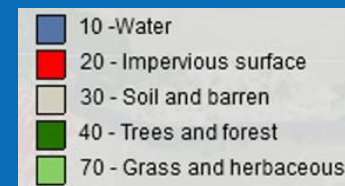


# Meter-scale urban land cover data for EPA EnviroAtlas: methods, examples and use cases

*Drew Pilant, Ph.D., Keith Endres EPA R&D  
Sam Pardo, Daniel Rosenbaum, Chelea Fizer, Charles Rudder,  
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Stephanie Panlasigui, Ali Mackey (SSC/ORISE)*

Land cover  
over air photo

EPA RTP campus



**Introduce EPA EnviroAtlas** [www.epa.gov/enviroatlas](http://www.epa.gov/enviroatlas)

## **Meter-scale Urban Land Cover (MULC) data**

- Motivation
- Land Cover Schema
- Examples
- Supervised and Rule Based Classification and Processing Workflow
- Fuzzy Accuracy Assessment

## **Use cases and Examples**

- Street Trees Planting
- Roadway and Stream Vegetative Buffers
- Urban Heat Island Analysis, Portland, OR
- iTREE model output: carbon sequestration, ambient temperature mitigation, SO<sub>2</sub> reduction

# What is EnviroAtlas?

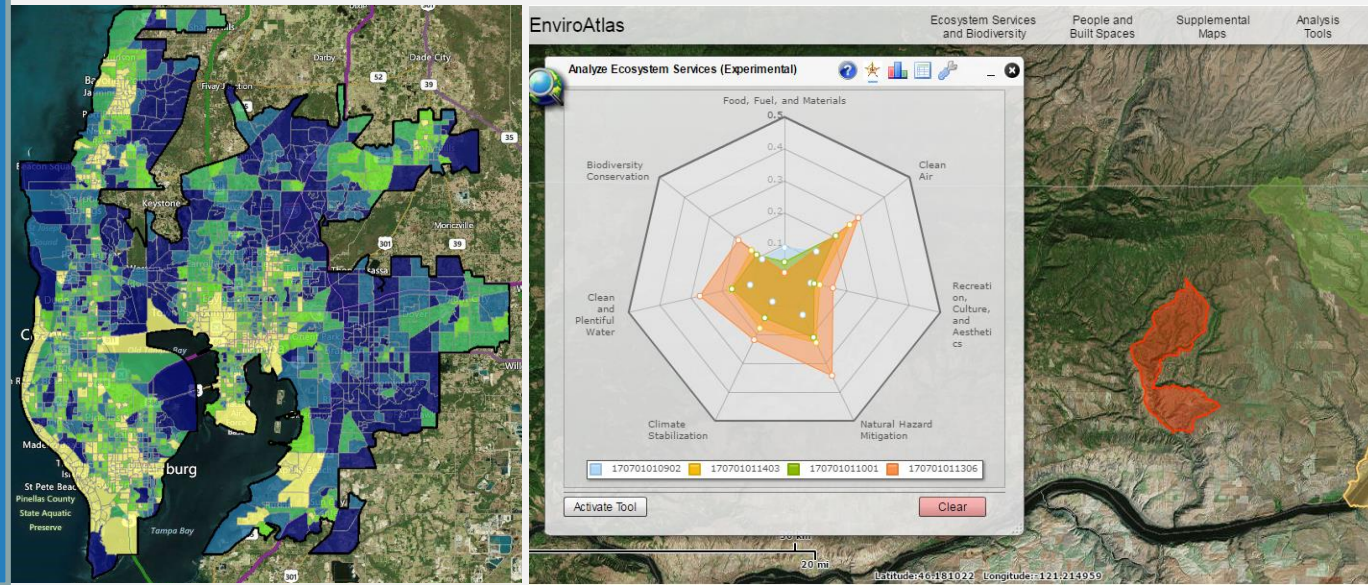
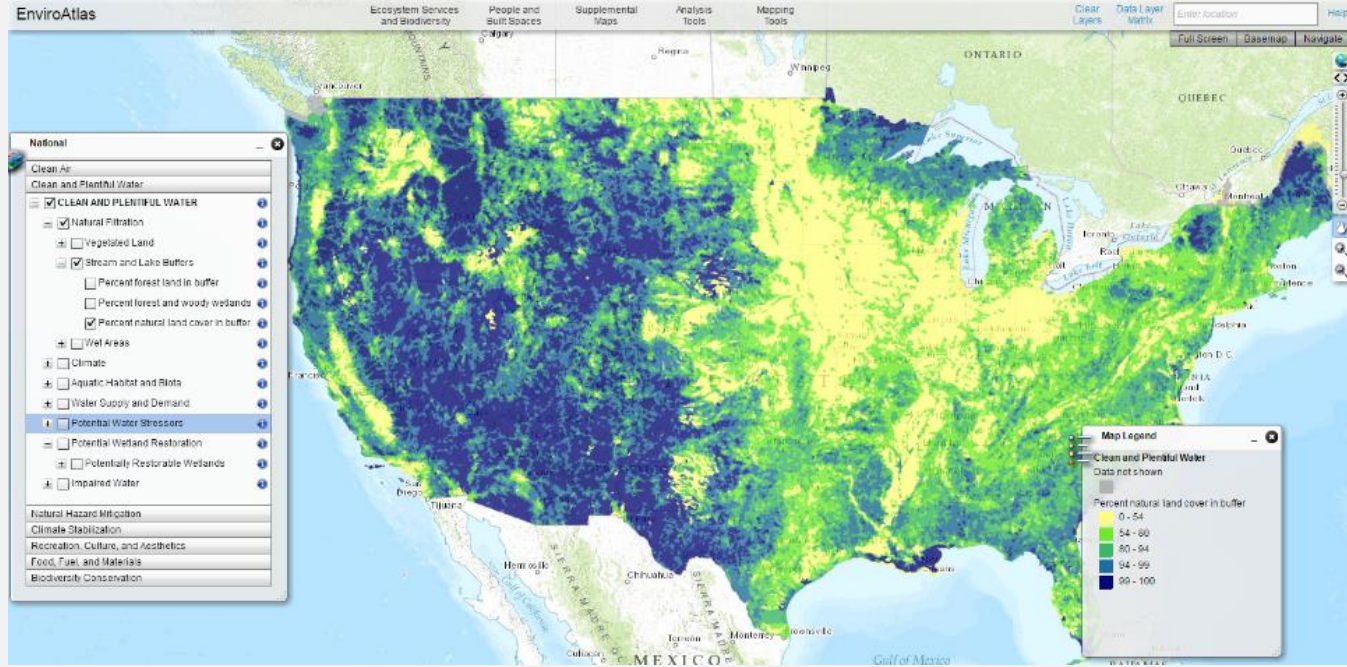
Web-based

Easy to use

Accessible

Centered on EGS

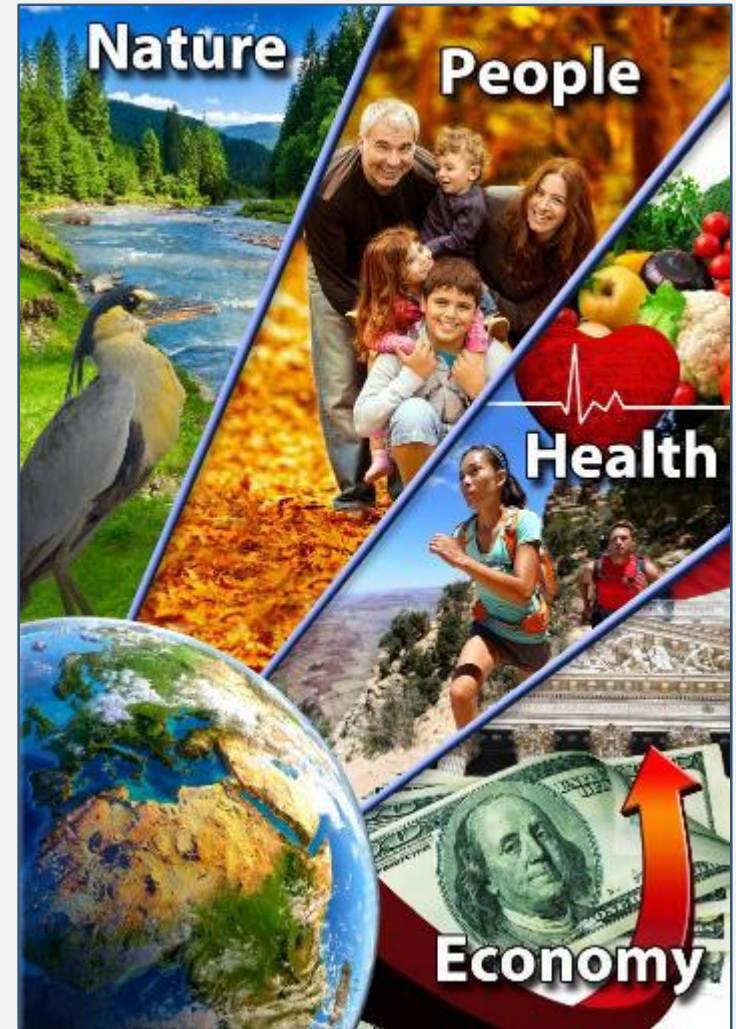
(Ecosystem Goods and Services)





# Why did we build EnviroAtlas?

- Inform efficient, effective, and equitable decision-making by providing access to consistent environmental, social, and economic data
- Facilitate systems approach to decision-making
- Provide data and tools for researchers and educators
- Synthesize research results to make them readily accessible

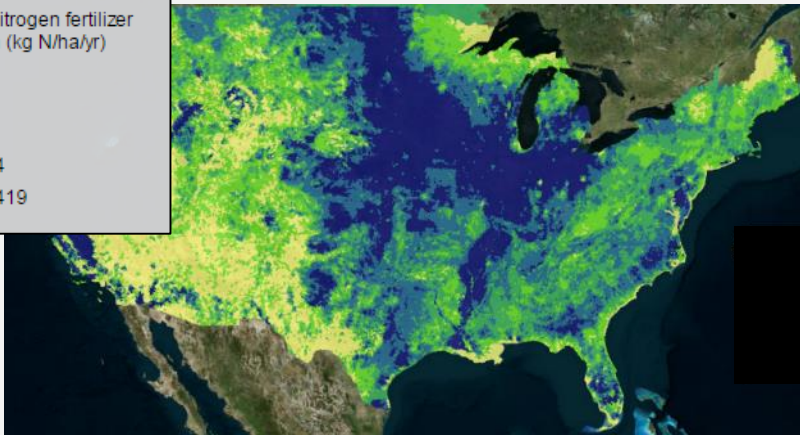
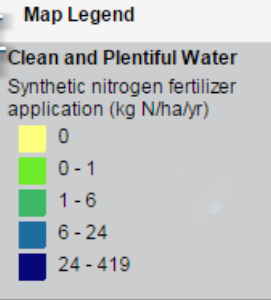


Collaborative effort among multiple Federal agencies and other organizations.

# Interactive Mapping & Screening Tool

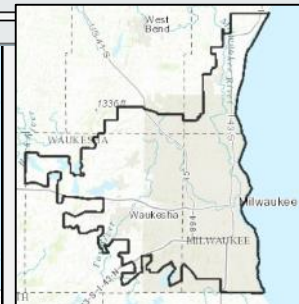
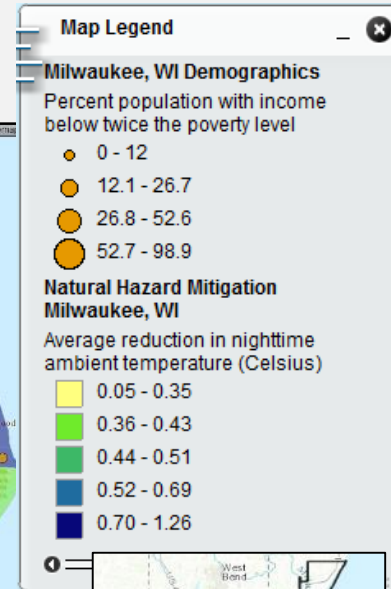
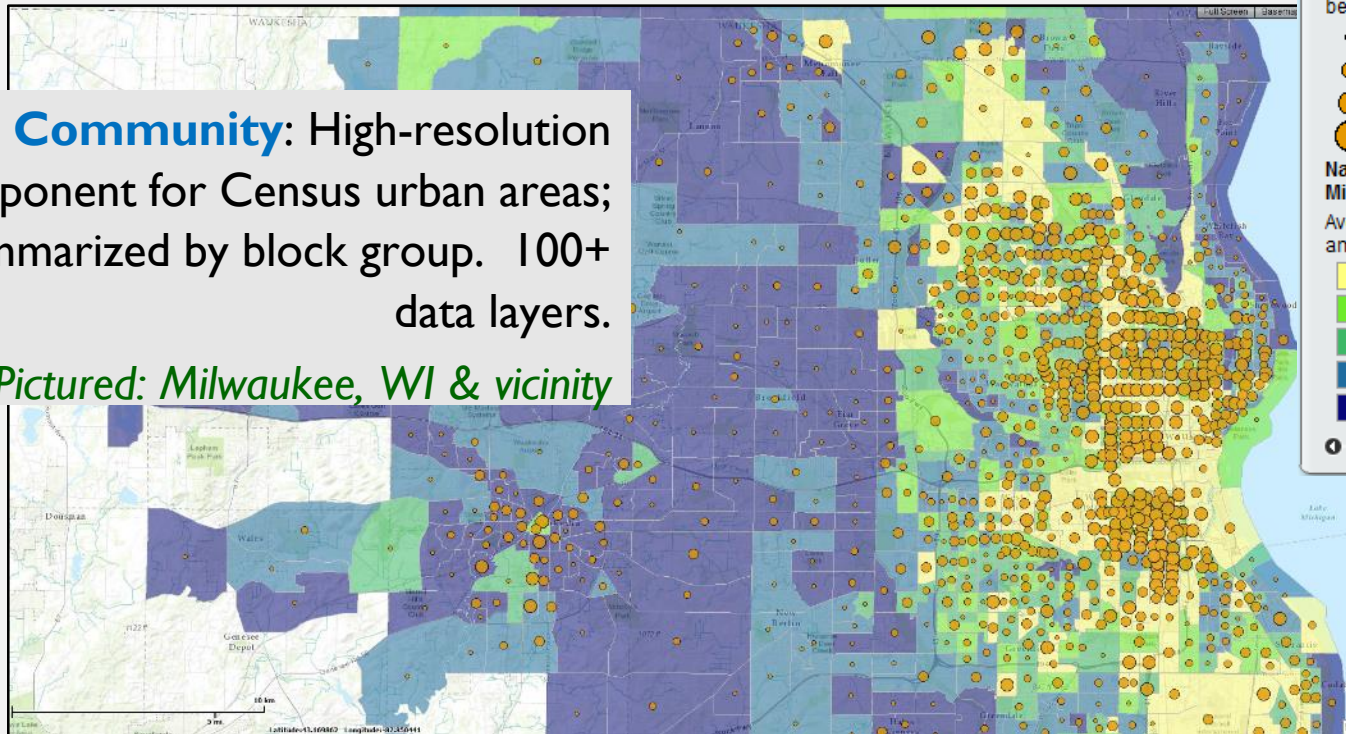
300+ map layers available online

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



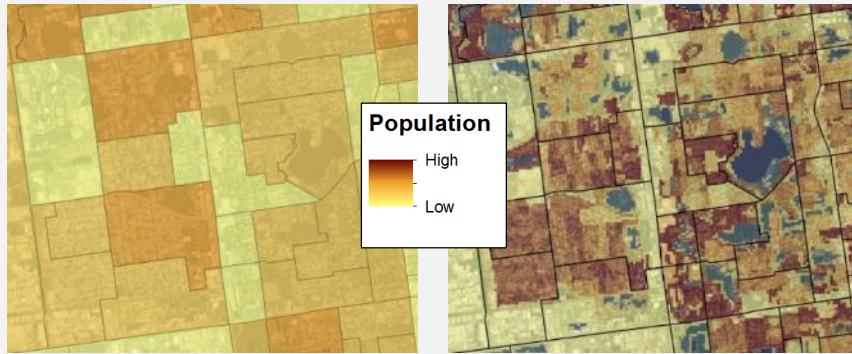
**Community:** High-resolution component for Census urban areas; summarized by block group. 100+ data layers.

*Pictured: Milwaukee, WI & vicinity*

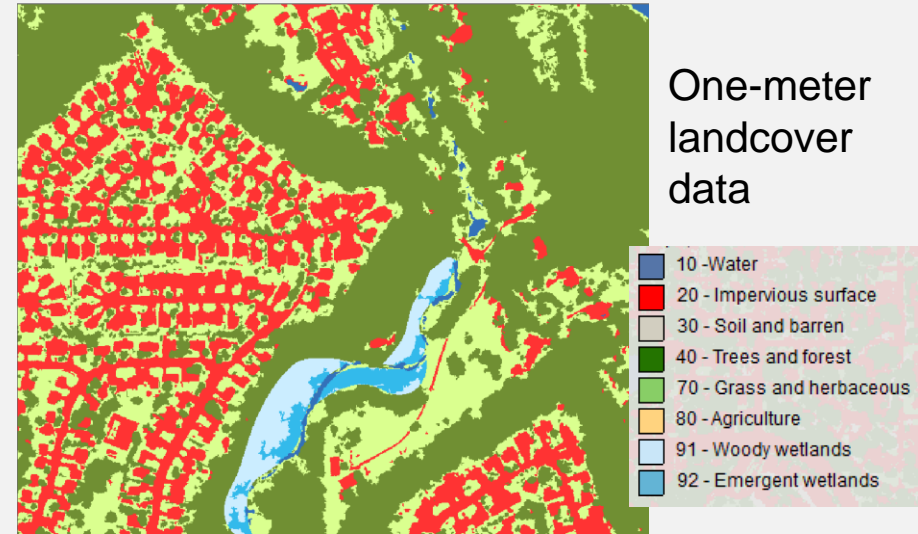




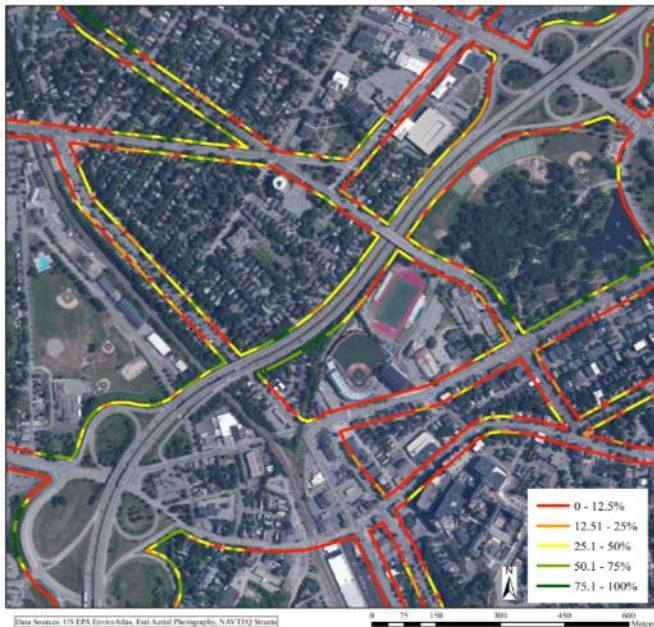
# All Data are Downloadable & Accessible via Web Services (incl. fact sheets for general users and technical metadata)



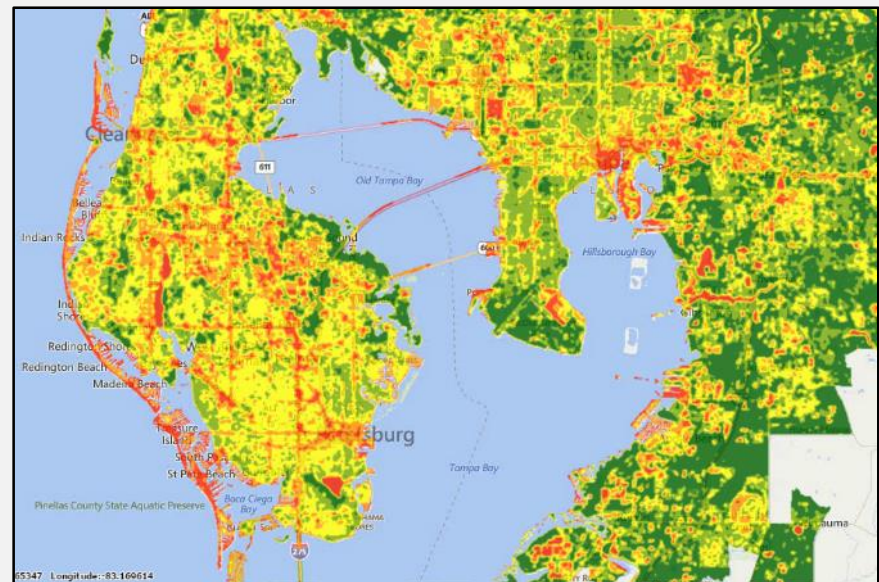
Downscaled (30-meter) U.S. Census population grid



One-meter landcover data



Precise maps of tree cover along roads & streams



Green-to-impervious "heat" maps

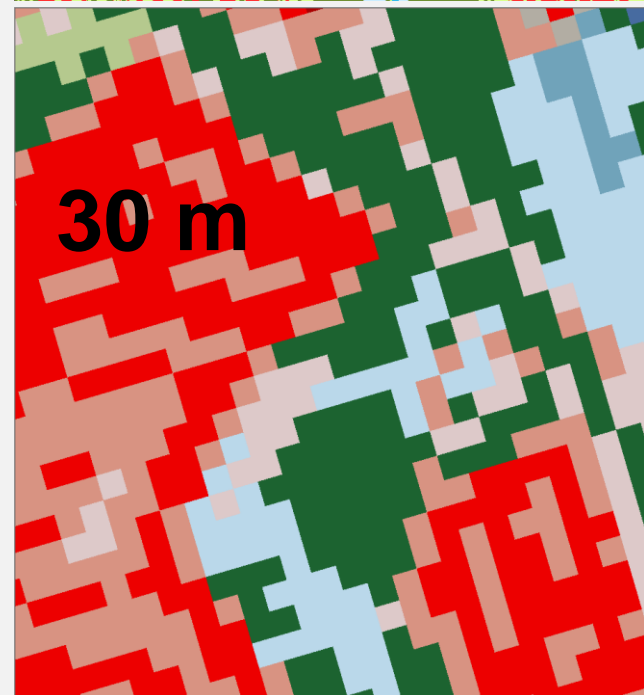
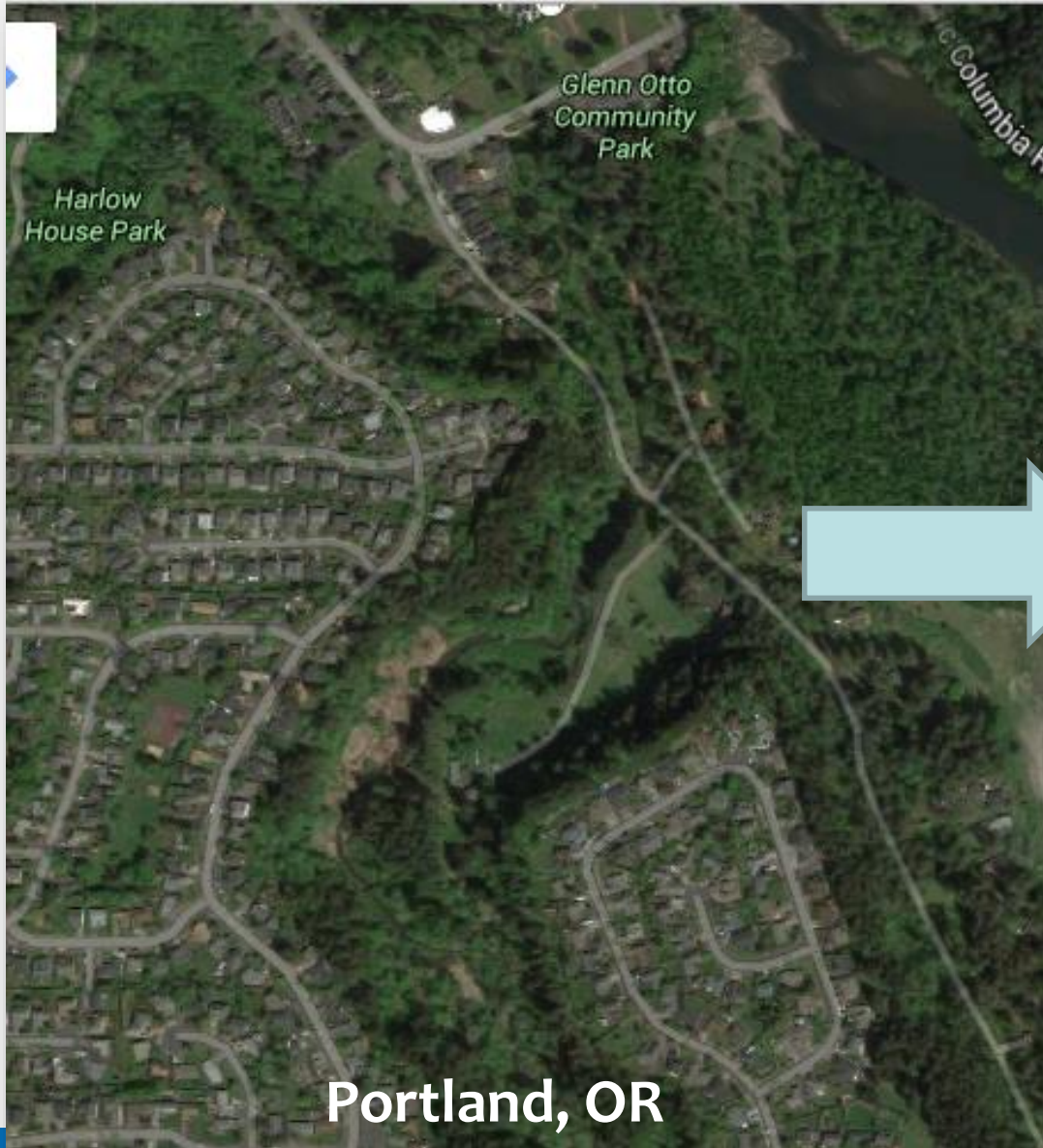


## EnviroAtlas Community Areas



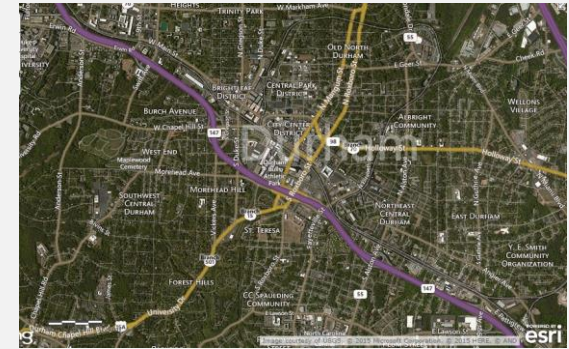
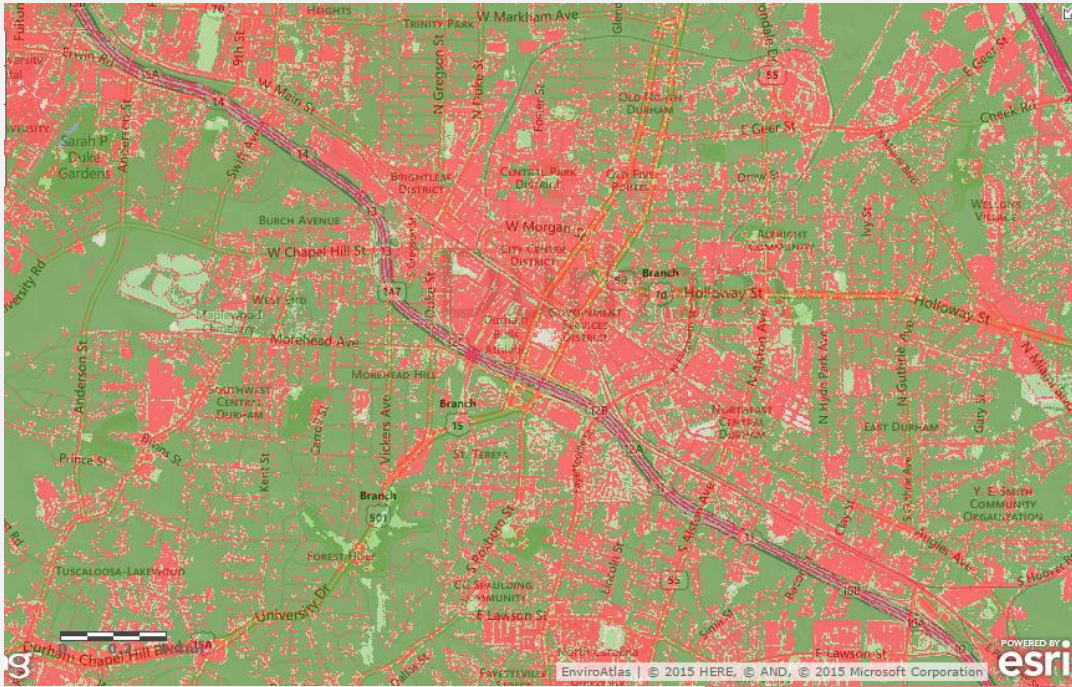


# Compare 1 m and 30 m pixel land cover

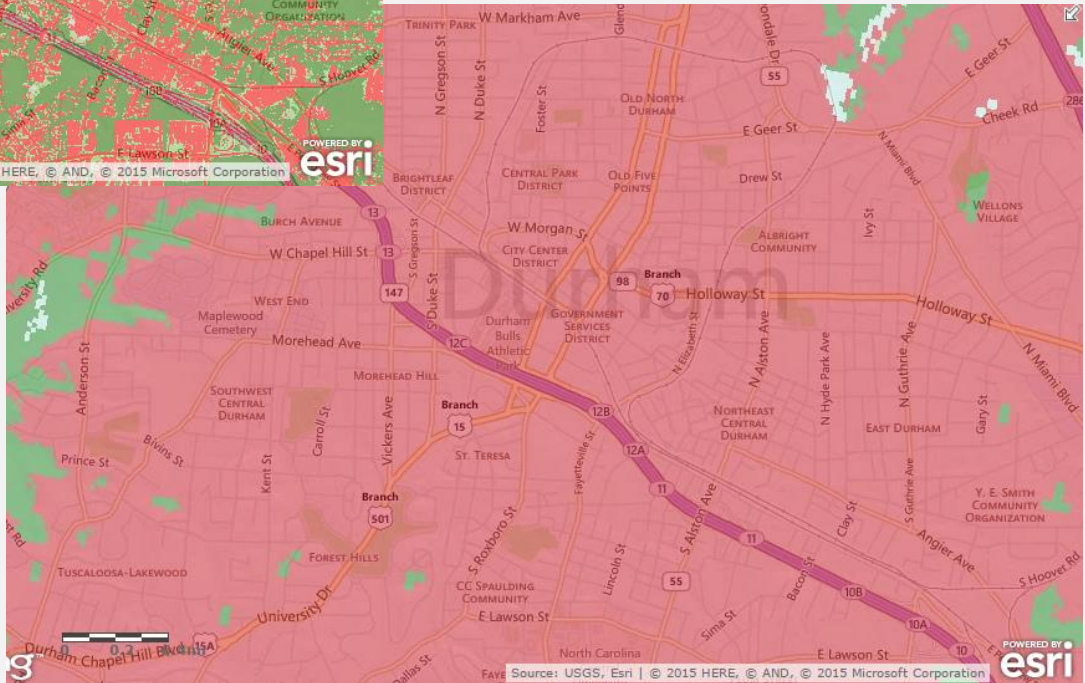




# Compare 1 m and 30 m pixel land cover Durham, NC



↑ 1 m EnviroAtlas MULC



→ 30 m NLCD LC

# EnviroAtlas Meter-scale Urban Land Cover (MULC) Classes

## Legend





## Meter Scale Urban Land Cover Green Bay, WI

Land cover (LC) is the surface components of the land that are physically present and visible, and provides a means to examine landscape patterns and characteristics. This layer is a high spatial resolution urban land cover (ULC) map that quantifies the type and areal extent of the material composition at earth's surface, such as trees, grass, impervious surfaces, water and barren land. It is a foundational layer for the EnviroAtlas community component that serves as input to approximately 85 sustainability and ecosystem services data layers. These ULC data are derived from one-meter-pixel aerial photos, and represent the detailed biophysical landscape of urban life and infrastructure. The ULC classes are similar to the National Land Cover Data<sup>1</sup> (NLCD), but at higher spatial resolution: there are approximately 900 ULC pixels inside the footprint of one 30x30 m NLCD pixel.

### Why is land cover important?

Land cover is the foundation of the terrestrial biosphere, the zone of life on land. LC is the matrix of surface materials in which cities are embedded. LC data are necessary to sound urban planning and sustainable development. Anticipated users of these data include city and county environmental decision makers, water authorities, wildlife and natural resource managers, citizens, teachers and students. Some potential applications of this map include: **stormwater** and urban heat island mitigation; habitat, wildlife corridors and riparian buffers; recreation and access to green space; urban forestry; conservation; and urban landscape ecology. LC data at this high spatial resolution (1 m pixel) are rare. Created from aerial photography, the EnviroAtlas ULC data present a "birds-eye" view that can help identify important features, patterns and relationships in the landscape. Each land cover class has characteristic biophysical properties and processes that contribute to a healthy urban environment.

### How can I use this information?

The ULC data can be used alone or combined visually and analytically with other GIS layers. Approximately 85 EnviroAtlas data layers and metrics incorporate meter-scale urban land cover in their computation, including:

- Total carbon stored in above ground biomass (**mt**)
- Reduction in annual **stormwater** runoff (**m<sup>3</sup>/yr**)
- Value of asthma exacerbation cases avoided due to

sulfur dioxide removed (\$/yr)

- Percent tree cover within 15 m of roadway
- Reduction in median load of nitrites and nitrates, phosphorous, suspended solids, etc. (kg/yr).

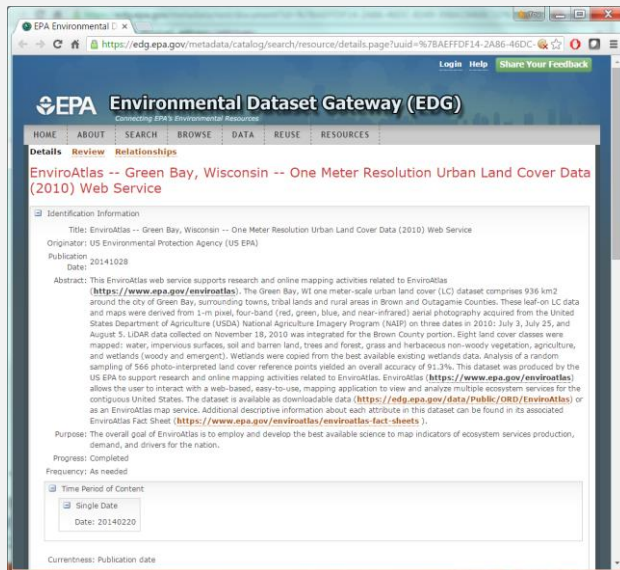
This layer shows land cover patterns that control or influence human and ecosystem health in the urban landscape, and supports numerous lines of investigation. Where are the green and grey spaces? Which streets need more trees? What areas are mostly impervious surface and subject to urban heat island and **stormwater** runoff effects? Do urban streams have healthy vegetated buffers?

Viewing tip: use the Transparency Slider to explore how land cover relates to imagery and other EnviroAtlas layers. Experiment with multiple layer blending using 50-100% transparent land cover overlaid on an imagery **basemap**. The Transparency slider bar is in a dropdown list from the **j**-button to the right of the map layer name.



Figure 1 Green Bay, WI urban land cover overlaid on air photo. Each color represents a specific LC class. Note the fine spatial detail showing individual buildings, trees, and roads.

## Detailed metadata



EPA Environmental Dataset Gateway (EDG)  
Connecting People, Ecosystems, and Resources

HOME ABOUT SEARCH BROWSE DATA REUSE RESOURCES

Details Review Relationships

EnviroAtlas -- Green Bay, Wisconsin -- One Meter Resolution Urban Land Cover Data (2010) Web Service

Identification Information

Title: EnviroAtlas -- Green Bay, Wisconsin -- One Meter Resolution Urban Land Cover Data (2010) Web Service  
Originator: US Environmental Protection Agency (US EPA)  
Publication: 20141028  
Date:

Abstract: This EnviroAtlas web service supports research and online mapping activities related to EnviroAtlas (<https://www.epa.gov/enviroatlas>). The Green Bay, WI one meter-scale urban land cover (LC) dataset comprises 936 km<sup>2</sup> around the city of Green Bay, surrounding towns, tribal lands and rural areas in Brown and Outagamie Counties. These leaf-on LC data and maps were derived from 1-m pixel, four-band (red, green, blue, and near-infrared) aerial photography acquired from the United States Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) on three dates in 2010: July 3, July 25, and August 5. LiDAR data collected on November 18, 2010 was integrated for the Brown County portion. Eight land cover classes were mapped: water, impervious surfaces, soil and barren land, trees and forest, grass and herbaceous non-woody vegetation, agriculture, and wetlands (woody and emergent). Wetlands were copied from the best available existing wetlands data. Analysis of a random sampling of 566 photo-interpreted land cover reference points yielded an overall accuracy of 91.3%. This dataset was produced by the US EPA to support research and online mapping activities related to EnviroAtlas. EnviroAtlas (<https://www.epa.gov/enviroatlas>) allows the user to interact with a web-based, easy-to-use, mapping application to view and analyze multiple ecosystem services for the contiguous United States. The dataset is available as downloadable data (<https://edg.epa.gov/data/Public/ORD/EnviroAtlas>) or as an EnviroAtlas map service. Additional descriptive information about each attribute in this dataset can be found in its associated EnviroAtlas Fact Sheet (<https://www.epa.gov/enviroatlas/enviroatlas-fact-sheets>).

Purpose: The overall goal of EnviroAtlas is to employ and develop the best available science to map indicators of ecosystem services production, demand, and drivers for the nation.

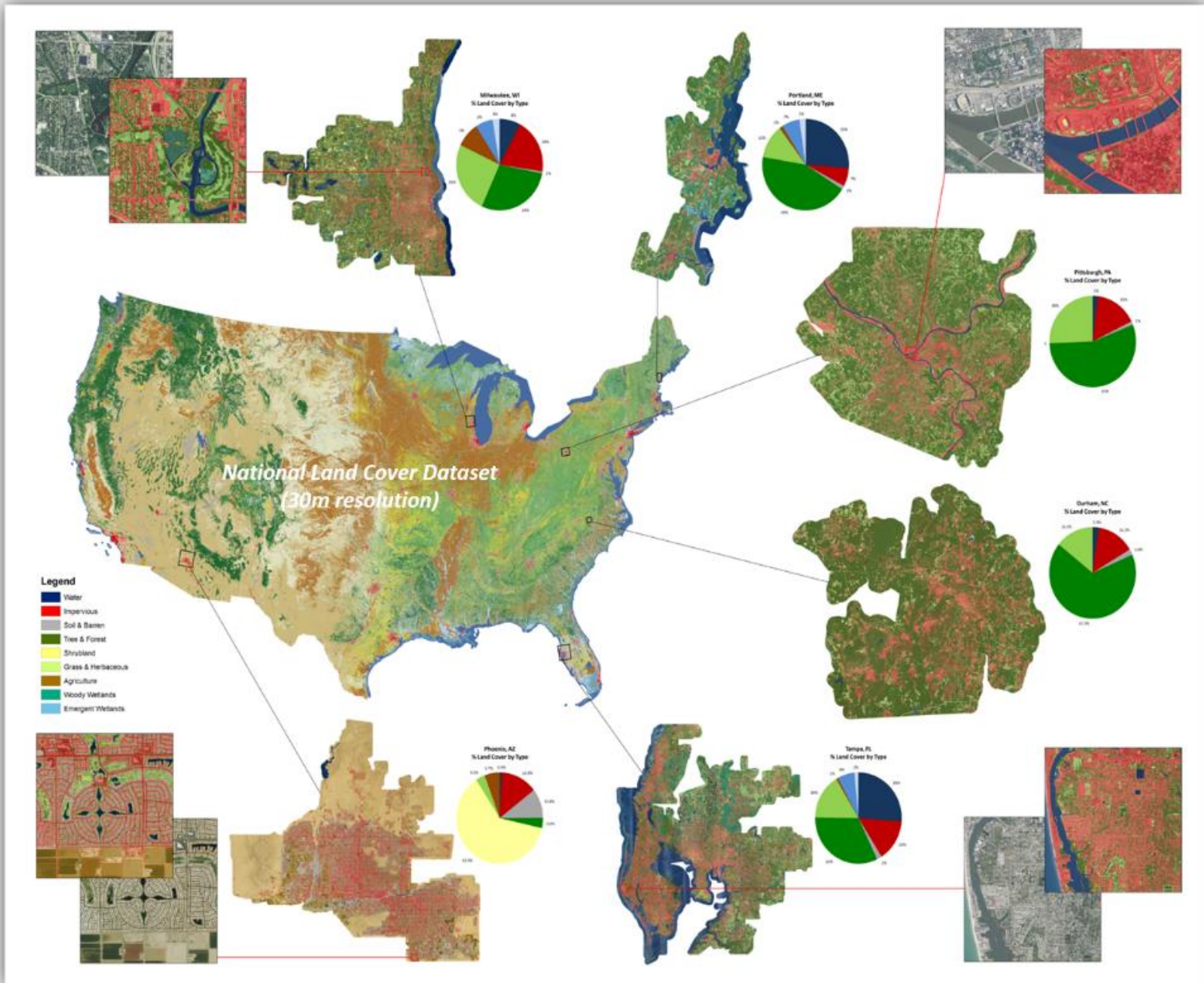
Progress: Completed  
Frequency: As needed

Time Period of Content

Single Date  
Date: 20140229

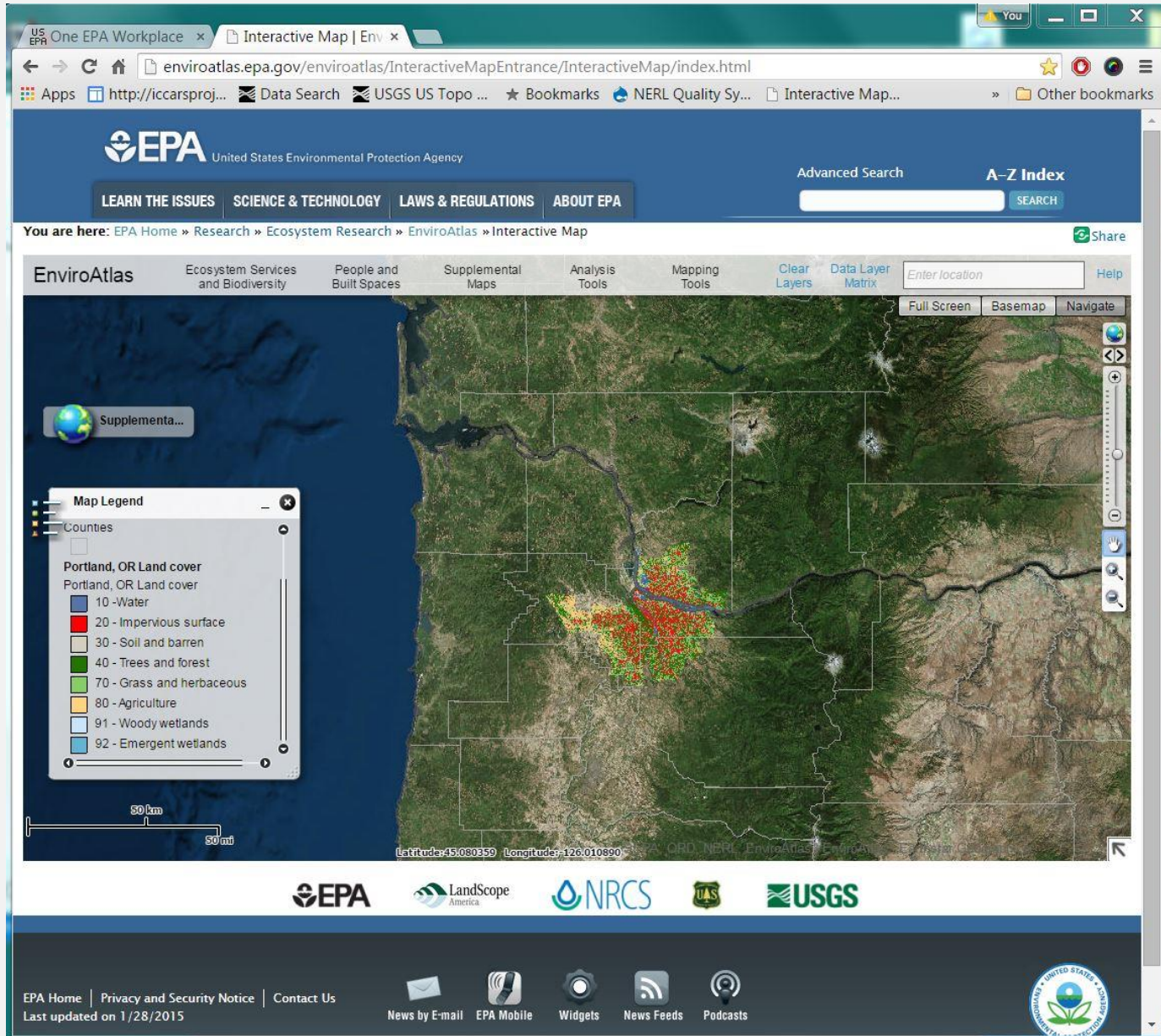
Currentness: Publication date

# Example EnviroAtlas Communities MULC





# Portland, OR MULC



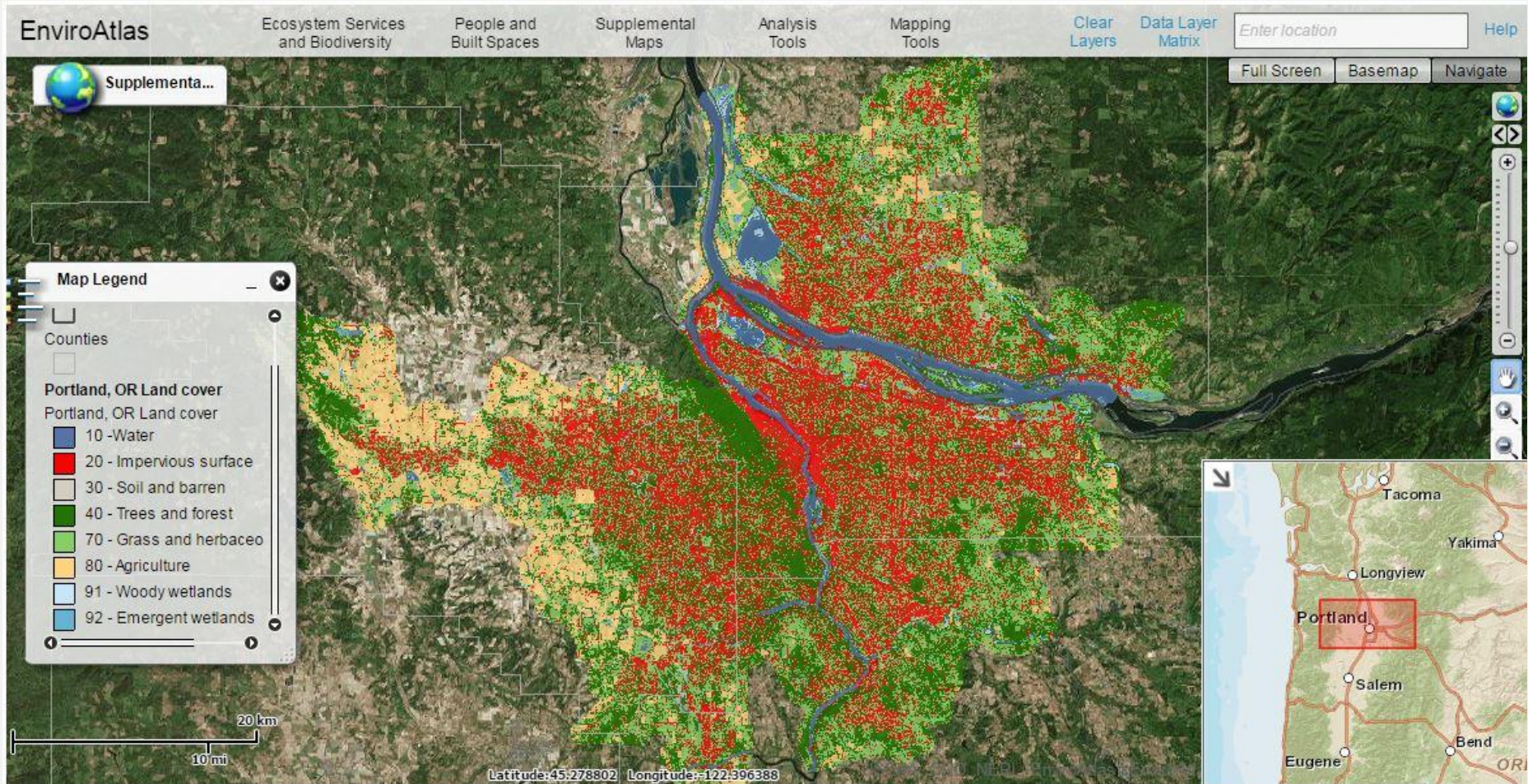
The screenshot shows the EnviroAtlas web application interface. At the top, there is a navigation bar with the EPA logo and the text "United States Environmental Protection Agency". Below this, there are several menu items: "LEARN THE ISSUES", "SCIENCE & TECHNOLOGY", "LAWS & REGULATIONS", and "ABOUT EPA". A search bar is also present with the text "Advanced Search" and "A-Z Index".

The main content area features a map of the Portland, OR region. The map is overlaid with a land cover data layer, showing various colors representing different land cover types. A legend window is open on the left side of the map, titled "Map Legend". The legend includes a section for "Portland, OR Land cover" with the following categories and colors:

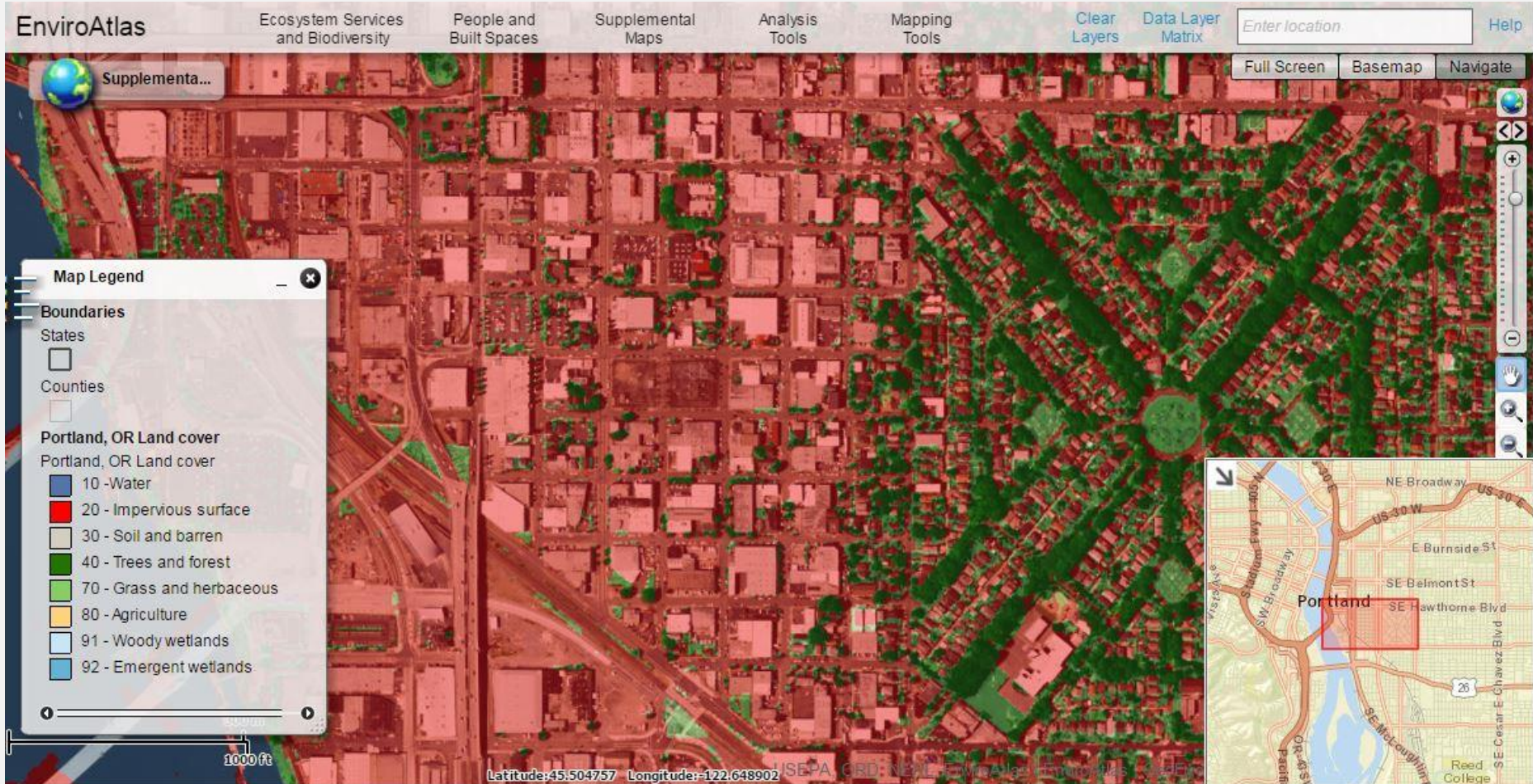
- 10 - Water (Blue)
- 20 - Impervious surface (Red)
- 30 - Soil and barren (Light Brown)
- 40 - Trees and forest (Dark Green)
- 70 - Grass and herbaceous (Light Green)
- 80 - Agriculture (Yellow)
- 91 - Woody wetlands (Light Blue)
- 92 - Emergent wetlands (Light Blue)

The map also includes a scale bar (50 km and 30 mi) and a coordinate display (Latitude: 45.080359, Longitude: -120.010890). The bottom of the page features logos for EPA, LandScope America, NRCS, and USGS. A footer contains links for "EPA Home", "Privacy and Security Notice", and "Contact Us", along with icons for "News by E-mail", "EPA Mobile", "Widgets", "News Feeds", and "Podcasts".



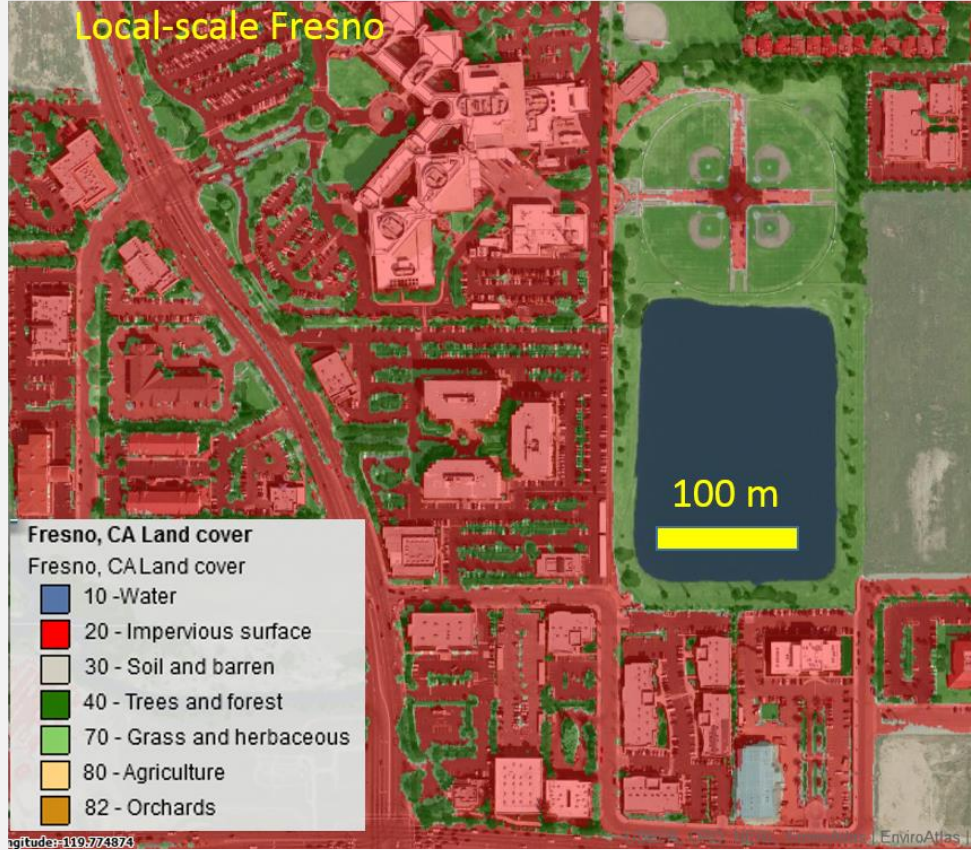
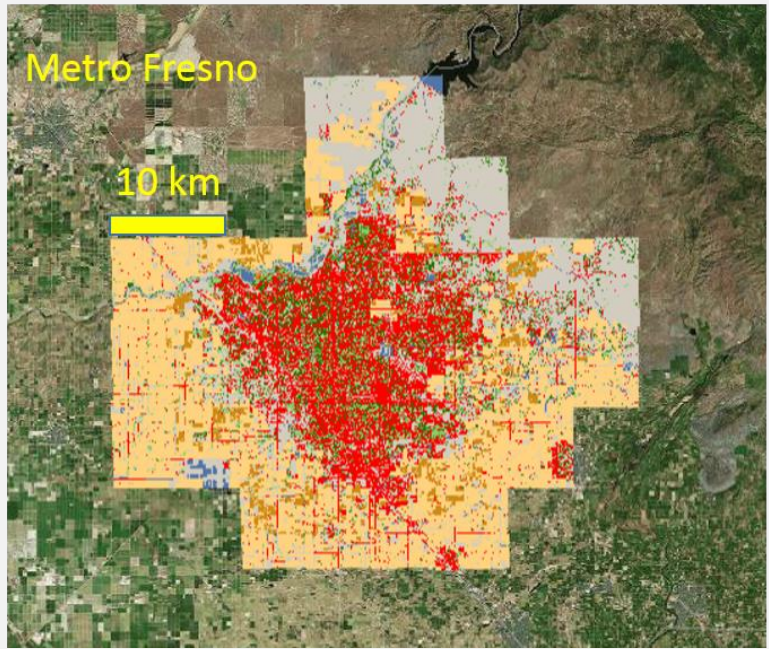






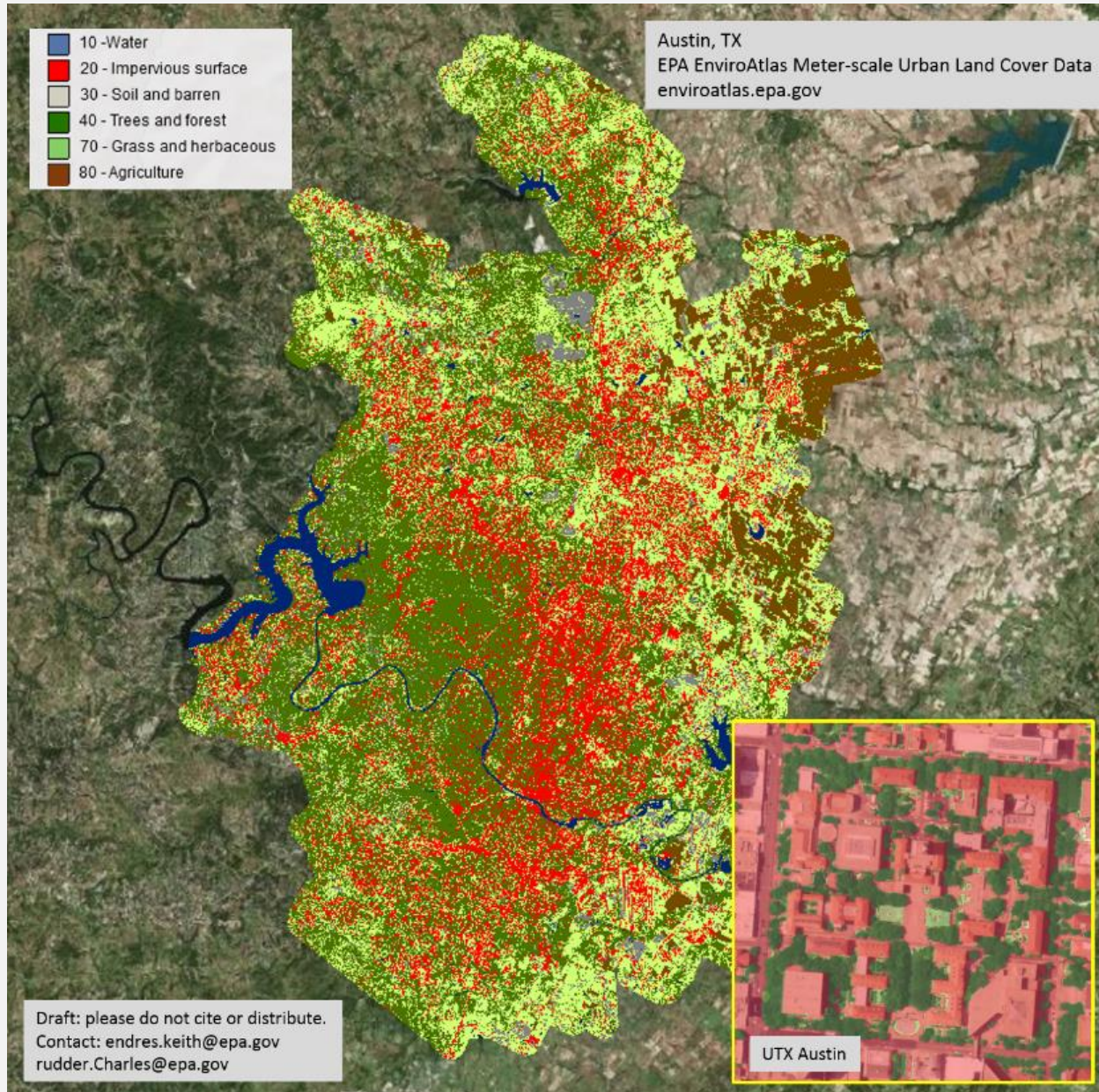


# Fresno, CA MULC at three scales of observation



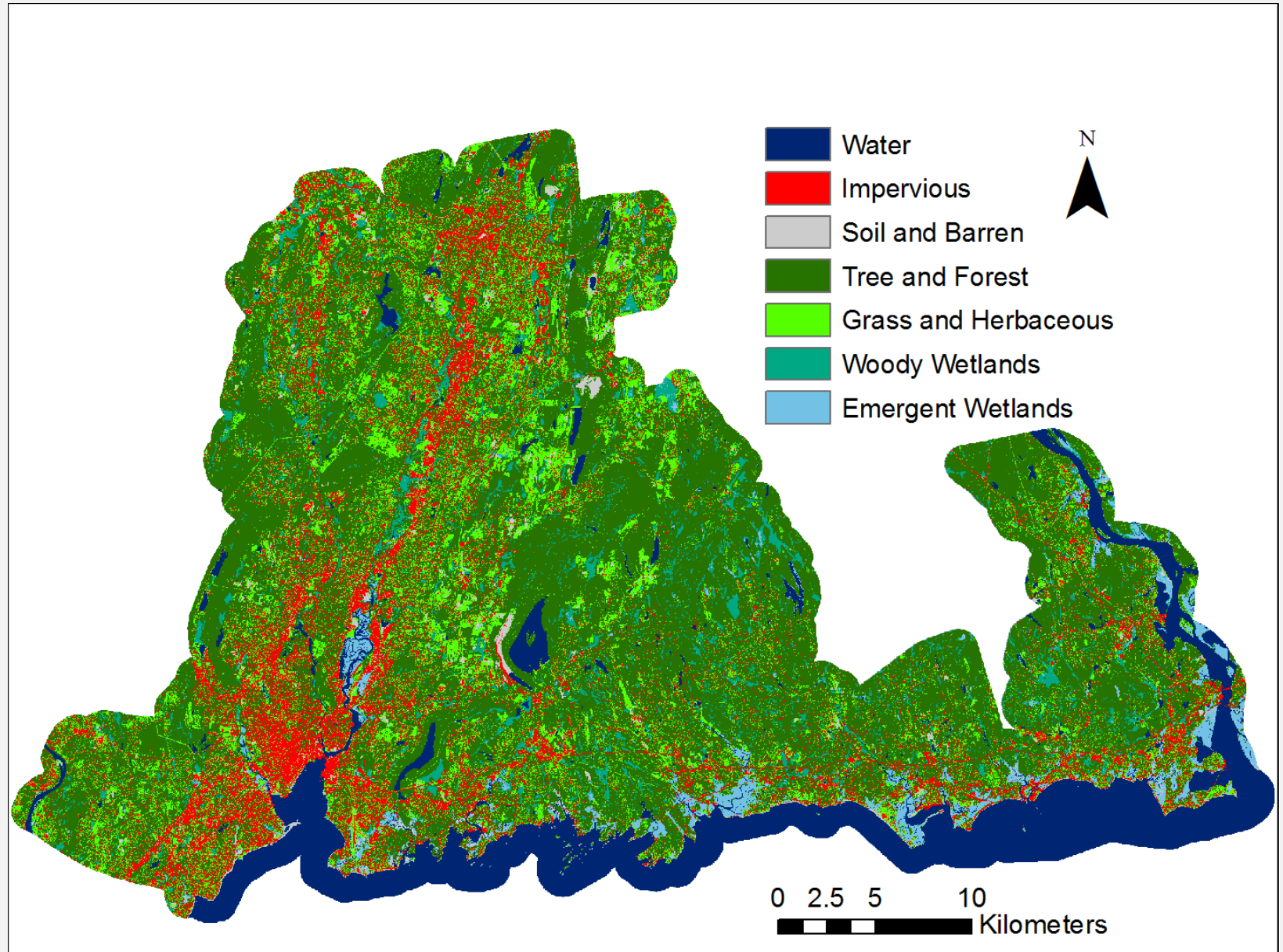


# Austin, TX MULC





# New Haven, CT MULC

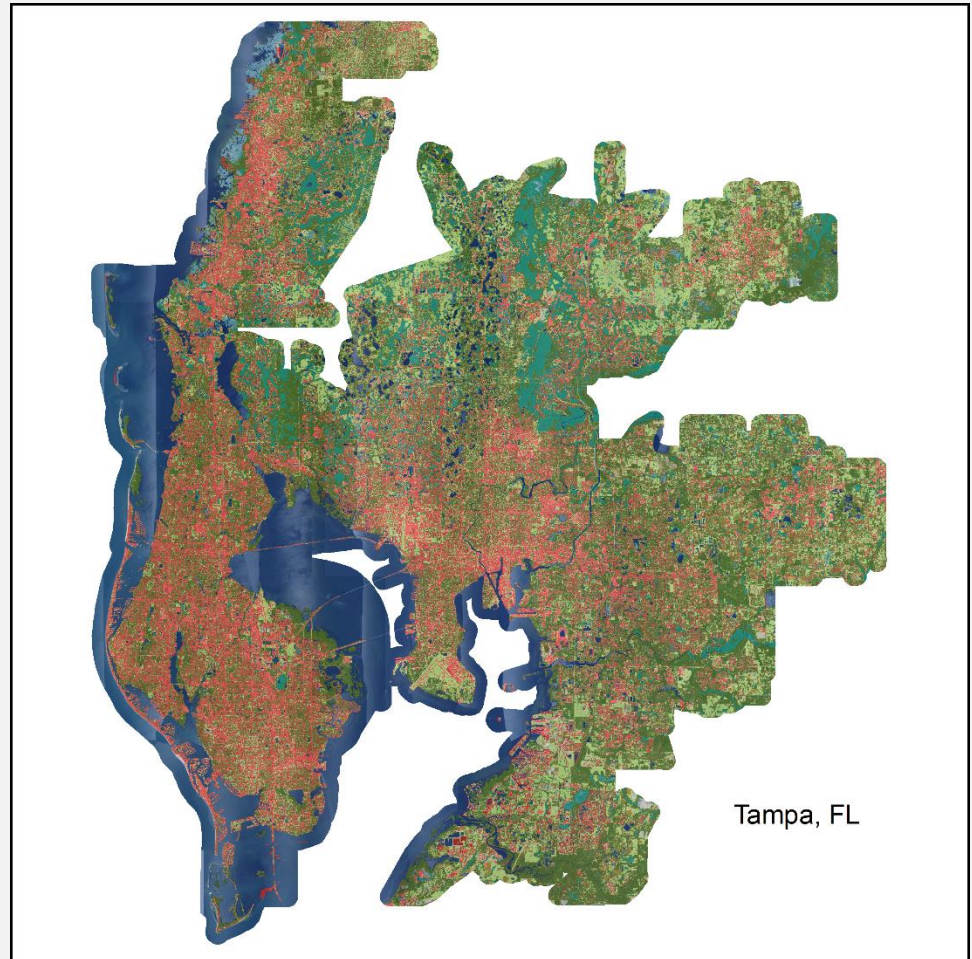
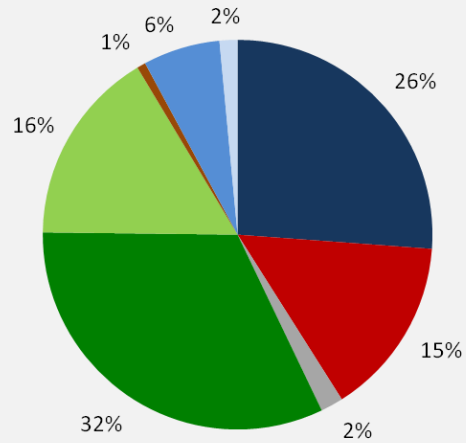




# Tampa, FL MULC

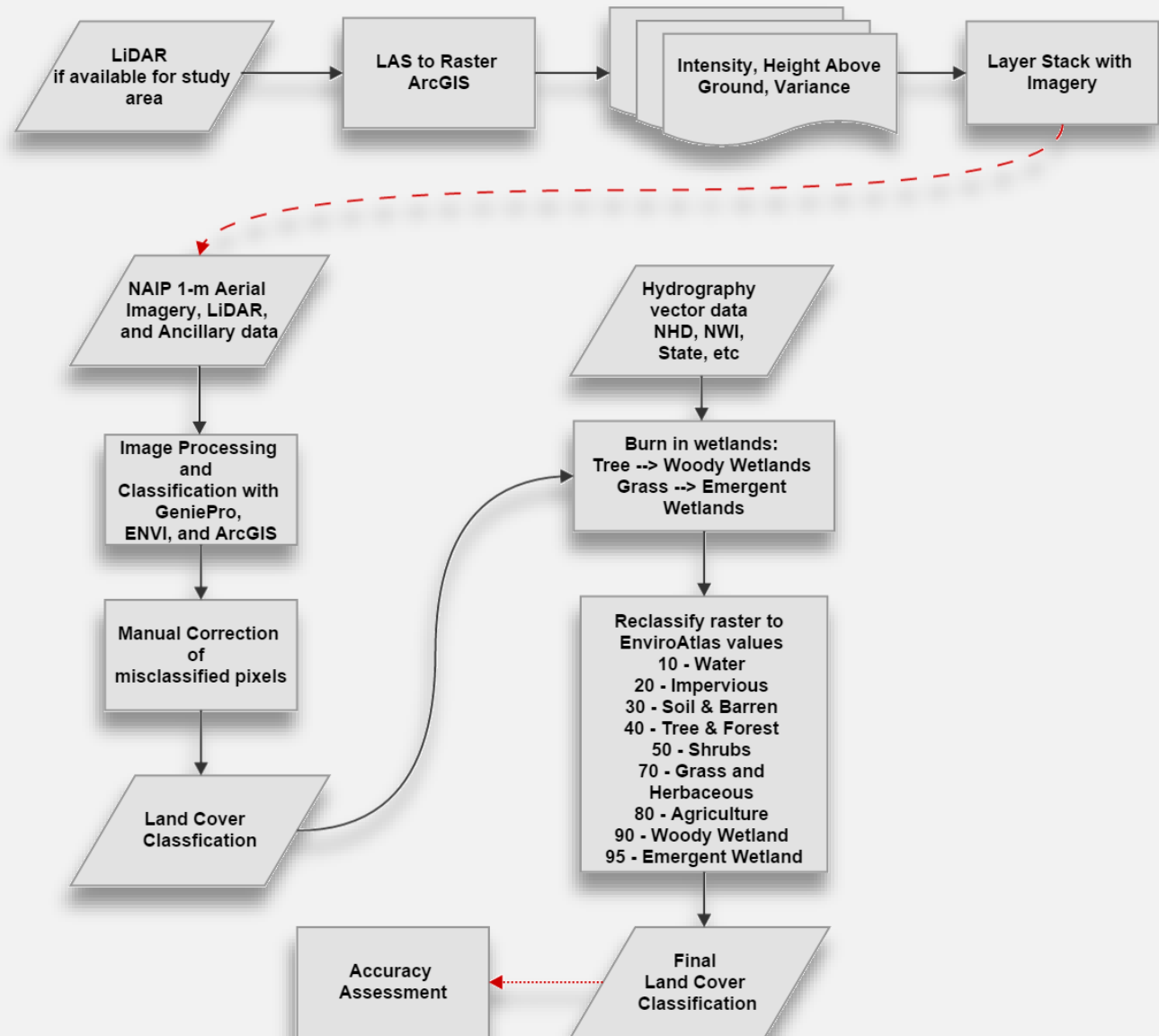
**Tampa, FL**  
**% Land Cover by Type**

- Water
- Soil & Barren
- Grass & Herbaceous
- Woody Wetlands
- Impervious
- Trees & Forest
- Agriculture
- Emergent Wetlands



# Generalized Classification Workflow

- Machine learning algorithms and supervised classification.
- Object Based Image Analysis (OBIA).



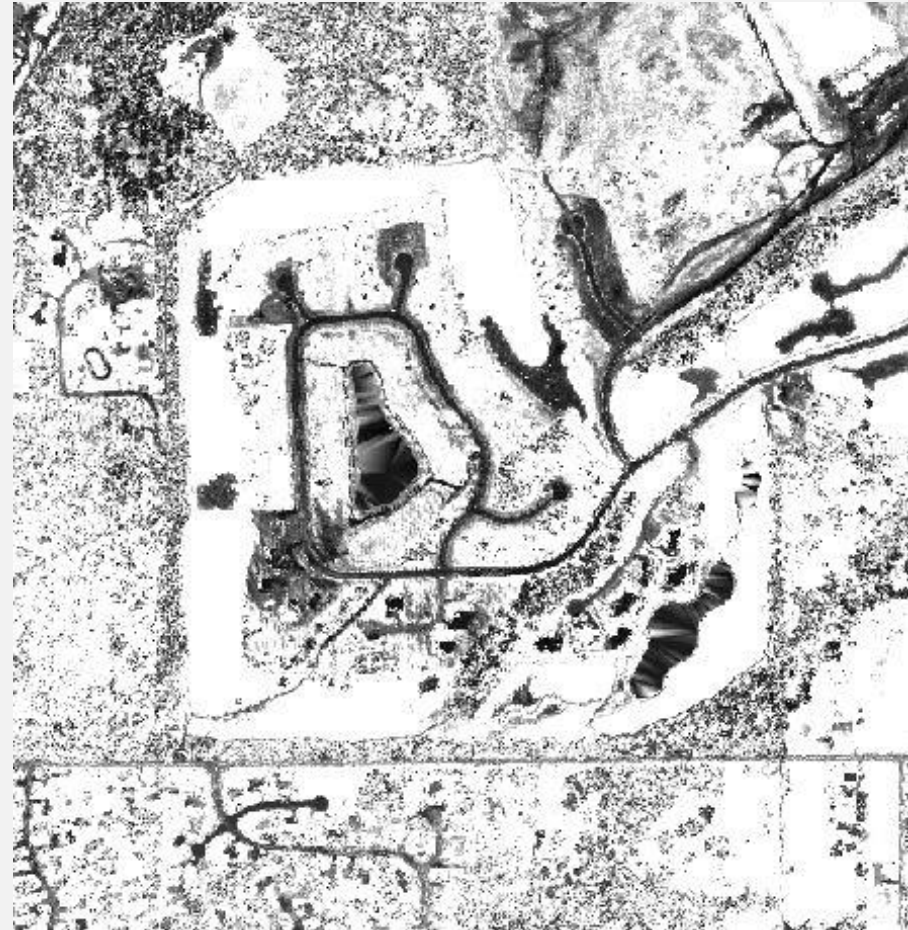


# Band stack used in classification



Band #	Band Description
1	NAIP blue
2	NAIP green
3	NAIP red
4	NAIP infrared
5	NAIP NDVI (Normalized Difference Vegetation Index) = $((b4-b3)/(b4+b3))$
6	Lidar HAG (Height Above Ground) = DSM – DEM
7	Lidar Intensity

# NAIP NC image and Lidar intensity

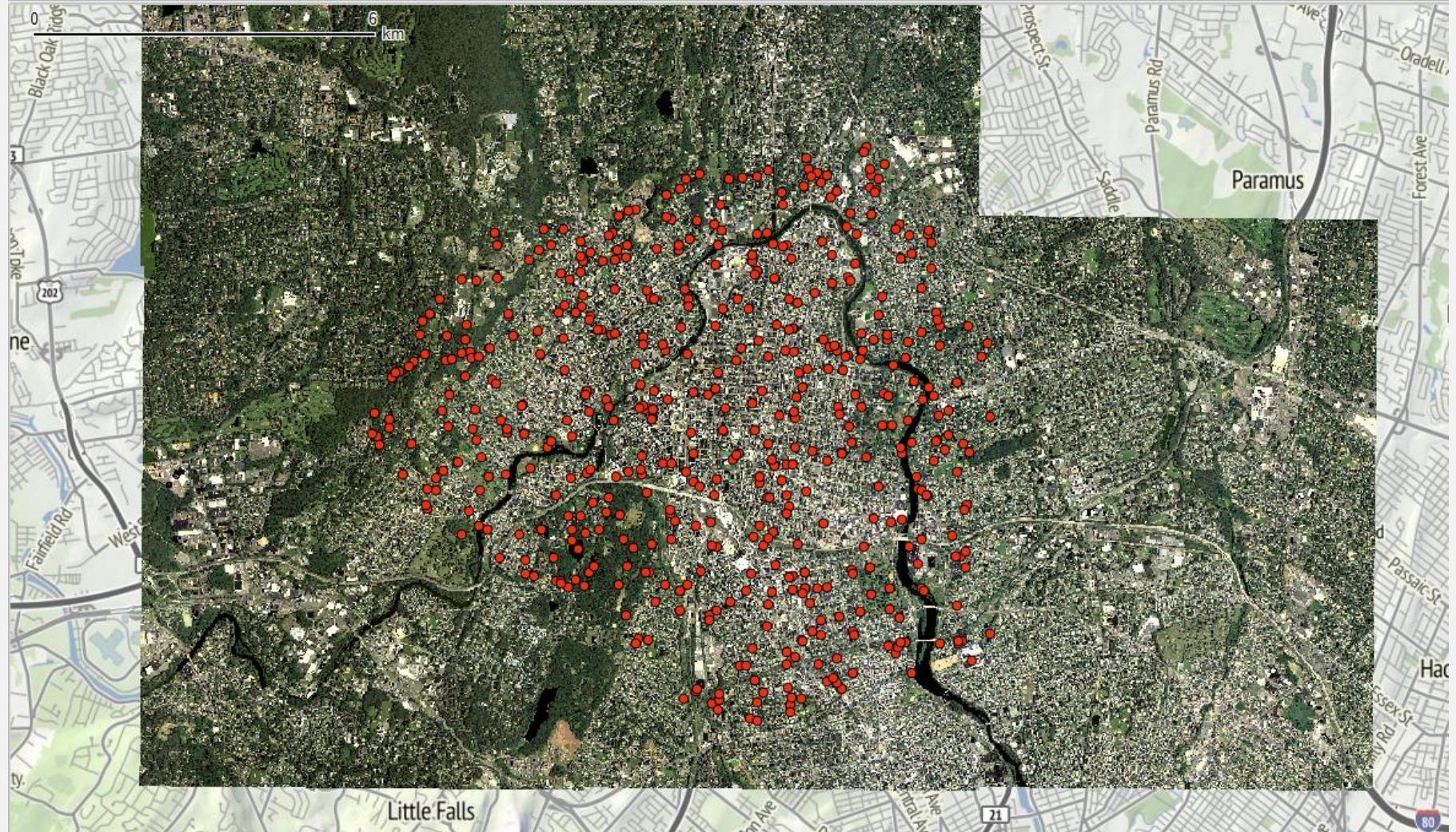




# Accuracy Assessment

## 500-600 NAIP-photointerpreted random reference points (~ 100/class)

### Fuzzy approach to labeling reference points





# Fuzzy Accuracy Assessment

1. Each Land cover class will be assigned a value between 1 and 5 based on the following Linguistic Scale (Gopal and Woodcock, 1994):
  - (1) *Absolutely Wrong*: classification value is unacceptable (**Very Wrong**)
  - (2) *Understandable but Wrong*: classification value is not good. There is something about the site that makes the answer understandable, but there is clearly a better answer. Classification would pose a problem for users of the map. (**Not Right**)
  - (3) *Reasonable or Acceptable*: Maybe not the best possible classification but it is acceptable; the classification does not pose a problem to users of the map. (**Right**)
  - (4) *Good Answer*: Would be happy to find this classification given on the map (**Very Right**)
  - (5) *Absolutely Right*: No doubt about the match. (**Perfect**)



# Overall Producer's Accuracy for 14 communities

	More Conservative Estimate		Less Conservative Estimate		LiDAR
	MAX	KAPPA	RIGHT	KAPPA	
DURHAM, NC	90.5	0.812	na	na	N
TAMPA, FL	74.48	0.680	na	na	N
PHOENIX, AZ *	69.23	0.577	na	na	N
MILWAUKEE, WI *	85.39	0.817	91.16	0.888	Y
PITTSBURG, PA	86.57	0.812	89.33	0.851	N
PATTERSON, NJ	86.88	0.812	92.55	0.892	N
WOODBINE, IA	87.03	0.793	90.23	0.844	Y
FRESNO, CA	81.09	0.762	86.9	0.835	Y
PORTLAND, OR	78.59	0.735	91.44	0.892	Y
GREENBAY, WI	90.39	0.880	94.14	0.927	Y
NEW BEDFORD, MA	92.29	0.892	95.05	0.930	N
AUSTIN, TX	86.45	0.826	90.65	0.879	Y
MEMPHIS, TN	86.93	0.835	89.05	0.861	Y
DES MOINES, IA *	77.56	0.717	84.58	0.807	Y

# Error (Confusion) Matrices showing Producers and Users Accuracy

Woodbine, IA Confusion Matrices (Completely Random Points + Stratified Random)									
MAX									
RASTER_TXT	Agricult	Grass_Herb	Impervious	SoilBarren	TreeForest	Water	N(n)	Users Accuracy	Errors of Commission
Agricult	374	24	0	3	1	0	402	93.03	6.97
Grass_Herb	7	60	0	1	3	0	71	84.51	15.49
Impervious	0	6	36	3	1	1	47	76.6	23.4
SoilBarren	10	20	0	16	0	0	46	34.78	65.22
TreeForest	0	6	0	0	65	0	71	91.55	8.45
Water	0	0	1	2	0	46	49	93.88	6.12
N(n)	391	116	37	25	70	47	686		
Producers Accuracy	95.65	51.72	97.3	64	92.86	97.87			
Errors of Ommission	4.35	48.28	2.7	36	7.14	2.13			
OVERALL ACCURACY	87.03								
Overall Accuracy		Po	=	0.87					
		Pe	=	0.373101344					
Kappa	=	(Po - Pe)/(1-Pe)							
	=	0.793108505							
RIGHT									
RASTER_TXT	Agricult	Grass_Herb	Impervious	SoilBarren	TreeForest	Water	N(n)	Users Accuracy	Errors of Commission
Agricult	381	18	0	2	1	0	402	94.78	5.22
Grass_Herb	0	69	0	1	1	0	71	97.18	2.82
Impervious	0	5	37	3	1	1	47	78.72	21.28
SoilBarren	10	15	0	21	0	0	46	45.65	54.35
TreeForest	0	6	0	0	65	0	71	91.55	8.45
Water	0	0	1	2	0	46	49	93.88	6.12
N(n)	391	113	38	29	68	47	686		
Producers Accuracy	97.44	61.06	97.37	72.41	95.59	97.87			
Errors of Ommission	2.56	38.94	2.63	27.59	4.41	2.13			
OVERALL ACCURACY	90.23								
Overall Accuracy		Po	=	0.90					
		Pe	=	0.372837848					
Kappa	=	(Po - Pe)/(1-Pe)							
	=	0.844218916							



# Use Case: Prioritizing Tree Planting in Durham, NC

EnviroAtlas Use Case
Prioritizing Tree Plant

An EnviroAtlas Use Case

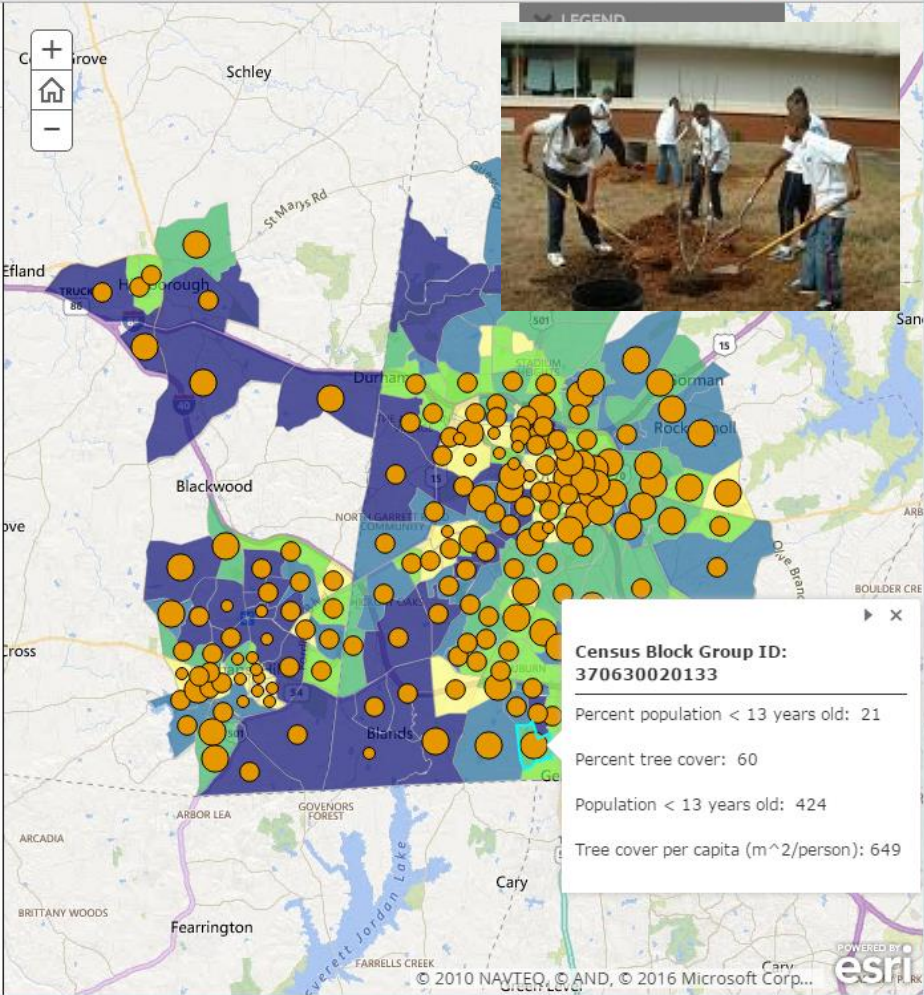
## Prioritizing Tree Planting in Durham, NC

### Percent Population Under 13 Years Old, with Percent Tree Cover

This map shows the percent tree cover by block group, overlaid with graduated markers depicting the percent of the population under 13 years old. This comparison provides a spatial overview of how the health benefits of tree cover align with a highly vulnerable human life stage.

As children develop, they are particularly susceptible to asthma and acute respiratory illnesses that can be caused and exacerbated by air pollution from sources such as factories, car exhaust, or coal-fired power plants. Children often receive higher exposure to chemicals than adults because the surface area of their lungs, skin, and other organs is larger relative to their body size. A child's cognitive development can be impaired by air pollutants such as carbon monoxide, a byproduct of combustion engines in cars and other machinery. Trees can serve as natural filters of air pollution; therefore, significant tree cover within cities and towns can help to provide clean air to all residents. It is especially beneficial to developing minds and bodies. Children as well as adults can benefit from additional positive effects of nearby trees on directed attention, physical fitness, and happiness.

*In the EnviroAtlas Interactive Map:* To display "Percent population under 13 years old," click on "People and Built Spaces" in the navigation bar and select the "Community" option. In the table of contents that opens, choose a

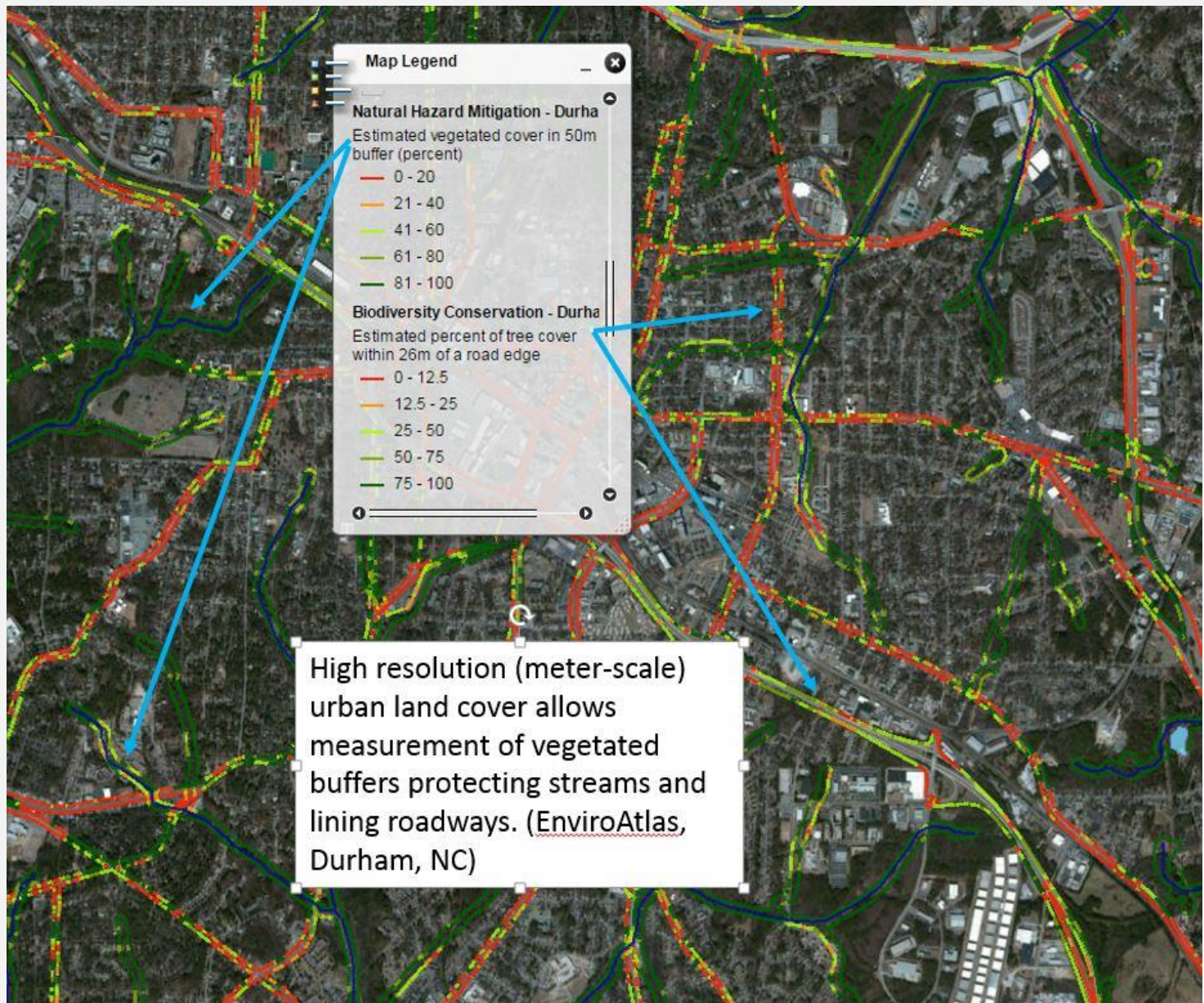


<b>Census Block Group ID:</b>	370630020133
Percent population < 13 years old:	21
Percent tree cover:	60
Population < 13 years old:	424
Tree cover per capita (m <sup>2</sup> /person):	649



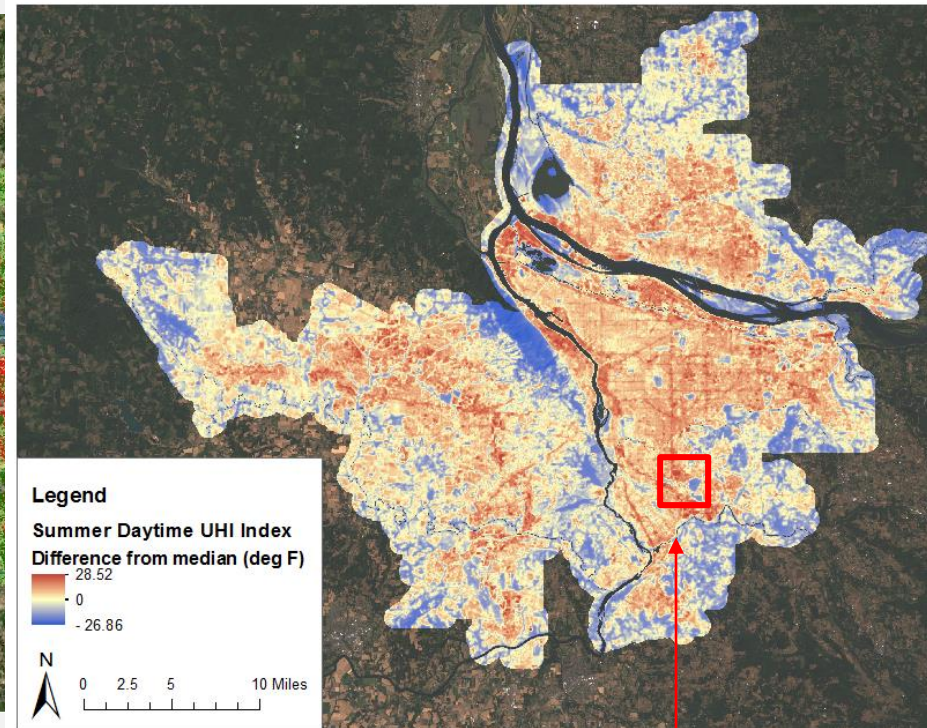
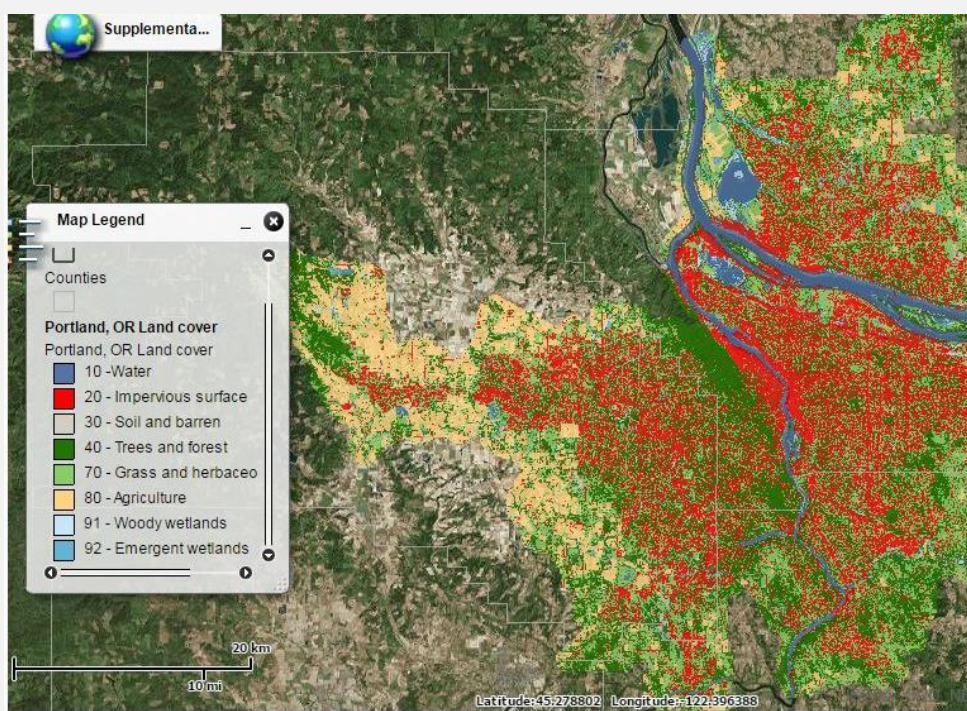
# Screening tool

## Road and stream vegetation buffers in Durham, NC



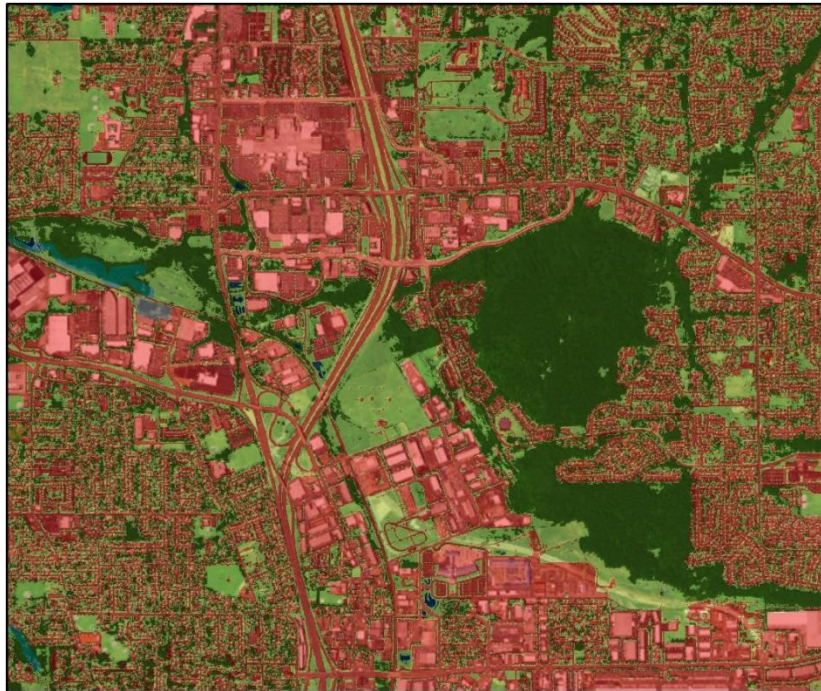


# Portland, OR Urban Heat Island (UHI) example





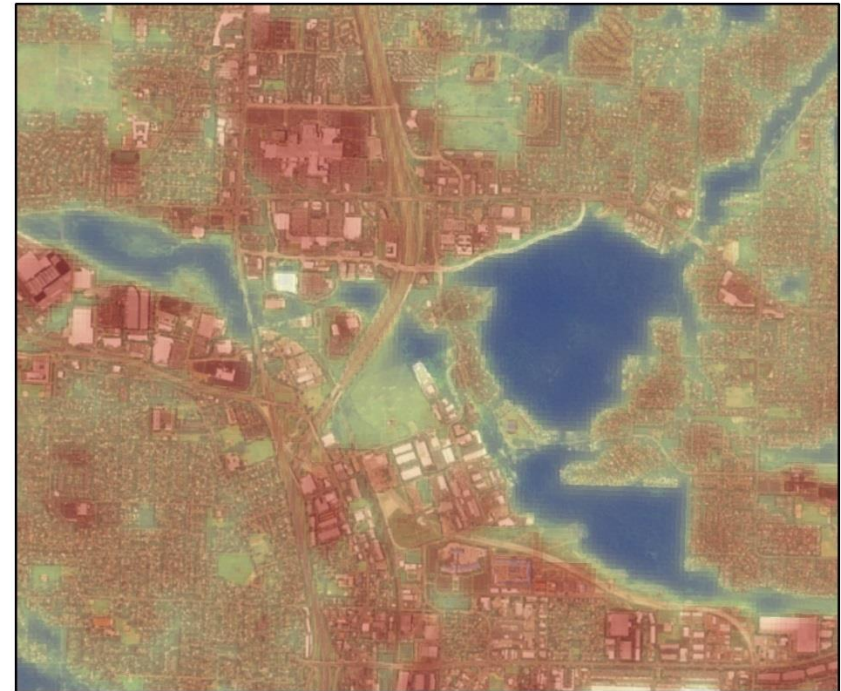
# Portland, OR Urban Heat Island (UHI) example



**Land Cover**

- |                     |                   |
|---------------------|-------------------|
| Unclassified        | Forest/Trees      |
| Water               | Grass/Herbaceous  |
| Impervious Surfaces | Agriculture       |
| Soil/Barren         | Woody Wetlands    |
|                     | Emergent Wetlands |

0 0.25 0.5 Miles



**Summer Daytime UHI Index**

**Difference from median (deg F)**

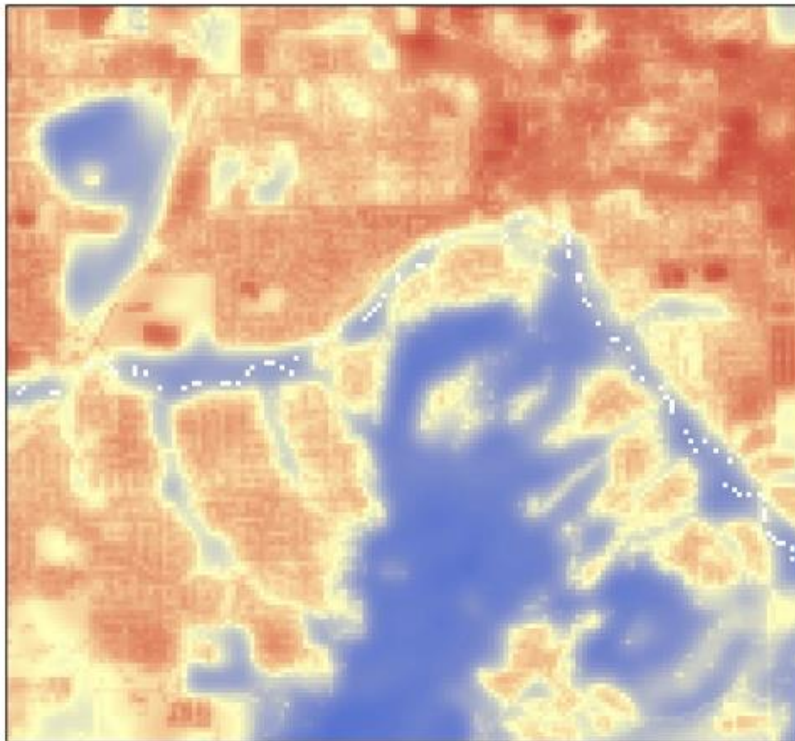
- |  |        |
|--|--------|
|  | 28.52  |
|  | 0      |
|  | -26.86 |

0 0.25 0.5 Miles



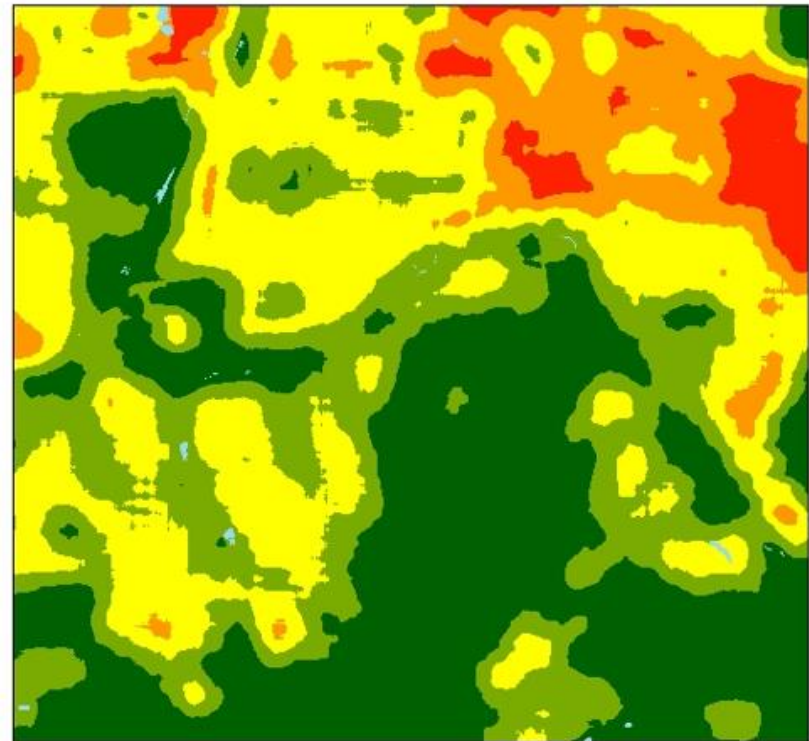


# Portland Urban Heat Island (UHI) example



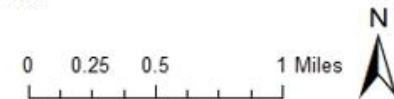
**Summer Daytime UHI Index**  
 Difference from median (deg F)

28.52
0
-26.86



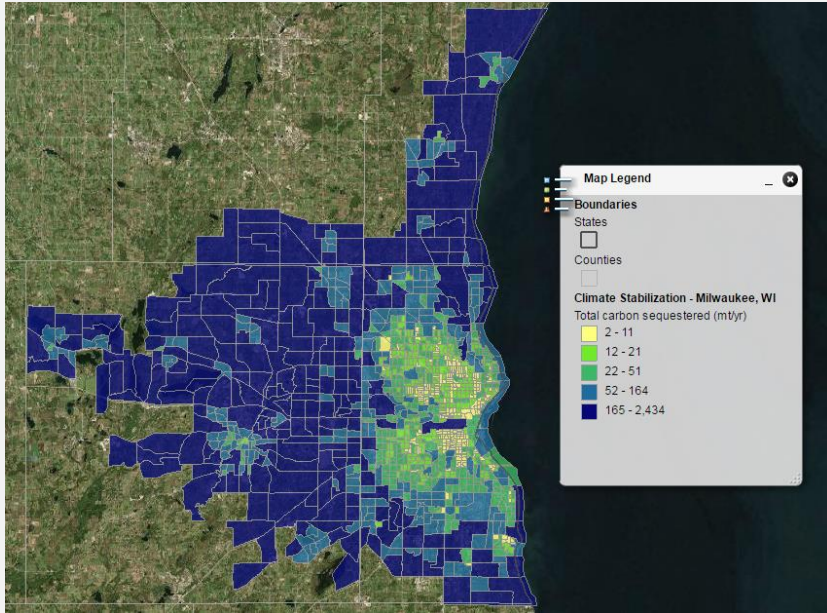
Water	41-60
0-20	61-80
21-40	81-100

**Percent Green Space**

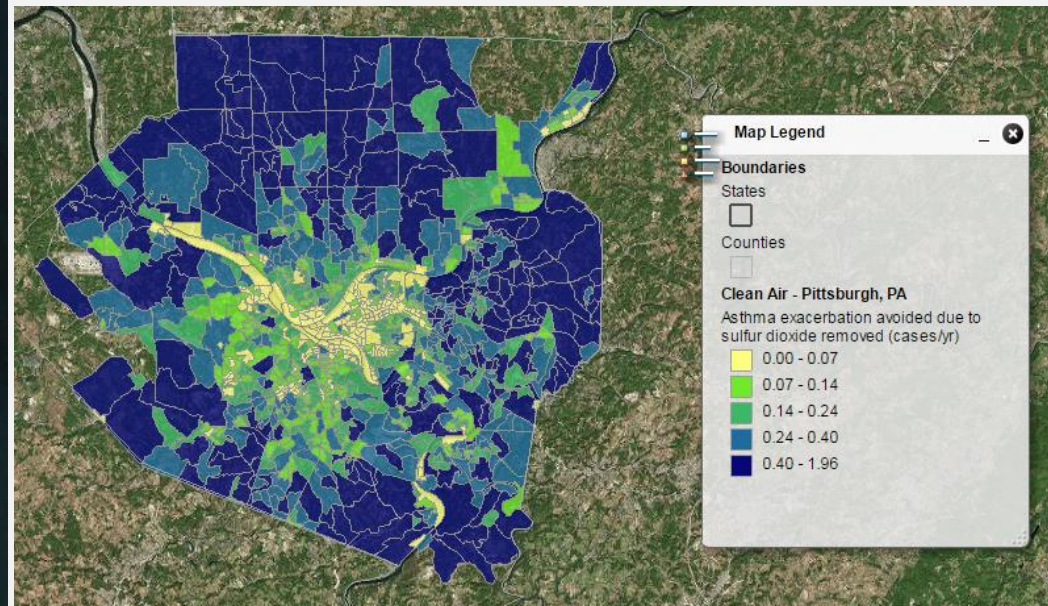


This map illustrates the percent of total land within each ¼ square kilometer that is covered by vegetation, or “green space.” Green space may include trees, lawns and gardens, crop land, and forested wetlands.

## Carbon sequestration (mt/yr)



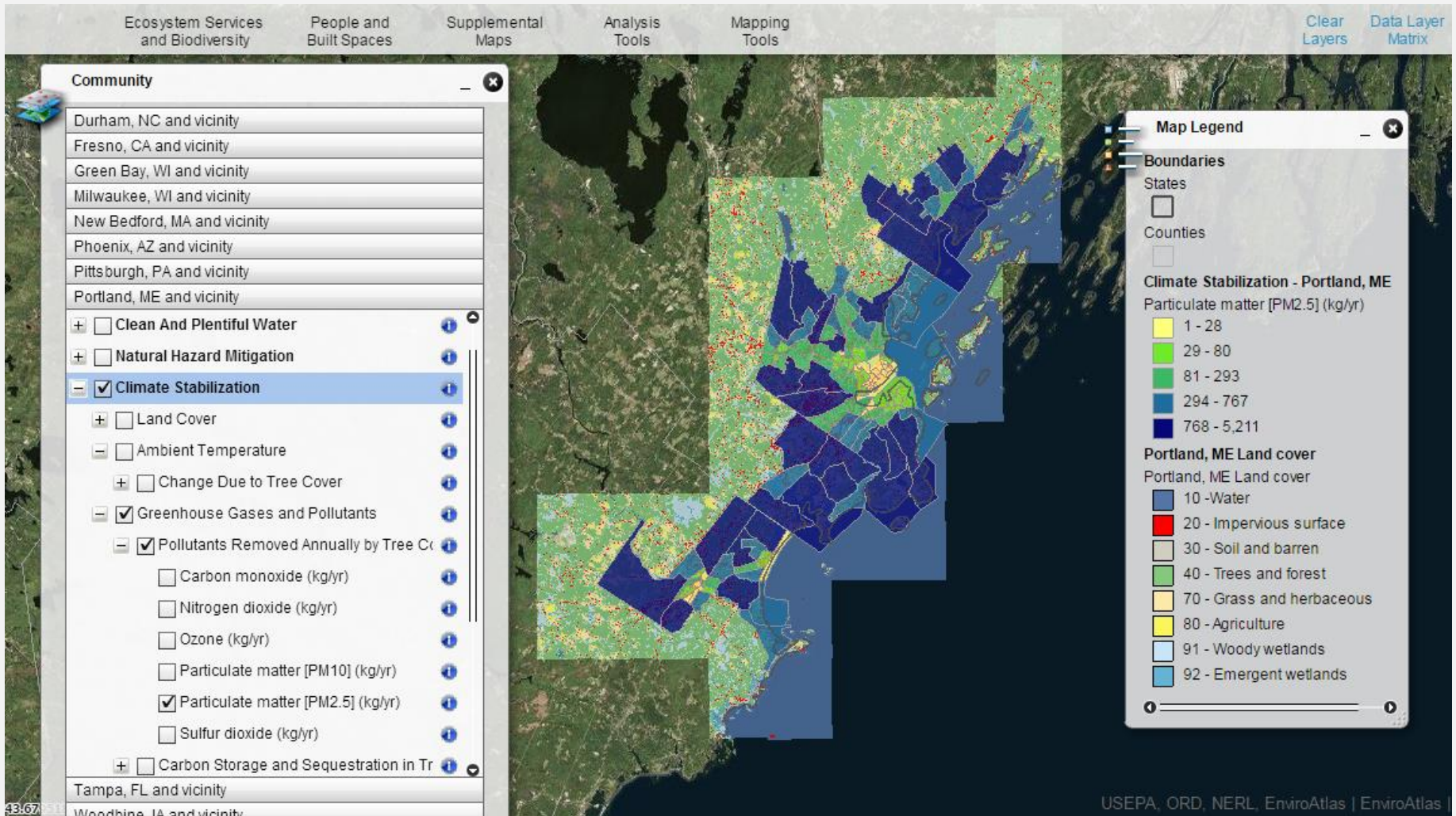
## Asthma exacerbation cases avoided due to SO<sub>2</sub> removal by tree cover (cases/yr)





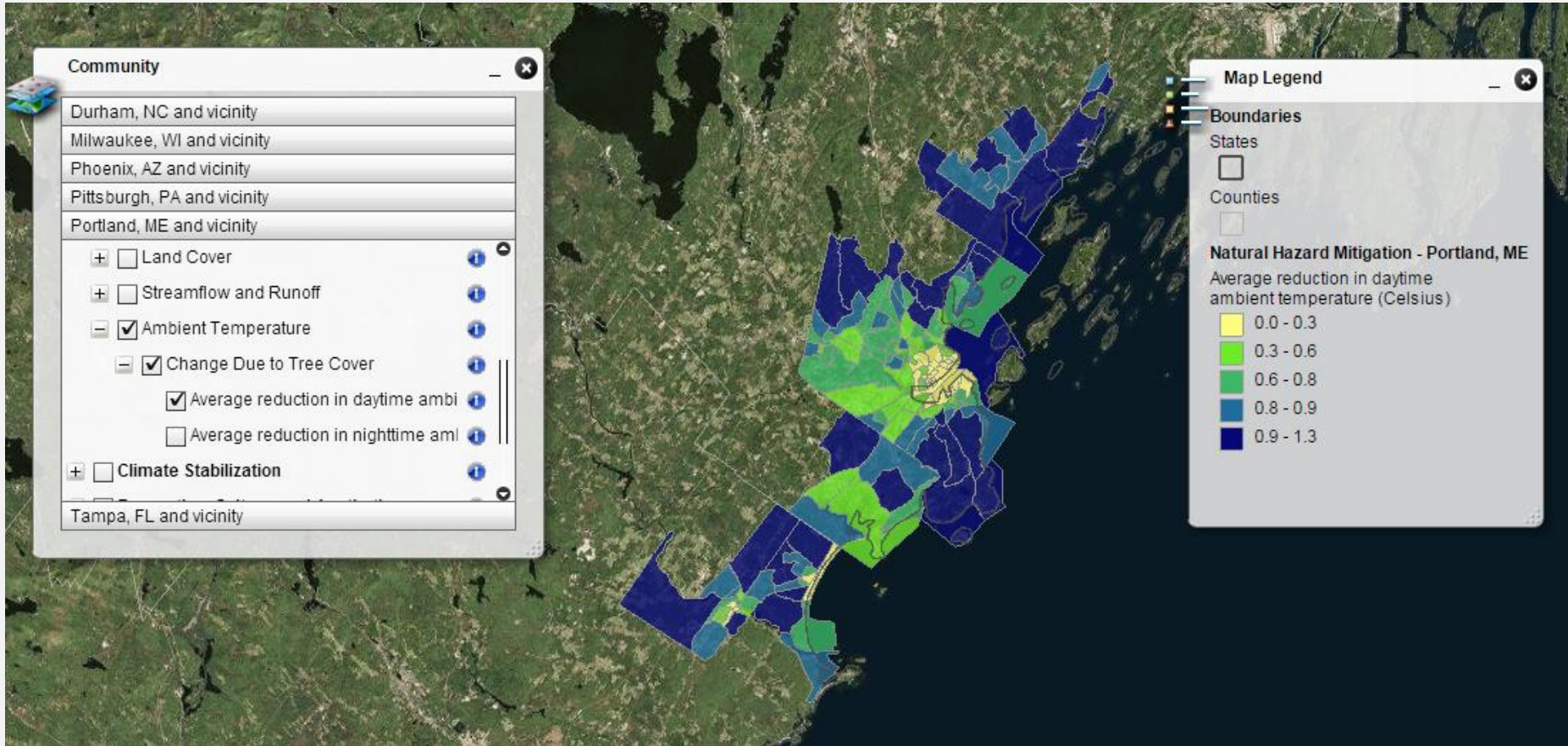
# iTREE modeled Ecosystem Services

## Particulate matter removed by trees (kg/yr/census block group)



# iTREE modeled Ecosystem Services

## Reduction in daytime temperature due to tree cover





- Point of contact:
- [Pilant.drew@epa.gov](mailto:Pilant.drew@epa.gov)
- EnviroAtlas <https://www.epa.gov/enviroatlas>
- EnviroAtlas interactive map:  
<https://enviroatlas.epa.gov/enviroatlas/InteractiveMapEntrance/InteractiveMap/index.html>

