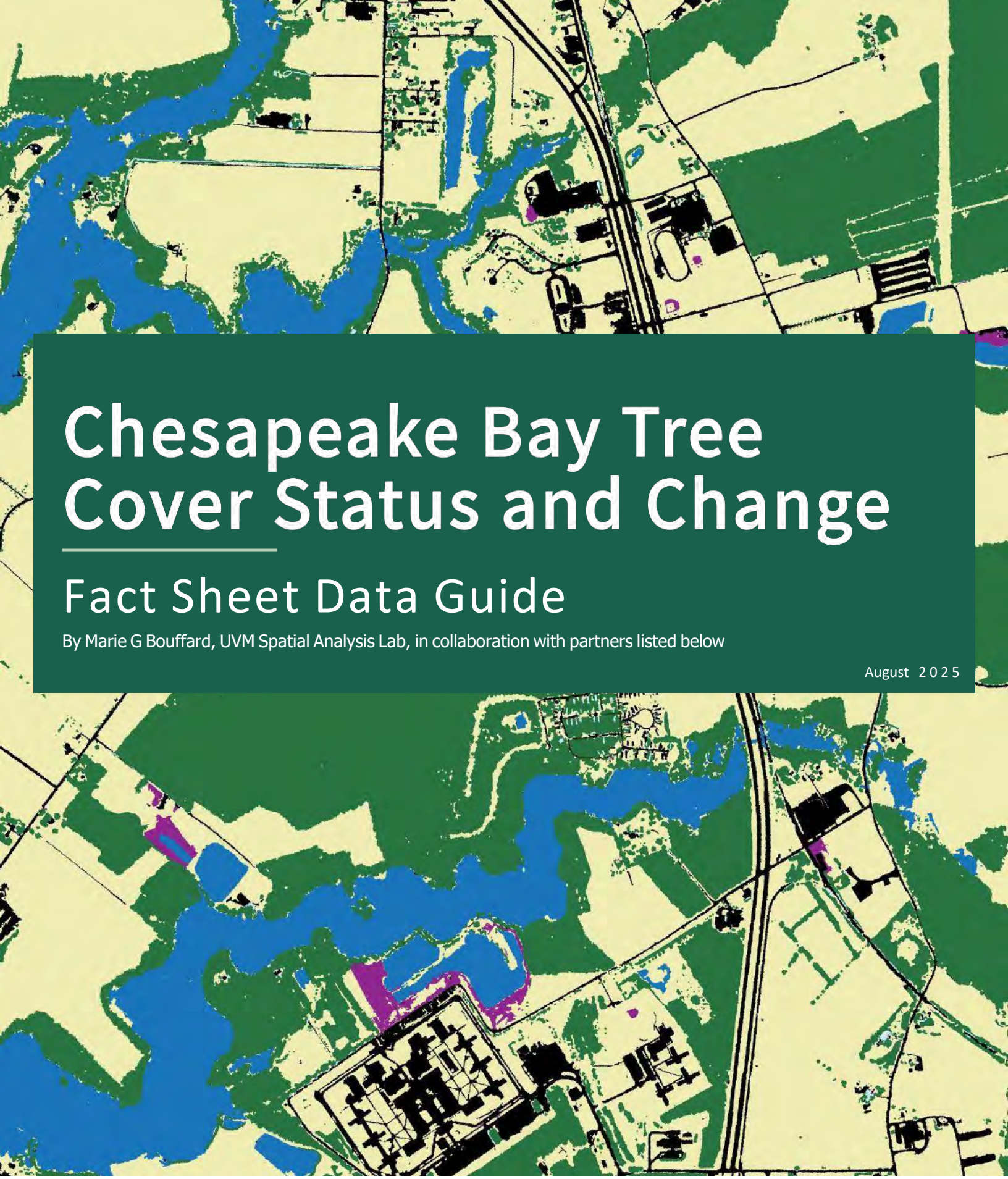

Chesapeake Bay Tree Cover Status and Change

Fact Sheet Data Guide

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Chesapeake Bay Program
Science. Restoration. Partnership.

University of Vermont
Spatial Analysis Lab

Chesapeake Conservancy

USGS
science for a changing world

Forest Service
U.S. Department of Agriculture

Why do trees matter?

Trees provide numerous public benefits in the form of ecosystem services. Ecosystem services refer to all the ways we benefit from the services that healthy natural systems provide, such as improved air quality, reduced stormwater runoff, carbon sequestration, temperature regulation, and wildlife habitat.

Why map tree cover?

It is important to map and monitor tree cover change over time to detect trends that can inform management decisions. This information can be used to improve access to ecosystem services, decide where new trees should be planted, and ensure healthy tree cover for future generations.

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About the Data

The Chesapeake Conservancy's Conservation Innovation Center, University of Vermont Spatial Analysis Lab, and the U.S. Geological Survey worked together to create very- high resolution land use and land cover datasets for the Chesapeake Bay watershed.

These data will be used to describe land use and land cover conditions and change over time. The data are foundational, authoritative, and transformative to the Bay restoration effort. They are foundational because they inform most outcomes in the 2014 Chesapeake Bay Watershed Agreement and will serve as the basis for developing the next generation of watershed models. They are authoritative due to their accuracy and transparency; any person viewing the data can recognize features and areas of interest and compare them to their local knowledge. They are transformative because they will ultimately change the way restoration and conservation actions are implemented, enabling both to be targeted at a fine scale to locations where they will be most effective.

Moreover, establishing accurate trends in impervious cover, forests, and tree canopy will enable the Chesapeake Bay Program Partners to improve the efficiency and effectiveness of stormwater and forest management activities. The data are being developed for the years 2013/2014, 2017/2018, and 2021/2022 and derived from aerial imagery coupled with a variety of ancillary datasets.

See Land Use/Land Cover Classification Methods documentation

Land Cover Change Mapping

Land Cover Mapping Workflow

1 Preliminary Road Mapping

New or modified roads were digitized manually using the 2013/2014 and 2021/2022 National Agricultural Imagery Program (NAIP) Imagery as reference imagery. The digitized layer with new, modified, or removed roads was then used in subsequent modeling routines to guide change detection for the Impervious class.

2 Object Based Image Analysis

Automated feature extraction was performed in eCognition, state-of-the-art software for performing object-based image analysis. This technique groups pixels that form meaningful landscape objects, providing a more realistic, contextual representation of features than by looking at pixels individually.

3 Modeling Scenarios

All mapping was performed at the county/municipality level. The small extent was necessary due to the large size of the high-resolution imagery mosaics and varying data availability by region for Light Detection and Ranging (LiDAR), NAIP imagery, and vector GIS datasets. After assessing the availability and quality of the inputs for each county/municipality, a specific modeling scenario was identified and coded into an eCognition rule set that executed the complete mapping workflow.

4 Change Detection Classes

To represent change across the analysis period, the original 12-class classification scheme was expanded to include all types of change that were likely to occur in the Chesapeake Bay watershed. Change types with a low probability of occurrence or classes that could not be mapped effectively with the available data were excluded.

5 Automated Feature Extraction

2013/2014 land cover was revised from the original land cover map in order to avoid false change estimates resulting from differences in techniques between the two studies. After finalizing the revised 2013/2014 map, the LiDAR, imagery, and thematic datasets available for 2021/2022 were used to perform change detection, assigning altered 2013/2014 features to one or more of the change classes to explicitly track individual land-cover conversions.

Data Types

2013/2014 Land Cover

The original 1-meter resolution 2013/2014 land cover was used as a starting point for all subsequent analyses.

NAIP Imagery

NAIP imagery acquired by the USDA Farm Services Agency allowed for high resolution land-cover classification.

LiDAR

Where available, LiDAR facilitated mapping and differentiation of tree canopy and buildings.

Thematic GIS Datasets

Thematic GIS datasets developed by individual municipalities, including building footprints, roads, parking lots, sidewalks, and water bodies, informed improvements to the original 2013/2014 land cover and subsequent change analysis to 2021/2022. To address the lack of Emergent Wetlands class in the 2013/2014 land cover for Virginia, National Oceanic and Atmospheric Administration (NOAA) Coastal Change Program (C-CAP) land cover and NOAA's tidal shore elevation data were used as guides for mapping tidally-influenced wetlands.

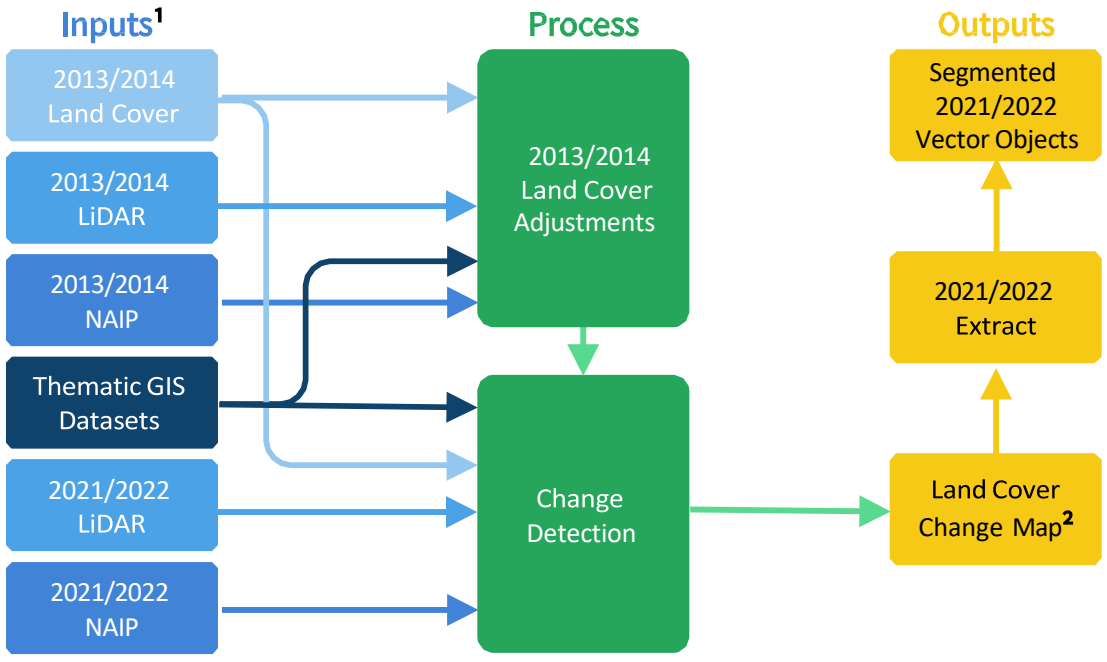
Change Mapping

1 2013/2014 Land Cover Adjustments

The mapping workflow initially focused on improving the 2013/2014 land cover, where necessary, using the available data inputs to add features omitted from parts of the original layer and to remove erroneous ones. This step was important to avoid false change estimates.

2 Change Detection

After finalizing the revised 2013/2014 map, NAIP and LiDAR imagery coupled with thematic datasets available for the 2021/2022 timeframe, were used to detect changes in land cover from 2013/2014 to 2021/2022.

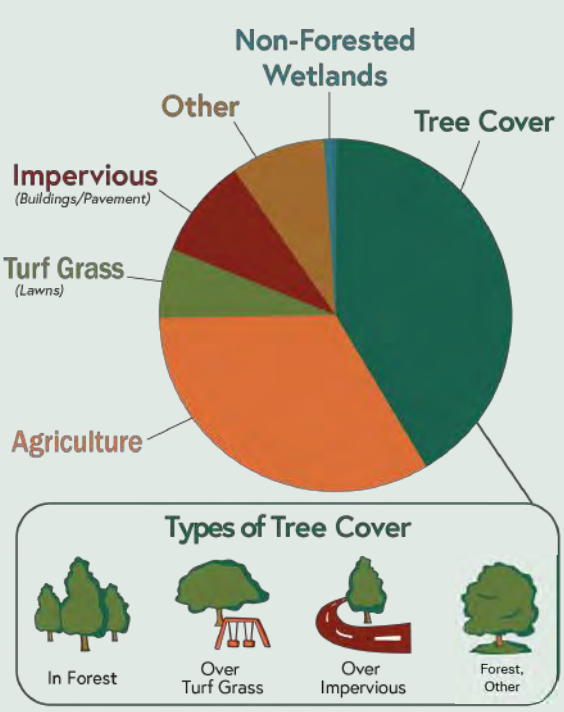


1 Represents the best possible scenario, actual data inputs varied by county based on availability

2 Land-cover change detection map can be reclassified to yield 2013/2014 and 2021/2022 maps

Land Use/Land Cover Classification

The very-high resolution land cover and change data described in Section 2 are combined with ancillary datasets to generate the land use/land cover datasets used in Chesapeake Bay Program modeling tools. A team at the Chesapeake Bay Program led by U.S. Geological Survey and the Chesapeake Conservancy, with stakeholder input from many groups including the Chesapeake Bay Program's Land Use Workgroup and Forestry Workgroup, developed a detailed 54 class land use/land cover dataset for the watershed.



Class Definitions

The following provides the official definitions for some of the major land use/land cover classes that are summarized in the Tree Cover Status & Change Fact Sheets. Please note that the fact sheet's land use/land cover pie chart is a land-based summary; the area classified as "Water" is intentionally excluded to generate land-based tree cover percentages.

Tree Cover includes

Forest (FORE) = Tree canopy with an unmanaged understory that is part of a large patch. Large patches are at least 1-acre in area with a minimum patch diameter of 36-meters (~120 feet) and may include areas of early successional forest (natural succession and harvested forest). Smaller patches of tree canopy are classed as forest if they are part of a large early-successional forest patch and comprise at least 10% of the patch area. Forests that are also wetlands are included in this class.

Tree Canopy over Turf Grass (TCTG) = Tree canopy overhanging low vegetation in developed areas assumed to be turf grass or otherwise altered through compaction, removal of surface organic material, and/or fertilization.

Tree Canopy over Impervious Surfaces (TCIS) = Tree canopy overhanging roads, structures, or other impervious surfaces rendering them partially or completely invisible from above.

Tree Cover Continued

Forest, Other (FORO)* = All trees that do not qualify as "Forest" but are presumed to have an undisturbed/unmanaged understory. Such areas include narrow windbreaks adjacent to cropland and roads and tree canopy patches not qualified as "forest" that are fully surrounded by agriculture. Wetlands with "other tree canopy" are included in this class.

Agriculture includes

Cropland (CROP) = Low vegetation, shrubland and barren lands used for the production of grains, legumes, vegetables, fruits and nuts, grapevines, or other agricultural crops.

Pasture/Hay (PAST) = Low vegetation and barren lands used for grazing livestock (e.g., cattle, goats, sheep) or producing fodder (e.g., hay and alfalfa).

Turf Grass includes

Turf Grass (TURF) = Low vegetation associated with residential, commercial, industrial, and recreational areas (e.g. residential lawns, sports fields, cemeteries, golf courses, and airports) that is assumed to be altered through compaction, removal of organic materials and/or fertilization.

Impervious includes

Impervious Roads (ROAD) = Paved roads and bridges. Dirt and gravel roads may be mapped as impervious depending on the spectral characteristics of the substrate.

Impervious Structures (IMPS) = Buildings (e.g. houses, malls, sheds, and warehouses) made of impervious materials that are greater than ~2 meters in height.

Impervious, Other (IMPO) = Human-constructed surfaces (e.g. sidewalks, parking lots, field-mounted solar panels, and rail lines) through which water cannot penetrate, and that are less than ~2 meters in height.

***Formerly "Other Tree Cover"**

Other includes

Pervious Developed (PDEV) = Low vegetation, shrubland, and barren land that is assumed to be unfertilized and where the regrowth of trees is suppressed. This includes utility transmission lines, pipelines, road rights-of-way, landfills, pervious portions of solar fields, barren construction zones, and baseball diamonds.

Harvested Forest (HARF) = Recently cleared tree canopy patches via clear cut, that are low vegetation or barren. These areas mostly represent rotational timber harvests, but the clearings' ultimate purpose is unknown (e.g., forest conversion to agriculture, development). This class includes harvests that occurred in forested wetlands.

Natural Succession (NATS) = Low vegetation, shrubland, and barren land that is presumed to be undergoing natural or managed succession and may eventually transition to tree canopy. This includes recovery of previously harvested areas and other forest disturbances.

Extractive (EXTR) = Barren lands and impervious surfaces associated with surface mining operations, such as quarries.

Non-Forested Wetland includes

Tidal Wetlands, Non-Forested (TDLW) = Wetlands near or adjacent to tidal waters including the Chesapeake Bay, Delaware Bay, Atlantic Ocean, or their tidal tributaries, not including tree canopy.

Riverine Wetlands, Non-Forested (RIVW) = Wetlands adjacent to non-tidal streams and rivers (within the floodplain or at the headwaters), not including tree canopy.

Terrene Wetlands, Non-Forested (TERW) = Wetlands that are not adjacent to non-tidal streams and rivers or tidal waters, not including tree canopy.

Estimating the value of ecosystem services with i-Tree

Ecosystem services are often difficult to account for but are important to consider in community planning. This analysis used i-Tree Landscape models which are part of the i-Tree forestry assessment suite of tools developed by the USDA Forest Service and partners. Using the very high-resolution land cover data for 2021/2022, these models helped quantify the monetary value of some of the tangible benefits of tree cover: air pollution removal, stormwater runoff reduction, and carbon sequestration.

Note: i-Tree estimates are not directly comparable with the estimates provided in the original county tree cover fact sheets because of updates to model input and validation data.

i-Tree Outputs

Air Pollution Removal

Factors used to estimate pollution removal in terms of g/m2 tree cover include: leaf area index, percent evergreen trees, weather, population, and pollution data for carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter ($PM_{2.5}$, PM_{10}) (averaged over 2016-2020).

The estimated value of the air pollution reduction is based on local health impact estimates from the U.S. EPA BenMap model.

Reduced Runoff

Estimates for the volume of stormwater intercepted, transpired, and evaporated are based on total tree cover, height, canopy percentage, crown width, leaf area indices and local weather data (averaged over 2016-2020).

The value of avoided runoff is estimated using the i-Tree Eco model which uses the U.S. national average dollar value of $0.008936/gallon based on studies of stormwater control and treatment costs.

Carbon Sequestration

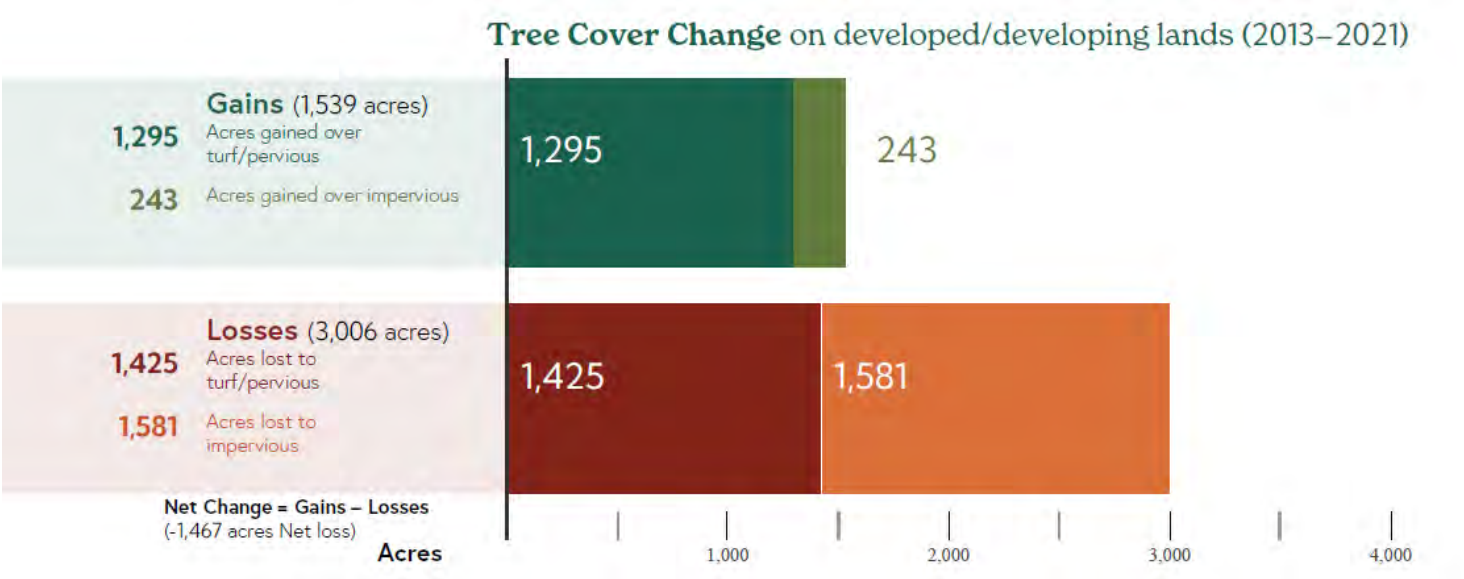
Carbon storage and sequestration values are calculated separately for forested and non-forested land cover classes. Carbon sequestration for trees in non-forest areas is estimated using values from urban forests (Nowak et al. 2013).

The value of carbon sequestration for forested regions is currently estimated at $477 per metric ton based on the social cost of carbon (Interagency Working Group, 2025), which marks a major increase over the values reflected in the original county tree cover fact sheets.

Tree Cover Change

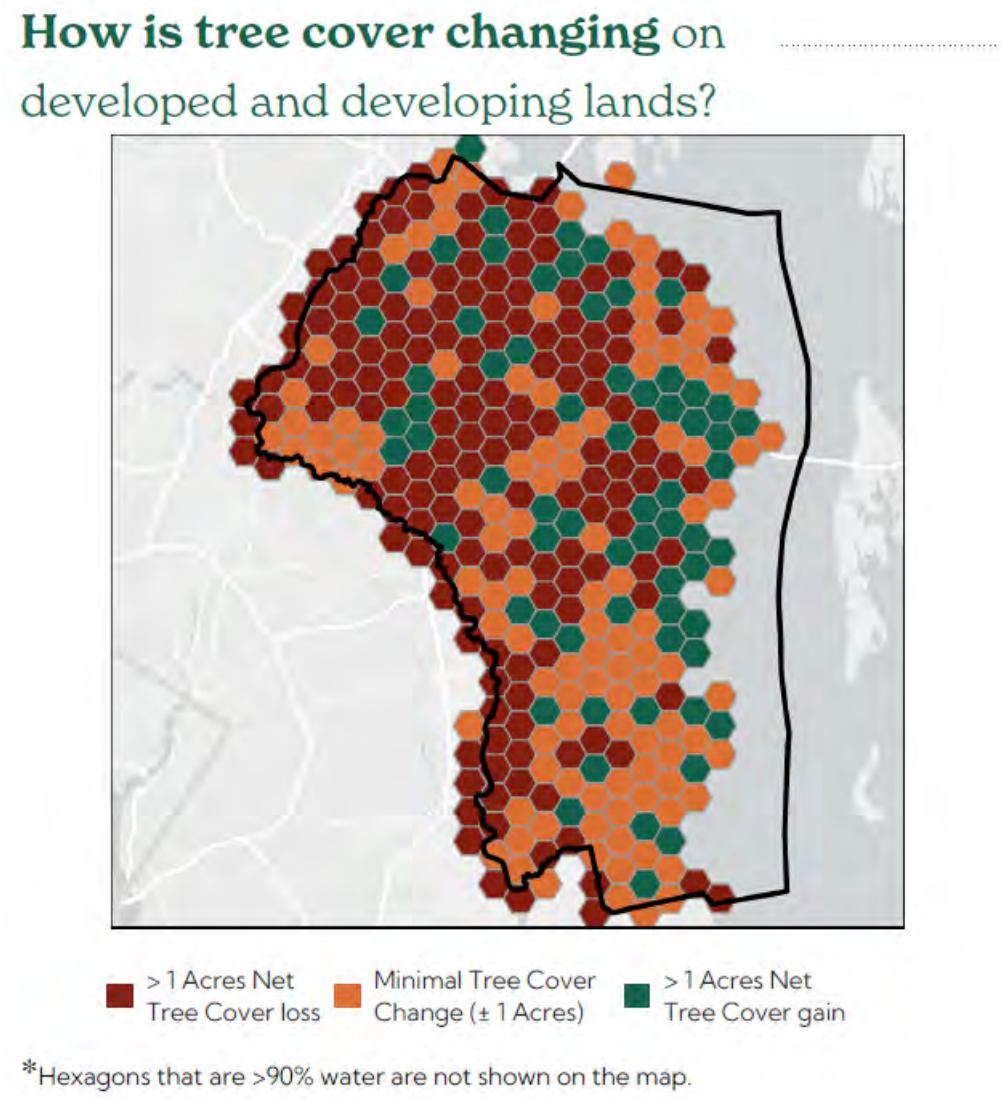
Gains and Losses

The Fact Sheets summarize tree cover gains, losses, and net change* (gains - losses) related to developed and developing lands. Gains include acres that transitioned from a non-treed developed class (impervious, turf, other pervious developed) to one of the four tree cover classes (forest, tree canopy over turf, tree canopy over impervious, and forest, other). And vice versa, losses include acres that transitioned from one of the tree cover classes to a non-treed developed class.



A few important caveats should be noted. First, these regional datasets are based primarily on National Agriculture Imagery Program (NAIP) imagery (supplemented by LiDAR datasets where available) and pick up losses of tree cover more readily than gains. Newly planted trees can take 10 - 15 years to be reliably detected, so that should be taken into account when interpreting the fact sheets. Local analyses using two dates of high quality LiDAR could yield different net change results, picking up more of the gains from newly planted trees and growth at the margins of existing canopy.

In addition, it has been observed that tree cover loss on developed and developing lands, as summarized in these fact sheets, may be overestimated in some counties where there is a higher level of forest management activity (timber harvest and regeneration cycles). Significant effort went into gathering and analyzing available timber harvest data and patterns to correctly classify them as "Harvested Forest", but data gaps can cause errors in classification. In these cases, part of the acreage categorized as "losses" may represent transitions from a more mature forest to a young, regenerating forest, without the loss of watershed benefits that we associate with land conversion to development.



The Fact Sheet hexagon map shows the spatial distribution of change in tree cover, net gains (green), no/minimal change (orange), or net loss (red).

To view the actual areas where gains and losses were mapped, visit the Land Use Change Viewer.

Map hexagons size and legend units were selected based on jurisdiction size to summarize the net tree canopy change between two time periods 2013 or 2014 and 2021 or 2022. Tree cover change was summarized into three categories: tree cover loss, minimal tree cover change and tree cover gain. The category thresholds (i.e. legend unit) are based on hexagon size as outlined in the chart below. Tree cover loss is a change > -1 legend unit, tree cover gain is a change > +1 legend unit, and minimal change is between -1 and +1 legend units. Hexagons containing ≥ 90% water were omitted from the map.

Jurisdiction Size	Hexagon Size	Nominal Change Threshold
< 150 Acres	1 Acre	400 ft^2
< 2,500 Acres	10 Acres	2000 ft^2
< 6,500 Acres	50 Acres	4000 ft^2
< 40,000 Acres	100 Acres	0.1 Acre
> 40,000 Acres	1000 Acres	1 Acre

Note on the Accuracy of Change Data:

Due to minor differences in the NAIP image registration and incidence angle in 2013/14 and 2021/22, fuzzy accuracies were assessed within a 3m x 3m window surrounding each of 30,460 stratified-random sample points. The overall fuzzy land cover change accuracy is 86%. The producer's and user's accuracies of land cover change are 96% and 77% respectively, meaning that 96% of actual land cover change between 2013/14 and 2021/22 are represented in the data and where change is identified, there is a 77% likelihood that it's actual change. For tree canopy change, the producer's and user's accuracies are 75% and 56% respectively.

Image Center: Example of a forest cleared for a new development construction site.

Additional Resources

Chesapeake Land Use/Land Cover Datasets and Tools

Links to all of these resources and the full set of county and municipal scale fact sheets can be found on the Chesapeake Tree Canopy Network Understand Your Canopy Page.

GIS Datasets

The local Tree Cover Status and Change Fact Sheets are a starting point for understanding what is happening with tree canopy at the community scale. We encourage those with GIS expertise to download and utilize the actual Land Use/ Land Cover and Change datasets as a foundation for further analysis of planting opportunities and information on gains and losses. The land use/ land cover data can be overlaid with parcel data and local land use/ zoning data to identify areas of existing and potential tree canopy on different types of private lands (low/ medium/ high density residential, commercial, industrial, etc.) and public lands (street tree/ rights-of way, parks, schools, Homeowner Association common spaces, etc.). Further prioritization of areas to conserve or expand tree canopy can be achieved by overlaying available data layers related to social, economic or environmental priorities.

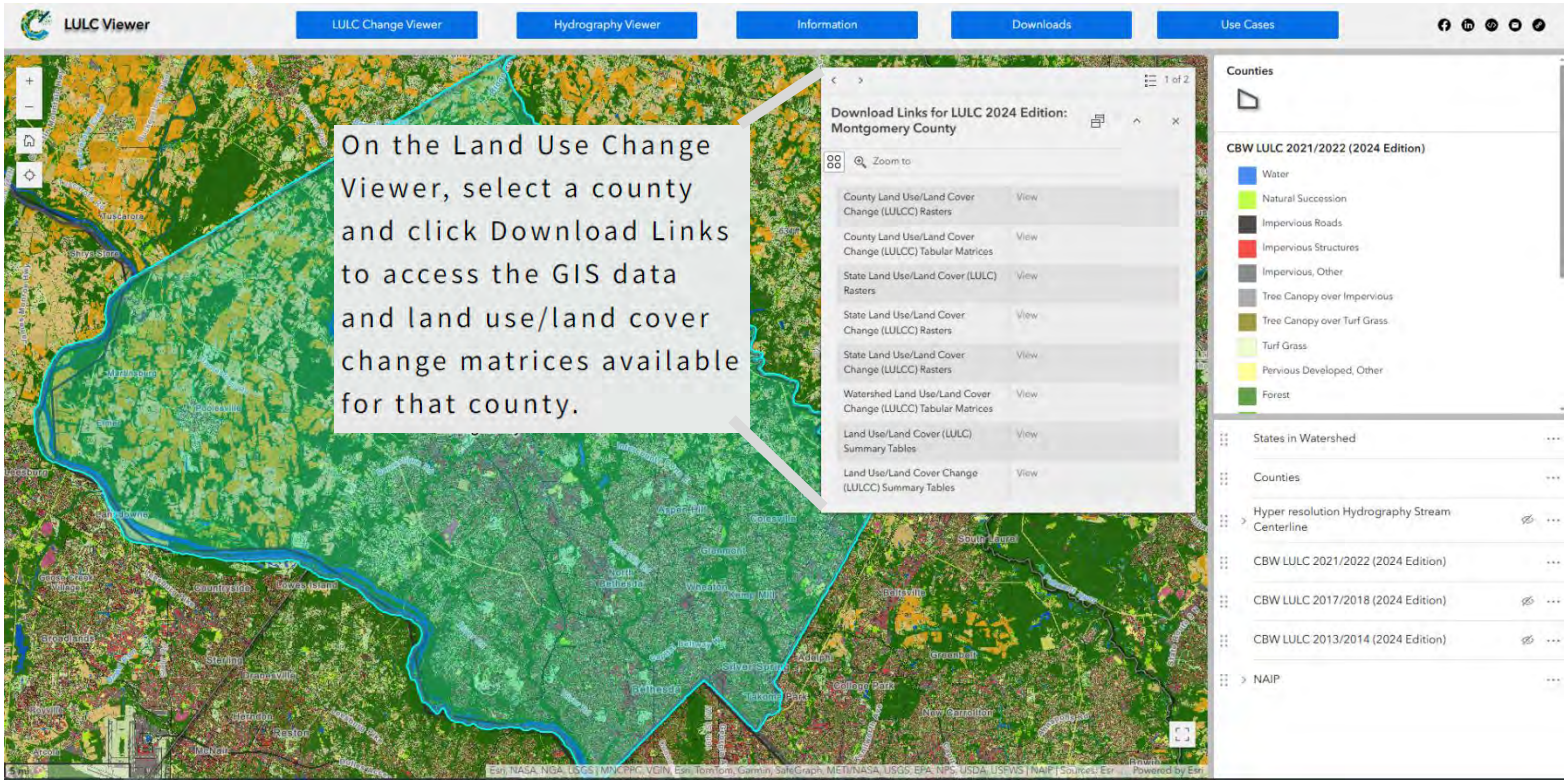
For a local example using similar data to assess and communicate tree canopy changes over time, see the District of Columbia Tree Canopy Change Story Map (2006 - 2020).

Land Use/Land Cover Change Matrices

For each county that is in or adjacent to the Chesapeake Bay watershed, a Land Use/Land Cover Change matrix is available showing acres of change between each combination of land uses in 2013/2014 and 2021/2022. Although it takes some time to familiarize yourself with the land use codes and matrix format, the product condenses a rich amount of land use/land cover change information in one table. The matrices are accessible through the Land Use Change Map Viewer as shown on page 14.

See the 2024 edition Land Use/Land Cover methods documentation for details on interpreting Land Use / Land Cover Change Matrices.

Map Viewers



For those who want to simply view and explore the data online, map viewers are available for the 2021/2022 land use/ land cover data, as well as the land use/ land cover change data (2013/2014 – 2021/2022) at this link.

Other Resources

Local Government Curriculum

Capitalizing on the Benefits of Trees & State Tree Resource Guides

Funding

Financing Urban Tree Canopy Programs (Guidebook for Local Governments in the Chesapeake Bay watershed)

Schools

Trees and Schools: Growing the Connection

(A Resource Guide for Chesapeake Communities)

Policy

Making Your Community Forest - Friendly: A Worksheet for Review of Municipal Codes and Ordinances

Public Health

Healthy Trees, Healthy Lives

Website

Case Studies

Vibrant Cities Lab

Chesapeake Tree Canopy Network: Community Spotlight

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