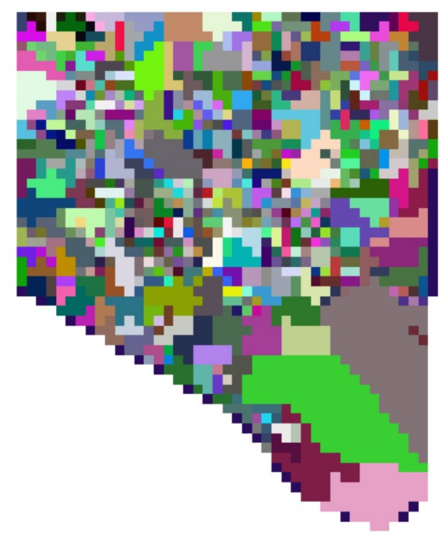
Land Cover

Classes

- 11 - Water
- 21 - Developed, Open Space
- 22 - Developed, Low Intensity
- 23 - Developed, Medium Intensity
- 24 - Developed, High Intensity
- 31 - Barren Land (Rock/Sand/Clay)
- 41 - Deciduous Forest
- 42 - Evergreen Forest
- 81 - Pasture/Hay

Census Block Groups

>560 Groups in Baltimore

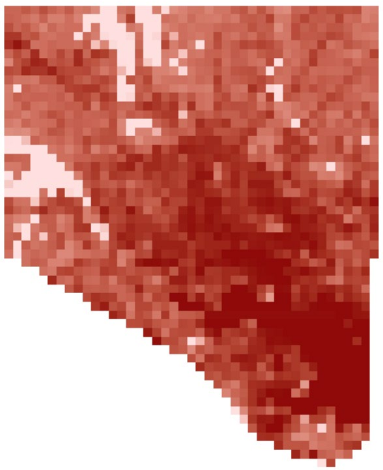


Step 2. Reductions in Temperature

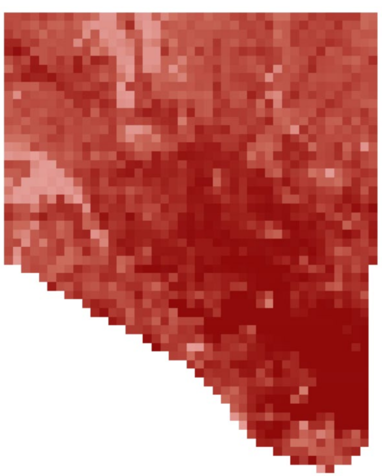
Air temperature (K) for the hottest hour of 2015 in Baltimore, Maryland

July 19, 2015, 16th hour

Current Land Cover



0% Tree Cover Scenario



Statistics
(Air Temperature in Kelvin)

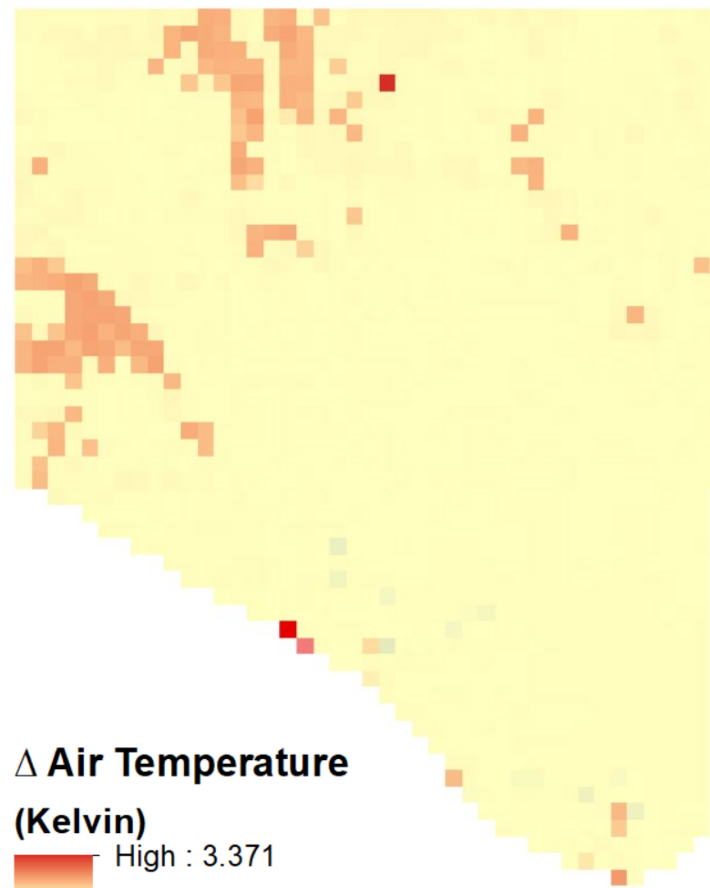
<u>Current TC</u>
Max: 311.01
Mean: 309.34
Min: 304.99

<u>0% TC</u>
Max: 311.01
Mean: 309.41
Min: 306.59

<u>Difference</u>
Max: +3.37
Mean: +0.09
Min: -0.44

Air Temperature (Kelvin)
High : 311.009
Low : 304.987

Δ Alternative – Base Case



Δ Air Temperature (Kelvin)
High : 3.371
Low : -3.371

Step 3. Reductions in Heat-related Health Effects

Health Impact Function (Voorhees et al (2010)):

$$\Delta y = y_0 * (e^{\beta \Delta T} - 1) * P$$

- ΔT is the estimated change in extreme heat
  - Metrics used to characterize “extreme heat” varies widely
  - General consensus: metrics suitable for each location should be used (Example: include humidity when determining ambient temperature in humid areas but less useful in arid climates)
- y_0 is the baseline health incidence rate for the health endpoint
- P is the exposed population
- β represents the relationship between the change in temperature and the health effect
  - Estimates of β are derived from the relative risk or odds ratio measures that are provided by epidemiological studies (e.g. Zanobetti et al., 2012)

- What-if scenario analysis:
  - Assuming average estimates of parameters and a change of 4 degrees in temperature, in a Block Group of about 2000 people, $\Delta y \sim 1$

Step 4. Economic Value of the Avoided Health Impacts

- Estimating the benefits of reduced temperatures in monetary terms
  - **for each prevented health effect and each population sub-group**

$$\Delta B = \Delta y * V$$

- ΔB is the economic value of each avoided health effect due to reduced temperatures
- Δy is the estimated health effect for each population sub-group
- V is an average estimate of the economic value for each prevented health (e.g. Viscusi, 1992)
- Once the dollar values are estimated for each health effect and each age group, they can be aggregated to estimate the total benefits of avoided health effects due to reduced temperatures.

- What-if scenario analysis:
  - Assuming average estimates of parameters and a change of 4 degrees in temperature, in a Block Group of about 2000 people, $\Delta B \sim 8$ million dollars

Next steps

- Implement Steps 3 and 4
- Refine and finalize results for all block groups in Baltimore
- Expand to national context
- Include impacts of temperature on human comfort
  - People prefer milder temperatures and attach a value to level of comfort
  - Human comfort due to milder temperatures cannot be directly measured; people's value for changes in comfort can be elicited by observing where people choose to live.
  - Places with milder seasons attract more people and people are willing to pay more to live in a more desirable city; premium captures the value people attach to milder temperatures. (Albouy, 2012; Albouy et al., 2016; Sinha, Caulkins & Cropper, 2016, 2018)

Questions/ Comments?

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